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Reducing Environmental Pollution through Behavioral Change and Education: A Repeated Cross-Sectional Pilot Study

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Abstract

This repeated cross-sectional pilot study examined the impact of environmental education on reducing overall waste generation among students enrolled in an environmental health course from Fall 2020 to Spring 2023. The data included trash generation, single-use plastic, and paper products. Each student logged their daily usage of these waste products in a standard spreadsheet. The data collection phases were divided into three behavioral change intervention timelines: Before-Intervention (BI-Week 1-5), Phase -1 (PH1I- Week 6-10), and Phase-2 Intervention (PH2I-Week 11-14). The study found a significant reduction in the use of grocery bags ($p<0.001$*), produce bags ($p=0.03$*), cutlery/straws ($p=0.01$*), paper towels ($p<0.001$*), toilet paper ($p<0.001$*), the weight ($p=0.003$*) and number($p=0.02$*) of trash. The results indicated that the mean differences in waste such as paper towels $p<0.001$*(PH1I VS BI);$p<0.001$*(PH2I VS BI); $p=0.009$*(PH2I VS PH1I)], toilet paper [$p=0.003$*(PH1I VS BI); $p=0.001$*(PH2I VS BI); $p<0.001$*(PH2I VS PH1I)], grocery bags [$p=0.001$*(PH1I VS BI); $p=0.001$*(PH2I VS PH1I), Cutlery/Straw [$p=0.006$*(PH1I VS BI);$p=0.007$*(PH2I VS BI), and the average weight of trash bags [$p=0.002$* (PH1I VS BI); $p=0.004$*(PH2I VS PH1I)] were statistically significant after the interventions. Therefore, the study concluded that environmental awareness, self-accountability, and education are effective in controlling single-use plastic and paper products and reducing trash generation.

Introduction

The environmental and health impacts of solid waste generation, microplastics from plastic products, paper waste, and other pollutants are extensive. These waste products contribute to various environmental and health consequences, including pollution, climate change, ecosystem degradation, and direct health risks to humans from chemical exposures and pollution-related diseases. Solid waste generation leads to significant environmental pollution, as improper disposal and accumulation of waste can contaminate soil, water, and air (Landrigan et al., 2018).

Due to increased production, solid waste generation, such as trash that includes plastics and paper products, has become critical for the environment and public health. According to the United Nations Environmental Programme (UNEP) Global Waste Management Outlook 2024, municipal solid waste generation is predicted to grow from 2.1 billion to 3.8 billion tonnes from 2023 to 2050 (UNEP, 2024). According to the United States Environmental Protection Agency (EPA), the amount of trash generated in the United States reached approximately 292.4 million tons in 2018, highlighting the urgency of addressing waste management practices (USEPA, 2018). While solid waste management is constantly being addressed to reduce environmental pollution, it is essential to tackle the problem from the roots of per capita waste generation. Reports show that high-income countries like the United States contribute enormous amounts of solid waste to land and oceans despite the robust waste management systems (Law et al., 2020). This is due to the large coastal populations and high per capita waste generation. The US also produces an enormous amount of plastic waste in the world and has the most significant annual per capita plastic waste generation (>100 kg), followed by other highly populated countries like India and China (Kaza et al., 2018; USEPA, 2019). With growing concerns about environmental degradation and the consequences of solid waste accumulation, there is a critical need to raise awareness and explore strategies for mitigating pollution levels at an individual level.

Solid waste generated individually and municipally contributes a menace to the environment in varying degrees. Worthy of note is the particularly insidious threat that microplastics from plastic products pose. These tiny plastic particles can persist in the environment for centuries, accumulating in oceans, rivers, and soil (Hammer

et al., 2012, Landrigan et al., 2020). They are ingested by marine life and other wildlife, leading to the bioaccumulation of toxins up the food chain, ultimately affecting human health through the consumption of contaminated seafood and water. Additionally, microplastics can cause physical harm to organisms, disrupt endocrine systems, and carry harmful pathogens and pollutants (Jambeck et al., 2015). Although paper waste is often considered less toxic and biodegradable, it also contributes to environmental degradation. Recycling paper, although beneficial in reducing waste and conserving resources, is not without its environmental costs. Recycling requires energy and water, and the de-inking process can produce sludge that must be managed carefully to avoid environmental contamination. In addition, not all paper products are recyclable, especially those contaminated with food waste or coated with plastic, leading to more waste ending up in landfills (USEPA, 2019). The chemicals used in producing plastics and paper, such as bisphenol A (BPA) and various bleaching agents, can be toxic, leading to severe health issues, including cancer, endocrine disruption, and reproductive health illnesses. BPA, commonly found in reusable plastic water bottles, is known for its ability to mimic estrogen, leading to hormonal imbalances and associated health problems such as polycystic ovarian syndrome, hypothyroidism, and liver function abnormalities (Hengstler et al., 2011). Similarly, the bleaching agents used in paper production can release harmful substances into the environment, which may cause adverse health effects when humans are exposed. Polychlorinated biphenyls (PCBs) are additives commonly used in plastic production and have been indicated in the proliferation of reproductive disorders in humans, altered hormone levels, and contamination of aquatic life even at minimal concentrations (Alabi et al., 2019). Another pollutant is methane gas - a potent greenhouse gas that exacerbates climate change and is a byproduct of organic waste decomposition in landfills. In landfills, the anaerobic decomposition of organic materials, including paper waste, produces methane, which has a global warming potential many times greater than carbon dioxide over a brief period. This makes managing organic waste critical in mitigating climate change impacts (USEPA, 2021).

Exposure to pollutants from waste further exacerbates health risks. Chemicals released during the breakdown of plastics and paper can contaminate air, water, and soil, leading to various health issues. Respiratory problems are common in areas with prominent levels of air pollution, often resulting from the incineration of waste or the release of volatile organic compounds from decomposing materials. Cardiovascular diseases are also linked to prolonged exposure to environmental pollutants, which can lead to inflammation and other adverse health outcomes (Landrigan et al., 2018; USEPA, 2018).

Research indicates that promoting healthy behaviors and reinforcing existing practices can be effectively achieved by applying research-based strategies and targeted interventions. In addressing the environmental impacts of pollution, public awareness campaigns and educational programs are critical in influencing how individuals use and dispose of potential pollutants. By fostering a deeper understanding of environmental issues and encouraging behavior change, such interventions can play a pivotal role in mitigating the negative effects of environmental pollution on ecosystems (Orji et al., 2018).

Therefore, this pilot study aims to understand how changes in individual behaviors can reduce the overall volume of solid waste produced by examining daily waste generation habits and the effectiveness of educational interventions. The research also seeks to identify practical ways to encourage more sustainable practices. This includes promoting waste reduction, increased recycling, and the adoption of more environmentally friendly consumption patterns.

Method

Study Design

The research employs a multi-year repeated cross-sectional study design to systematically track and analyze waste generation among students over several semesters. The study was conducted from Fall 2020 to Spring 2023, a total of six semesters. This study involves collecting data from students each semester, allowing for the assessment of temporal trends and variations in waste generation patterns. The data collection methodology involves students actively participating in the study by tracking their daily waste generation over an entire semester. Each student is provided with a standardized data log sheet at the beginning of the semester to ensure consistency and accuracy in data recording. The log sheet includes fields for various types of waste (e.g., recyclables, compostables, non-recyclables) and requires students to log the quantity or number of waste items generated each day. (See the Attached Appendix). This hands-on approach gathers valuable data and raises students' awareness of waste-generation habits (Figure 1).

Three distinct behavioral activities were used for data collection:

- Tracking plastic products such as grocery bags, produce bags, other bags made of plastic, and single-use plastic such as food containers, straws, and forks.
- Tracking single-use paper products such as toilet paper and paper towels.
- Solid waste management by tracking the amount of trash and recyclables.

The study aims to educate students about waste management and sustainability practices. By involving them directly in the data collection process, students become more aware of their waste generation habits and the broader implications of waste management. This hands-on experience enhances a deeper understanding of sustainability issues. It encourages students to adopt more environmentally responsible behaviors, contributing to the overall goal of promoting sustainable practices within the community.

Institutional Review Board

This research project was approved by the University's Institutional Review Board (IRB), Protocol 21-010. The study involves the voluntary participation of students who will track their daily waste production over a semester using standardized data log sheets provided at the beginning of the term. At the end of the semester, the instructor emailed all students who completed the semester project, requesting their permission to use the collected data for this research. An informed consent form was included in the email, which is essential for approving the release of their data for further analysis. If students do not consent to release their data, the instructor will exclude it from the study.

Data Collection and Analysis

At the beginning of the semester, the instructor provided a detailed methodology for the semester project, outlining the objectives and procedures. A standard data log sheet was distributed to each student to ensure consistency in the data collection strategy, and this log sheet was also shared in an online folder for easy access and real-time updates. Students had to enter their daily waste generation data in real-time into the log sheet.

The instructor worked closely with each student throughout the semester to refine their data collection methodology and ensure accurate and consistent data recording. As our goal is to find the long-term effect of the intervention on waste management, we recognize that initial enthusiasm and commitment often wane over time. When we learn something new, we are typically excited and dedicated for the first few weeks, but maintaining consistency becomes challenging as time progresses. Therefore, we aim to evaluate the long-term effectiveness of general education about waste generation and management. To achieve this, we divided our data into three time points:

i. Before the intervention (BI), from Week 1 to Week 5 (W1-W5)
ii. Phase 1- Five weeks after the intervention (PH1I), from Week 6 to Week 10 (W6-W10), and
iii. Phase 2- Four weeks after the Phase 1 intervention (PH2I), from Week 11 to Week 14 (W11-W14).

This division allows us to analyze the immediate impact of the intervention as well as its sustained effectiveness over a longer period. During the pre-intervention phase, students maintained their usual daily routines and collected data on their waste generation. In the post-intervention phase, students adopted best practices to limit their waste generation sustainably, implementing strategies learned through educational interventions. This approach allowed for a comparative analysis of waste generation before and after adopting sustainable practices. The study used an MS Excel program for data entry and then R version 4.4.1 for the statistical analysis. Data were tested for outliers and violations of normality and sphericity assumptions. The Shapiro-Wilk normality test and Mauchly's test of sphericity were employed to assess these assumptions. In cases where extreme outliers were detected, a log transformation was applied to the data to mitigate their impact and meet the necessary assumptions for further analysis.

Repeated measures ANOVA (RM-ANOVA) was used to determine whether the mean or log-transformed means of waste generated significantly differed across the three-time points (BI, PH1I, PH2I). Paired t-tests were conducted to compare all possible pairs of different time points. In cases where normality was violated, Friedman's test was used to assess significant differences between the distributions of the groups (time). The Wilcoxon Signed Rank test was employed for matched-pair comparisons of the groups.

In cases of violating the sphericity assumption, the Greenhouse-Geisser correction was applied. This correction adjusts the degrees of freedom for the F-distribution in RM-ANOVA to account for the violation of sphericity. The significance level was set at 0.05. For pairwise comparisons, significance levels were adjusted using the Bonferroni correction (i.e., 0.05 / 3 = 0.017). If a log transformation was applied, all statistical analyses were conducted on the transformed data.

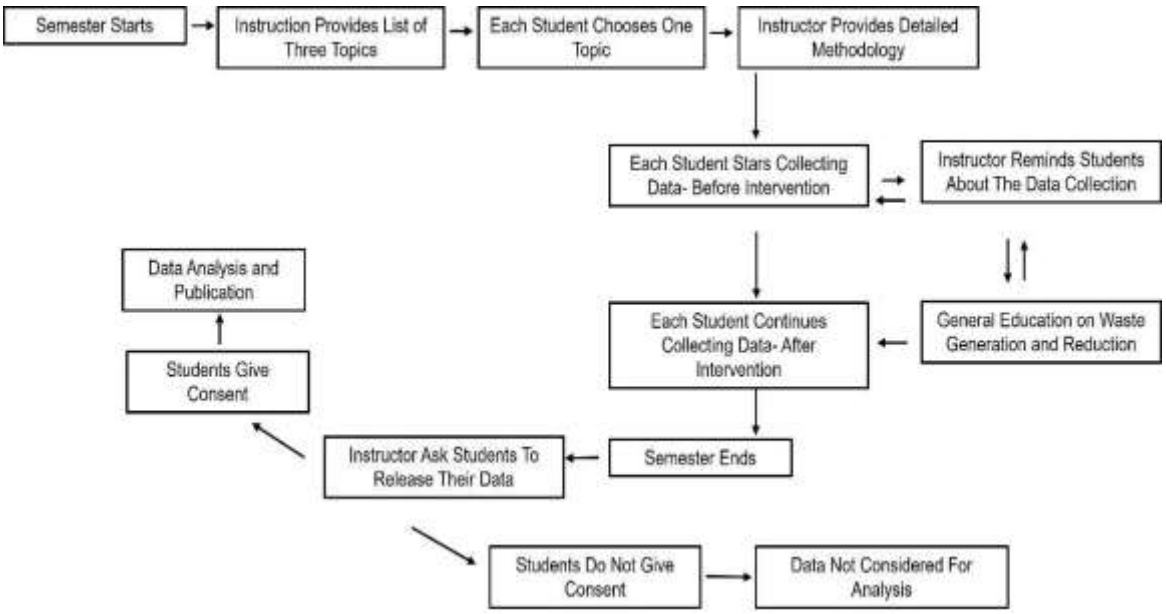

Figure 1. Flowchart of the research design

Results

The data used in this study were collected from students enrolled in the Fall 2020 to Spring 2023 semesters. 109 students took the class over six semesters, and 34 consented to use their data for this study. Each semester, students were asked to track plastic products such as grocery bags, produce bags, other plastic bags, and single-use plastics like food containers, straws, and forks. They were also asked to track paper products such as paper towels and toilet paper. Additionally, they tracked the amount of trash, the number of trash bags, and recyclables for solid waste generation. 12 participants tracked single-use paper products, 11 tracked single-use plastic products, and 11 tracked solid waste generation.

Testing for Outliers, Normality, and Sphericity

After separating our data into three intervention groups (BI, PH1I, PH2I) based on our research questions, we analyzed the descriptive statistics for each group. All waste types in Table 1 had outliers, including extreme outliers. We considered these outliers to be natural and retained them in the dataset. We applied a log transformation for waste types with extreme outliers and violations of the normality assumption. If outliers were still present after transformation, we performed the analysis both with and without the outliers and compared the results. In all cases, we observed the same conclusions. We then checked the normality and sphericity assumptions for each type of waste. The results (P-values) of the Shapiro-Wilk normality test (S) and Mauchly's test of sphericity (M) are presented in Table 1 for each group.

The data for single-use produce bags, cutlery and straws, toilet paper, pounds of trash, and the number of trash bags satisfied the normality assumption but did not satisfy the sphericity assumption. Therefore, we applied one-way RM-ANOVA with Greenhouse-Geisser sphericity correction. Additionally, the PH1I group for single-use grocery bags and the BI group for single-use paper towels did not satisfy the normality assumption, with P-values of 0.02 and 0.04, even after log transformation. Consequently, we used the non-parametric alternative to RM-ANOVA, the Friedman test, to check for significant differences between the distributions of the log-transformed waste amounts within groups (time).

Table 1. Shapiro-Wilk normality test (S) and Mauchly's test (M)

Waste type	Tests	BI	PH1I	PH2I
Grocery Bag*	S	0.34	0.02*	0.27
	M	0.08		
Produce Bag^{+}	S	0.11	0.38	0.1
	M	$< 0.001^{+}$		
Cups and lids+	S	0.58	0.15	0.51
	M	0.26		
Cutlery and straw^{+}	S	0.25	0.26	0.66
	M	0.003^{+}		
Paper Towel*	S	0.04*	0.11	0.39
	M	0.17		
Toilet Paper*	S	0.08	0.23	0.38
	M	0.007*		
Pounds of Trash*	S	0.85	0.25	0.48
	M	0.03*		
No. of Trash bag*	S	0.22	0.14	0.27
	M	0.002*		

*P- values obtained from log-transformed data
$^{+}$P-value obtained from original data

Single-Used Paper Products

This study analyzed two types of paper waste generated in common households: toilet paper and paper towels. Twelve subjects were included and divided into three timeline data point groups (BI, PH1I, PH2I). Figure 2 shows the average waste generated from single-use paper products each week. The average weekly waste of single-use paper towel sheets for each person was approximately 37 during the study period. In contrast, each person's average weekly waste of single-use toilet paper sheets was approximately 107.

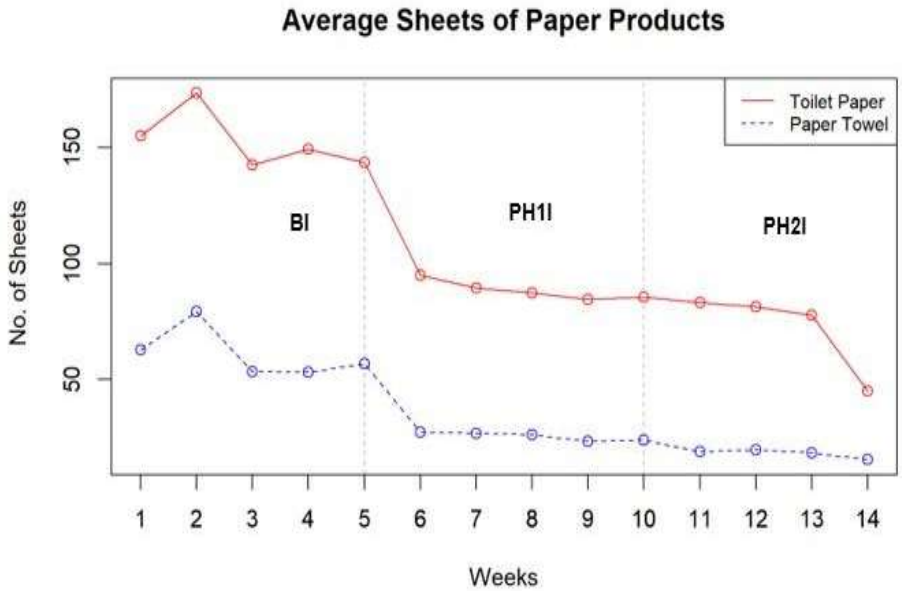

Figure 2. Average sheets of paper products

Table 2 presents the mean and 95% confidence interval for the waste generated from single-use paper products for the BI, PH1I, and PH2I groups. The normality assumption for toilet paper waste was satisfied after log transformation; however, the sphericity assumption was not. Thus, RM-ANOVA with Greenhouse-Geisser correction revealed a significant difference between the mean log number of sheets of toilet paper across the three data points BI, PH1I, and PH2I (P-value < 0.001). Since normality was not satisfied even after log transformation for one of the three groups of toilet paper waste, the Friedman test was applied. It revealed statistically significant differences between the distributions of the three paired groups (BI, PH1I, PH2I) (P-value < 0.001).

Table 2. Intervention effects on single-use paper products

Waste Type		BI	PH1I	PH2I	P-value
Paper Towel	Mean	129.78	51.72	22.71	
	95% CI	(44.11, 378.14)	(15, 166.8)	(6.62,77.91)	P < 0.001‡
Toilet Paper	Mean	328.95	136.62	80.50	P < 0.001*
	95% CI	(106, 1015.70)	(39.44, 473.25)	(23.02, 281.52)	

All results are obtained from back transformation.
*P-value is given for RM-ANOVA with Greenhouse-Geisser sphericity correction.
‡P-value is given for Friedman's test.

Given the significant differences between groups for both types of waste—paper towels and toilet paper—we performed pairwise t-tests and Wilcoxon signed-rank tests to identify which groups differed. The results are presented in Table 3, which shows statistically significant differences in waste generation for paper towels and toilet paper between the following time points: BI and PH1I, BI and PH2I, and PH1I and PH2I (P-value < 0.017). The mean waste generation for paper towels was 60% lower during PH1I than BI. For PH2I, the mean waste generation declined 83% compared to BI and 56% compared to PH1I. Similarly, the mean waste generation PH1I for toilet paper was 58% lower than BI. For PH2I, it was 75% lower than BI and 41% lower than PH1I. Therefore, education on waste generation/management proved to be very effective in controlling the use of single-use paper products.

Table 3. Pairwise comparison between groups for single used papers

Single-use paper products		PH1I VS BI	PH2I VS BI	PH2I VS PH1I
Paper Towel	Mean difference	0.40	0.17	0.44
	P-value‡	<0.001*	<0.001*	0.009*
Toilet Paper	Mean difference	0.42	0.25	0.59
	P-value*	0.003*	0.001*	<0.001*

All results are obtained from back transformation.
P-values* are obtained from paired t-tests.
P-values‡ are obtained from pairwise Wilcoxon signed-rank tests.
All the P-values are adjusted Using the Bonferroni Multiple Testing correction method.

Single-Use Plastic Products

This study analyzed four types of plastic waste generated in common households: grocery bags, produce bags, cups and lids, and cutlery and straws. Eleven subjects were divided into three data points (BI, PH1I, and PH2I). Figure 3 shows the average waste generated from single-use plastic products each week. The average weekly use of single-use grocery bags per person was approximately six, single-use produce bags were about three, and single-use cups and lids were approximately three, as was the single-use cutlery and straws per person during the study period.

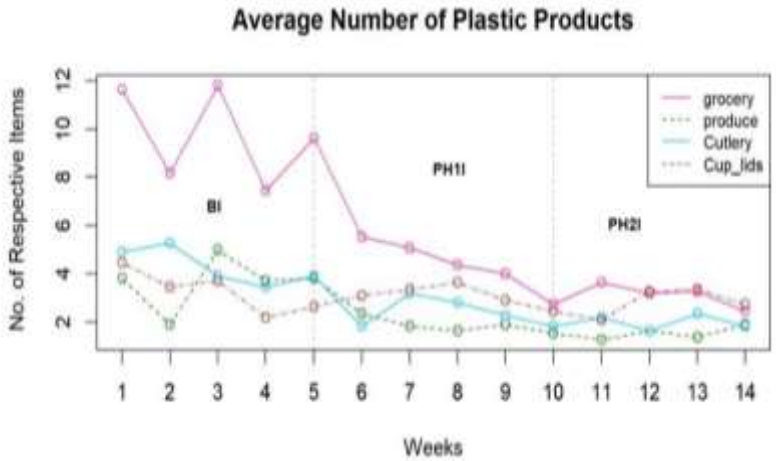

Figure 3. Average number of plastic products

Table 4 presents the mean and 95% confidence interval for the waste generated from single-use plastic products for the groups BI, PH1I, and PH2I.

Grocery Bags: The normality assumption was not satisfied for grocery bags even after log transformation for one of the three groups, so the Friedman test was applied. This test revealed statistically significant differences between the distributions of the paired groups BI, PH1I, and PH2I, with a p-value of <0.001.

Cups and Lids: The normality and sphericity assumptions were satisfied for cups and lids waste, so RM-ANOVA was performed to check for significant differences between the means of the three groups (time points). The difference was not substantial, with a p-value of 0.21.

Produce Bags, Cutlery, and Straws: After the log transformation, the normality assumption was satisfied for the produce bags, cutlery, and straws, but the sphericity assumption was not. Therefore, RM-ANOVA with correction was applied, indicating significant differences between the mean numbers of produce bags, cutlery, and straws across the three groups, with p-values of 0.03 and 0.01, respectively.

Table 4. Intervention effects on single-use plastic products

Waste type		BI	PH1I	PH2I	P-value
Grocery Bag†	Mean	40.29	12.18	8.41	P< 0.001†
	95% CI	(26.52, 60.94)	(4.20, 32.37)	(3.66, 18.01)	
Produce Bag	Mean	18.27	9.27	6.18	0.03*
	95% CI	(8.20, 28.34)	(5.57, 12.98)	(2.77, 9.59)	
Cups and lids	Mean	16.45	15.45	11.45	0.21‡
	95% CI	(9.34,23.57)	(5.71, 25.20)	(5.14, 17.77)	
Cutlery and straw	Mean	21.45	11. 91	8.00	0.01*
	95% CI	(11.93, 30.97)	(6.51, 17.31)	(3.89, 12.11)	

†Results are obtained from back transformation. †P-value is given for Friedman's test.
*P-value is given for RM-ANOVA with Greenhouse-Geisser sphericity correction.
‡ P-value is given for RM-ANOVA.

Table 5 shows statistically significant differences between mean log waste generated from single-use plastics.
Grocery Bags: There were statistically significant differences in the mean log waste generated from single-use grocery bags (P-value < 0.017), with a 58% reduction in mean usage five weeks post-intervention (PH1I) compared to before the intervention (BI) and a 29% reduction nine weeks post-intervention (PH2I) compared to PH1I. However, the difference from BI to PH2I was insignificant (P-value = 0.08) despite a 71% decrease in mean waste production.

Table 5. Pairwise comparison between groups for single-use plastic

Single-use plastic products		PH1I VS BI	PH2I VS BI	PH2I VS PH1I
Grocery Bag	Mean difference*	0.32	0.23	0.71
	P-value*	0.001*	0.08	0.001*
Produce Bag	Mean difference+	9.0	12.10	3.10
	P-value^{+}	0.06	0.02	0.05
Cups and lids	Mean difference+	1.0	5.0	4.0
	P-value^{+}	0.78	0.11	0.1
Cutlery and straw	Mean difference+	9.56	13.45	3.91
	P-value^{+}	0.006*	0.007*	0.05

Mean differences* are obtained from back transformation.
Mean difference+ are obtained from original data/without data transformation.
P-values* are obtained from pairwise Wilcoxon signed-rank tests.
P-values^{+} are obtained from paired t-tests.
All P-values are adjusted Using the Bonferroni Multiple Testing correction method.

Produce Bags: The RM-ANOVA with Greenhouse-Geisser sphericity correction indicated a significant difference in the mean waste generated from produce bags among the three groups. However, pairwise t-tests after correction were non-significant (P-value > 0.017): P-value = 0.06 for PH1I vs. BI, P-value = 0.02 for PH2I vs. BI, and P-value = 0.05 for PH2I vs. PH1I. This may be due to the increased stringency of the correction, a smaller effect size, or a small sample size in the individual comparisons.

Cups and Lids: The results showed a mean percentage decline of 6% from BI to PH1I, 30% from BI to PH2I, and 26% from PH1I to PH2I. Both the non-significant repeated measures ANOVA (P-value > 0.05) and non-significant pairwise t-tests (P-value > 0.017) indicate no significant differences between the means of groups BI,

PH1I, and PH2I. This suggests that the educational intervention did not significantly affect the use of cups and lids.

Cutlery and Straw: There were statistically significant differences in mean waste generation from single-use cutlery and straws between BI and PH1I and between PH2I and BI (P-value < 0.017), with a mean percentage decrease of 45% and 63%, respectively. However, there was no statistically significant difference between PH2I and PH1I, with a mean percentage decline of 33%. This indicates that education on waste management had a short-term effect on reducing waste from cutlery and straws but was ineffective in the long term.

Solid Waste Generation

In this study, we analyzed two types of waste generated in common households: the number and weight of trash bags. Eleven subjects were included and divided into three different time points (BI, PH1I, and PH2I). Figure 4 shows the average number and weight of trash generated each week. The overall average weekly waste generated from trash bags per person was approximately four bags, while the overall average weekly weight of trash generated per person was approximately thirteen pounds.

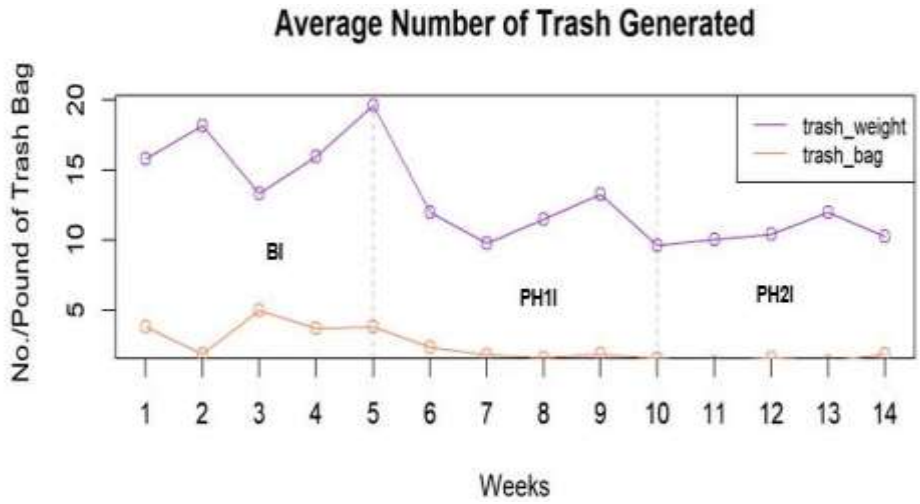

Figure 4. Average number/pound of trash generated

Table 6 presents the mean and 95% confidence interval for the waste generated from the number and weight of trash bags before intervention (BI), five weeks post-intervention (PH1I), and nine weeks post-intervention (PH2I). The normality assumption was satisfied after the log transformation of the number and weight of trash generated, but the sphericity assumption was not. Thus, RM-ANOVA with correction was applied, revealing significant differences between the mean log number of trash bags and the mean log weight for the groups BI, PH1I, and PH2I, with P-values of 0.02 and 0.003, respectively.

Table 6. Intervention effects on number and pound of trash

Waste type		BI	PH1I	PH2I	P-value
Weight of Trash	mean	70.40	41.67	27.50	0.003*
	95% CI	(46.09, 107.53)	(22.67, 76.67)	(13.03, 58.04)	
No. of Trash bag	mean	13.89	11.12	7.49	0.02*
	95% CI	(7.23, 26.71)	(6.22, 19.86)	(4.61, 12.17)	

All results are obtained from back transformation.
The P-value* is given for RM-ANOVA with Greenhouse-Geisser sphericity correction.

Given the significant differences between groups, we performed pairwise t-tests to identify which groups differed, and the results are shown in Table 7. Number of Trash Bags: The results indicated that the mean number of trash bags generated was 20% lower in PH1I and 46% lower in PH2I than BI. Additionally, the mean number of trash bags generated in PH1I was 48% lower compared to PH2I. However, these differences were not significant in pairwise comparisons using the t-test after adjusting for multiple comparisons (P-value > 0.017).

Weight of Trash Bags: There were statistically significant differences in the mean log weight of trash bags (P-value < 0.017), with 41% less mean waste generated in PH1I compared to BI and 34% less mean weight in PH2I compared to PH1I. However, there was no significant difference in the mean log weight of trash bags from BI to PH2I (P-value = 0.05), even though there was a 61% decline in the mean weight of trash bags generated in PH2I compared to BI.

Table 7. Pairwise comparison between groups for number/pound of trash

Trash Generated		PH1I VS BI	PH2I VS BI	PH2I VS PH1I
Weight of Trash	Mean difference	0.59	0.39	0.66
	P-value	0.002*	0.05	0.004*
No. of Trash Bags	Mean difference	0.80	0.54	1.48
	P-value	0.04	0.02	0.03

All results are obtained from back transformation.
P-values are obtained from paired T-tests and were adjusted using the Bonferroni Multiple Testing Correction Method.

Discussions and Conclusions

Several studies have examined the relationship between behavioral activities and environmental pollution. Individual behaviors, such as recycling and composting practices, significantly influence the amount of waste produced. Similarly, eco-friendly behaviors like reusable bags and containers can minimize environmental harm (Smith et al., 2017; Jones & Brown, 2019). Environmental education interventions (EEI) are essential in reducing waste generation and fostering pro-environmental behaviors. A study conducted among students at an academic public health institution indicated that waste generation dropped by 60.1% from the baseline measurement. The EEI program was particularly effective among women and graduate students, who significantly reduced their use of multilayer packaging and non-ecological materials (Torres-Pereda et al., 2020). Similar results were observed in our study, where students significantly reduced their waste generation following the behavioral change intervention through environmental education.

This study found that the mean number of trash bags generated was 20% lower during five weeks post-intervention (PH1I) compared to before the intervention (BI) and 46% reduction nine weeks post-intervention (PH2I) than before intervention (BI). We did not find a statistical significance in the mean number of trash bags generated in PH1I compared to PH2I. This means there is an effect in the first intervention but not during the second intervention for the number of trash bags generated. Similarly, the mean log weight of trash bags was 41% less waste generated in PH1I compared to BI and 34% less mean weight in PH2I compared to PH1I. However, there was no significant difference in the mean log weight of trash bags from BI and PH2I. This also showed that the long-term effects of intervention were challenging to maintain.

This study also found a significant reduction in the use of single-use paper towels and toilet paper between BI, PH1I, and PH2I, with a p-value of less than 0.001. When we compared the mean waste generation of each pair, the results indicated that the mean waste generation for paper towels was 60% lower during PH1I than BI. PH2I, the mean waste generation, declined 83% compared to BI and 56% compared to PH1I. Similarly, the mean waste generation PH1I for toilet paper was 58% lower than BI. For PH2I, it was 75% lower than BI and 41% lower than PH1I. Therefore, education on waste generation/management proved to be very effective in controlling the use of single-use paper products.

This study also analyzed single-use plastic products such as grocery bags, produce bags, cups and lids, cutlery, and straws. We found statistically significant differences in the mean log waste generated from single-use grocery bags with a P-value less than 0.017, with a 58% reduction in PH1I compared to BI and a 29% reduction in PH2I compared to PH1I. However, the difference between mean log waste generated among BI to PH2I was insignificant. This means the effect of the intervention did not last long for single-use plastic grocery bags. For single-use plastic produce bags, we found significant difference in the mean waste generated from produce bags among the three groups: BI, PH1I, and PH2I but there was not any difference between pairwise comparison. There were statistically significant differences in mean waste generation from single-use cutlery and straws between BI and PH1I and between PH2I and BI with a mean percentage decrease of 45% and 63%, respectively. However, there was no statistically significant difference between PH2I and PH1I, with a mean percentage decline of 33%. This indicates that education on waste management had a short-term effect on reducing waste from cutlery and straws but was ineffective in the long term. We did not find significant

evidence of a reduction in mean waste generated from cups and lids among BI, PH1I, and PH2I. This suggests that the educational intervention did not significantly affect the use of cups and lids.

Environmental education positively impacts students' knowledge and attitudes toward waste segregation. Studies indicate that students exposed to environmental education develop a more positive attitude toward waste segregation than those not (Erhabor, 2023). Community-based initiatives also play a key role in promoting sustainable behaviors and reducing waste generation. Educational campaigns and policy interventions encourage individuals to adopt environmentally responsible practices. Existing literature suggests that changing behavioral activities can reduce environmental pollution by addressing individual waste generation patterns. Strategies such as recycling, composting, and adopting eco-friendly consumer choices have contributed to mitigating solid waste accumulation and promoting environmental sustainability (Green et al., 2020; Steg et al., 2005; Pham et, al., 2023). However, further research is needed to assess the long-term effectiveness of these interventions and identify additional measures for enhancing environmental awareness and action. In summary, we found that environmental education positively impacts students' knowledge and attitudes toward waste generation and management. However, it is difficult to maintain the motivation to reduce waste management. So, we must frequently provide education on the importance of waste management in daily life.

Recommendations

Based on the findings of this study, it is recommended that educational institutions and policymakers incorporate targeted environmental education programs to reduce solid waste, single-use plastic, and paper waste among students. The significant reduction in waste generation observed through behavioral change interventions underscores the importance of integrating practical, hands-on learning experiences in environmental health curricula. However, in some waste generation, such as single-use plastic produce bags, plastic cups, and lids, we did not have enough evidence to prove if there is any reduction in pairwise comparison between each pair: PH1I vs. BI, PH2I vs. BI, and PH2I vs. PH1I for single-use plastic produce bags. This may be due to the increased stringency of the correction, a smaller effect size, or a small sample size in the individual comparisons. Therefore, further research should focus on expanding the sample size and exploring the long-term impacts of such educational interventions across diverse student populations. Through these collaborative efforts, institutions can be pivotal in cultivating environmentally responsible behaviors, contributing to broader sustainability goals.

Scientific Ethics Declaration

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

Acknowledgments or Notes

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Appendix

Appendix 1. Sample data collection excel sheet for paper products

	WEEK1						
	D1	D2	D3	D4	D5	D6	D7
How many sheet of paper towel							
How many sheet of toilet paper							
No. of paper napkins							
No. of paper used for printing							
No. of paperboard packaging used for food products such as breakfast cereal							
No. of carton that hold your milk, juice, or similar products							
No. of boxes for shipping products. Example: from amazon or uhaul							
No. of paper cups, plates, and bowl							
No. of sheets of newspaper							
No. of wipes (include pre-moistened wipes)							
Paper sandwich bags							
Others, Please mention							
Others, Please mention							

Appendix 2. Sample data collection excel sheet for plastic products

	WEEK1						
	D1	D2	D3	D4	D5	D6	D7
No. of grocery bags							
No. plastic produce bags							
No. of frozen vegetable bags							
No. of food packaging products (Example: Plastic bags containing Potato Chips, Croutons, Bread and others)							
No. of plastic water bottles, beverage bottles, juice, or milk jars							
No. of plastic takeout containers (clam shell container at work)							
No. of plastic cups and lids (coffee, fountain drink)							
No. of plastic wraps or trashbags							
No. of plastic cutlery and straw							
No. of Ziplock bags (work food baggies)							
No. of plastic rings to hold beverages							
No. of plastic bottle containing Personal Care Products							
No. of disposable coffee pods							
Others , please mention							

Appendix 3. Sample data collection excel sheet for solid waste

	WEEK 1						
	D1	D2	D3	D4	D5	D6	D7
Tracking Solid Waste (Non-recyclable)							
No. of total trash bags generated							
What capacity of trash bag used (in gallons)							
Total pounds of trash generated (measure all trash bags with garbage)							

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The Relationship between Gifted Students' Scientific Epistemological Beliefs and Climate Change Awareness Levels

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Abstract

One of the most talked about and discussed topics in our current time is climate change. Therefore, it is important to draw attention to this issue in educational environments. The purpose of this study is to examine the relationship between scientific epistemological beliefs and climate change awareness of gifted students and whether these variables differ according to gender. The study was conducted using a relational screening model. The Scientific Epistemological Belief Scale and the Global Warming/Climate Change Awareness Scale were used as data collection tools. The sample of the study consists of 106 gifted students at the secondary school level in a city in the western region of Turkey. The research findings showed that there was a relationship between the epistemological beliefs of gifted students and their awareness levels of the causes and effects of climate change, their awareness of personal initiatives, and their tendency to change behaviour. In addition, the awareness level of personal initiatives to prevent climate change and the scientific epistemological belief levels differed significantly in favor of gifted female students.

Introduction

Climate change is defined as long-term changes in the balance of climate systems worldwide as a result of human activities (Kurnaz, 2023). Global climate change has been discussed since the 1970s but has become a topic that has begun to attract attention in the 21st century as its effects have become more felt (Selçuk, 2023). For this reason, it is important for countries to develop correct and applicable strategies in case of exposure to the risks that climate change may cause (Calda et al., 2022). Education is one of the most effective methods in developing these strategies. In addition, climate change education has become one of the most emphasized topics in terms of increasing the awareness levels of individuals regarding the global environmental problem (Beasy et al., 2023; Cantell et al., 2019; Schreiner et al., 2005). However, climate change is a serious problem with no simple solutions and climate change education is also defined as a multidimensional problem (Cantell et al., 2019; IPCC, 2023; Liu & Roehrig, 2019). Climate change being a key issue in the field of natural sciences requires multifaceted scientific knowledge. Conflicts between scientific evidence and public perceptions of climate change lead to belief systems and discussions about climate change (Yli-Panula et al., 2021). Although there is a significant level of acceptance and discourse about integrating climate change into education and training activities and providing motivation for climate action (Cutter-Mackenzie & Rousell, 2018), researches show that these efforts may be ineffective in changing children's attitudes and behaviours (Benevento, 2023; Busch et al., 2019). Although school-aged individuals are interested and active in climate change, they may also be anxious and feel that they have no impact on the societal level. Some individuals may be completely indifferent to the issue of climate change or even deny its seriousness (Cordie & Maxwell, 2023; Veijonaho et al., 2024). In addition, researchers state that students have difficulty creating mental models to understand climate change and that learning and problem solving on these topics depend not only on knowledge but also on individuals' beliefs about the subject (Leiserowitz et al., 2010; Yli-Panula et al., 2021).

Engaging with scientific information, including climate change, may depend on epistemological factors that affect what a person chooses to believe and how these beliefs are justified (Quarderer et al., 2021). Epistemological cognition is a process that includes the dispositions, beliefs and skills that determine what individuals actually know, believe, doubt, or distrust (Green & Yu, 2016). Epistemological beliefs are subjective belief systems about the source of knowledge, its certainty, creation, learning and structure of knowledge (Schommer, 1990). Epistemological beliefs allow individuals to understand the ways they determine the accuracy of conflicting information, evaluate new information and make decisions that will affect their own lives and those around them (Kuhn, 1991 as cited in Sapancı, 2012). Scientific epistemology includes topics such as how scientific knowledge develops, how its accuracy is proven and how the quality of data used to obtain knowledge is evaluated, along with general subjective beliefs (Coban & Sengoren, 2020). According to

researchers in the field of science education, the subject of climate change can be seen as a tool through which students' epistemological cognitions can be explored and how students choose to believe and interpret information can affect their decisions to take action on climate (Busch et al., 2019; Sinatra et al., 2012; Quarderer et al., 2021). Although individuals know the content of climate science, the processes that scientists go through to make their claims are not fully understood. This shows that teachers should not only provide students with understanding of how climate systems work or the causes and effects of climate change but also provide cognitive support that supports how students know what they know (Holthuis et al., 2014). How an individual learns in the context of science in general and specifically is an epistemological issue and how an individual interacts with science depends on his/her epistemological cognition or basic assumptions about knowledge and how knowledge is developed (Quarderer et al., 2021). It can be said that the current constructivist understanding in the field of education also includes epistemological beliefs, that is, it shapes individuals' learning within the framework of their epistemological beliefs (Schreiber & Shinn, 2003). Research in the literature shows that epistemological beliefs can affect students' cognitive development and therefore their learning strategies and academic performance (Asut & Koksal, 2013; Greene et al., 2018; Kılıç & Demirbağ, 2020; Schommer-Aikins & Hutter, 2002). Especially for science education, students' epistemological beliefs are an important part of gaining a deeper understanding of scientific research, the scientific process and the nature of science (Fulmer, 2014; Kılıç & Demirbag, 2020). In this context, researchers working in the field of science education will need to better understand why students support certain ideas and beliefs about climate change which will help create and shape effective learning environments that promote the development of climate literacy and epistemological cognition (Quarderer et al., 2021).

One of the learner groups that should be carefully considered in shaping learning environments is gifted individuals (Koshy & Pinheiro-Torres, 2013). Gifted students are defined as individuals who need special education due to their cognitive characteristics that differ from their peers (MEB, 2024). One of the distinguishing aspects of gifted children is that they are more sensitive to global and environmental problems than their peers (Davis & Rimm, 1989; Nacaroglu &Karakaya, 2020; Ugulu, 2013; Sontay, 2014; Karakaya et al., 2018). Researchers state that gifted children need cognitive stimulation, support to solve complex problems and goals that will challenge them to deeply investigate and question the topics they are interested in (Daglıoglu, 2010; Koshy & Robinson, 2006; Taber, 2010; VanTassel-Baska, 2010). The potential of gifted children and the roles they can undertake in the world of the future should be taken into consideration, and this potential should be considered when planning educational activities (Koshy & Robinson, 2006; Yalman & Çepni, 2021). In the MEB (2024) Science and Art Centers Directive, the principles of the education and training program for gifted students include the following statements:

> *Programs are prepared under the guidance of relevant class/branch teachers, in a student-centered and interdisciplinary structure, suitable for individual learning, and differentiated and enriched according to their interests, abilities, and potential in a way that will enable students to acquire high-level mental, social, personal, and academic skills that they will need in adulthood, such as effective problem solving, decision-making and creativity.*

In this context, it is thought that a study on the scientific epistemological beliefs of gifted students can also provide clues for differentiation in the teaching process on climate change. When the studies on gifted students are examined in the literature, it is possible to come across studies on the epistemological beliefs of students. Kılıc and Demirag (2020) tried to measure the epistemological beliefs of students with a field-independent scenario in order to determine and compare the epistemological belief profiles of gifted students and their parents. Based on the study findings they stated that gifted students and their parents have definitive epistemological belief profiles. Akpınar (2018) examined the effect of STEM education on the students' self-regulation, motivation for science teaching and epistemological beliefs and at the end of the study it was revealed that there was a significant difference in the pre-test-posttest scores of self-regulated learning strategies, motivation for science learning and epistemological beliefs scale. Apart from the studies mentioned above on general epistemological beliefs in the national literature only one study (Asut & Koksal, 2013) was found on the scientific epistemological beliefs of gifted students. In their study conducted with gifted students at the middle school level Asut and Koksal (2013) examined the relationship between the students' scientific epistemological beliefs and their motivation level for learning science and their success in science. In their research findings they stated that there was a statistically significant relationship between the motivation level for learning science and their scientific epistemological belief scores. It is possible to come across various studies in the national literature on the climate change awareness of gifted individuals (Akhan et al., 2022; Balaban, 2023; Bodur et al., 2013; Mutlu & Nacaroglu, 2019; Nacaroglu &Karakaya, 2020; Ozarslan, 2022; Yılmaz & Emir; 2024). This study focused on the relationship between the scientific epistemological beliefs of gifted individuals and their climate change awareness levels. It is thought that this study will provide a

framework for research on the awareness of gifted individuals regarding global environmental problems, climate change, and epistemological beliefs, as well as provide clues for differentiating teaching processes for gifted students.

Purpose of the Research

The purpose of this study is to examine the relationship between scientific epistemological beliefs and climate change awareness of gifted students and whether these variables differ by gender. The research questions created for this purpose are as follows:

1. Is there a significant relationship between Scientific Epistemological Beliefs and Global Warming/Climate Change Awareness of gifted students?
2. Are there any significant differences in the Scientific Epistemological Beliefs and Global Warming/Climate Change Awareness of gifted students based on gender?

Method

Research Design

In this study the relational screening method which is one of the quantitative research methods was used. Survey studies allow the determination of the tendencies and attitudes of a sample (Creswell, 2017). In the relational screening model the relationship between the determined characteristics of the sample group is examined (Buyukozturk et al., 2019). In this study the relational screening method was used because it was aimed to examine the relationship between the Scientific Epistemological Belief Scale scores and the Global Warming/Climate Change Awareness Scale scores of the students in the sample and to examine the change in scale scores depending on gender.

Participants and Procedure

The sample of the study consists of 106 gifted students at the secondary school level who are studying in three different Science and Art Centers in Aydın province in the 2023-2024 academic year. Science and art centers (BİLSEM) are institutions affiliated with the Ministry of National Education that provide support education to gifted students in Turkey. At the end of a diagnosis process determined by the Ministry of National Education, students were diagnosed as gifted according to the scores they got from the Wechsler Nonverbal (WNV) test. Typical case sampling, one of the purposive sampling methods was used in the selection of the study group. In typical case sampling a group typical of many situations in the universe related to the research problem is selected and this group is examined (Buyukozturk et al., 2019). Students' academic achievement socioeconomic status and the schools they attend show similar characteristics. The characteristics of the participants regarding gender and grade level are presented in Table 1.

Table 1. Distribution of participants according to grade level and gender

		Frequency (f)	Percentage (%)
Gender	Female	50	47.2
	Male	56	52.8
	Total	106	100
Grade level	5	54	50.9
	6	38	35.8
	7	14	13.2
	Total	106	100

Measurements

Scientific Epistemological Belief Questionnaire

It was developed by Conley et al. (2004) and adapted to Turkish by Ozkan (2008). The scale used by Ozkan (2008) in his study with 7th grade students is a 26-question, five-point Likert-type scale (5; strongly agree, 1;

strongly disagree). The scale aims to measure the epistemological beliefs of the participants in the sub-dimensions of justification of knowledge, development of knowledge, source of knowledge, and certainty of knowledge. Ozkan (2008) reported the overall reliability coefficient of the scale as .76. The Scientific Epistemological Belief Scale was also used by Kılıc and Demirbag (2020) in a study on gifted middle school students.

We examined the construct validity of the scale for the sample within the scope of this study using the LISREL program. In the first step of the confirmatory factor analysis, it was seen that the data set did not meet the normality assumption (Khattree & Naik, 1999) as a result of Mardia's multivariate normality test (Skewness=68.34, Kurtosis=295.73). Accordingly, as a result of the analysis we conducted the items with factor loadings less than .30 (1, 2, 6, 7, 14, 15, 16, 18, 19, 21, 26) were removed from the scale and the analyses were repeated. The Scientific Epistemological Beliefs Questionnaire which was originally four-dimensional (Conley et al., 2004) was analyzed in three dimensions within the scope of this study in parallel with the study adapted to Turkish by Ozkan (2008). The Cronbach's Alpha values for the scale, which consists of a total of 15 items, are given in Table 2.

Table 2. Reliability analysis values for the scientific epistemological belief questionnaire

Dimensions	Items	Cronb. Alpha
Justification	3,4,5,9,11,22,25	.88
Source/Certainty	10,12,20,23	.75
Development	8,13 17,24	.81
All scale	All Item	.88

In Table 2, it is seen that the reliability coefficient values for the dimensions of the Scientific Epistemological Beliefs Questionnaire and the general reliability coefficient value are above .70 which is an acceptable value (Buyukozturk, 2011).

Global Warming/Climate Change Awareness Questionnaire

The questionnaire developed by Halady and Rao (2010) was adapted to Turkish by Dal et al. (2015). The sections of the four-point Likert-type scale (4; I am quite aware, 1; I am not aware) consist of awareness of the causes and effects of climate change, awareness of personal initiatives related to climate change, awareness of industrial initiatives related to climate change, and behavioral change tendency. Reliability coefficients were reported by Dal et al. (2015) as .91 for awareness of the causes and effects of climate change, .91 for awareness of personal initiatives related to climate change, .89 for awareness of industrial initiatives related to climate change and .70 for behavioral change tendency. The scale was used in a study conducted with gifted 6th grade students by Bodur et al. (2023).

In this study we examined the construct validity of the scale for a gifted sample using the LISREL program. During the application of the scale, the “Awareness of Industrial Initiatives Related to Climate Change” section was not included in the analysis as it was thought to be inappropriate for the age level of the students based on the feedback received from the students. In the first step of the confirmatory factor analysis, it was seen that the data set did not meet the normality assumption as a result of Mardia’s multivariate normality test (Skewness=1611.80, Kurtosis=2839.88) (Khattree & Naik, 1999). Accordingly, at the end of the analysis, the items with factor loadings less than .30 (6, 9, 10, 20, 24) were removed from the scale and final analyses were performed. Cronbach’s Alpha values for the Global Warming/Climate Change Awareness Scale are given in Table 3. Table 3 shows that the reliability coefficient values for the sections of the Global Warming/Climate Change Awareness Scale are above .70, which is acceptable (Buyukozturk, 2011).

Table 3. Reliability analysis data on global warming/climate change awareness questionnaire

Sections	N	Cronb. Alpha
Reasons and impacts of climate change	15	.85
Awareness of individual initiative	23	.89
Propensity for behavioral change	7	.82

Results

Findings Regarding the First Research Question

In the first step of the analysis studies conducted for the first research question of the study, "Is there a significant relationship between the Scientific Epistemological Beliefs of gifted students and their Global Warming/Climate Change Awareness?", descriptive values of the scores for both scales were examined. Descriptive data regarding the Scientific Epistemological Belief Scale scores are presented in Table 4 and descriptive data regarding the Global Warming/Climate Change Awareness Scale are presented in Table 5. Considering the minimum and maximum scores in Table 4, it can be said that the participants' average scores are high in the scale dimensions and in the overall scale.

Table 4. Descriptive data on scientific epistemological belief scale questionnaire

	X	SD	Minimum	Maximum
Justification	3.86	.87	1	5
Source/Certainty	3.97	.90	1.75	5
Development	3.95	.84	1	5
Scientific epistemological belief	3.91	.70	1.40	5

Table 5. Descriptive data on global warming/climate change awareness questionnaire scores

	X	SD	Minimum	Maximum
Reasons and impacts of climate change	3.09	.53	1.73	4
Awareness of individual initiative	3.19	.47	2	4
Propensity for behavioral change	3.29	.59	2	4
Global warming/Climate change	3.19	.47	2	4

When Table 5 is examined, it is seen that the scale scores vary between 1.73 and 4 and the average scores are high when the minimum and maximum scores are taken into account. A correlation test was conducted to determine whether there was a significant relationship between the scores of the Scientific Epistemological Belief Questionnaire and the Global Warming/Climate Change Awareness Questionnaire. The normality status of the scores obtained from the scales was examined and in the normality examination, the statistical values were found to be Skewness= -1.12 Kurtosis=1.33 for the Scientific Epistemological Belief Questionnaire and Skewness= -0.40 Kurtosis= -0.22 for the Global Warming/Climate Change Awareness Questionnaire, and it was determined that both scale scores showed a normal distribution. In this direction the parametric test Pearson test correlation was used. The analysis data regarding the correlation levels between the scores of the Scientific Epistemological Belief Scale and the scores obtained from the sections of the Global Warming/Climate Change Awareness Scale are presented in Table 6.

Table 6. The level of correlation between scientific epistemological belief questionnaire scores and global warming/climate change awareness questionnaire scores

	I	II	III	IV
I. Scientific epistemological belief	1			
II. Reasons and impacts of climate change	,364**	1		
III. Awareness of individual initiative	,375**	,722**	1	
IV. Propensity for behavioral change	,523**	,619**	,631**	1

**p< .01

When Table 6 is examined, it is seen that there is a positive significant relationship (p< .01) between the participants' Scientific Epistemological Belief Questionnaire scores and the scores obtained from all three sections of the Global Warming/Climate Change Awareness Questionnaire. It can be said that the scientific epistemological belief scores are lowly related to the level of awareness of the causes and effects of climate change (r= .36); lowly related to the awareness of personal initiatives (r= .38) and moderately related to the tendency to change behavior (r= .52).

Findings Regarding the Second Research Question

In the analysis study conducted for the second research question of the study, "Are there any significant differences in the Scientific Epistemological Beliefs and Global Warming/Climate Change Awareness of gifted students based on gender?", tests were conducted using a statistical program in order to determine whether the scores obtained from the scales differed significantly according to gender. A normality analysis of the Scientific Epistemological Belief Questionnaire scores was performed and it was seen that the scores were normally distributed for both genders (female participant scores Skewness= -0.87 Kurtosis= 0.00; male participant scores Skewness= -1.12 Kurtosis=1.29). Statistical results were obtained by performing an independent samples t-test.

The statistical values regarding the difference in the Scientific Epistemological Belief Questionnaire scores according to gender are presented in Table 7:

Table 7. t-test results regarding gender-related differences in scientific epistemological belief questionnaire scores

	Gender	N	X	SD	t	p
Scientific epistemological belief	Female	50	4.07	.60	2.14	.03
	Male	56	3.78	.76		

When Table 7 is examined, it is seen that the mean scores of the Scientific Epistemological Belief Questionnaire are higher in female students (X=4.07) than in male students (X=3.78) and this difference is significant (p< .05). A normality analysis of the Global Warming/Climate Change Awareness Questionnaire scores was conducted, and it was seen that the scores were normally distributed for both genders (female participant scores Skewness= -0.50 Kurtosis= -0.43; male participant scores Skewness= -0.31 Kurtosis=0.07). Statistical results were obtained by performing an independent samples t-test. The statistical values regarding the gender-based differentiation status of the Global Warming/Climate Change Awareness Questionnaire scores are presented in Table 8:

Table 8. t-test results regarding gender-related differences in global warming/climate change questionnaire scores

Section	Gender	N	X	SD	t	p
Reasons and impacts of climate change	Female	50	3.12	.54	.67	.50
	Male	56	3.05	.52		
Awareness of individual initiative	Female	50	3.30	.41	2.30	.02
	Male	56	3.09	.51		
Propensity for behavioral change	Female	50	3.37	.62	1.21	.23
	Male	56	3.23	.56		

When Table 8 is examined, it is seen that the mean scores for the Awareness and Behavior Change Tendency section on the Causes and Effects of Climate Change do not differ significantly between male and female participants while in the Awareness of Personal Initiatives section, the mean scores of female students (X=3.30) are higher than the mean scores of male students (X=3.09) and this difference is significant (p< .05).

Discussion

In this study, it was examined whether there was a significant relationship between the Scientific Epistemological Beliefs and Global Warming/Climate Change Awareness of gifted students and whether the scores of both scales differed according to the gender variable. When the descriptive data obtained in this study are compared with the data of similar studies on epistemological beliefs (Asut and Koksal, 2013; Ozbay, 2016; Ozkan, 2008), it can be said that gifted students have scientific epistemological beliefs above the average level. Considering that gifted students have skills such as innately developed reasoning abilities, questioning attitudes and the ability to reflect on what they have learned (Gilbert & Newberry, 2017; Taber, 2017), it is a predictable result that these characteristics may have also affected their epistemological belief level. The data obtained from the Global Warming/Climate Change Awareness scale, another data collection tool in the study, show that the participants' global warming and climate change awareness levels are high. Yılmaz and Emir (2024) stated that there was a significant difference in favor of gifted students in terms of climate literacy in the findings of the study in which they aimed to compare the 21st century skills and climate literacy levels of gifted middle school students and their peers. Ozarslan (2022), on the other hand, stated in the findings of his study, which aimed to examine the solution proposals of gifted middle and high school students to global environmental problems, that the students emphasized air/water pollution and global warming. The findings of this study are similar to the findings of Yılmaz and Emir (2024) and Ozarslan (2022). Studies indicate that gifted students are more sensitive to global environmental problems than their peers (Davis & Rimm, 1989; Nacaroglu & Karakaya, 2020; Ugulu, 2013; Sontay, 2014; Karakaya et al., 2018). This situation may have caused the gifted students' climate change awareness levels to be high.

In the study, the relationship between the students' Scientific Epistemological Belief Questionnaire scores and the Global Warming/Climate Change Awareness Scale scores was examined and it was observed that there was a positive and significant relationship between the participants' Scientific Epistemological Belief Questionnaire scores and the scores obtained from all three sections of the Global Warming/Climate Change Awareness

Questionnaire. In the study where Quarderer et al. (2021) examined the relationship between the climate literacy level and epistemological beliefs of eighth-grade students, they stated that there was a positive relationship between the students' climate literacy level and epistemological beliefs. The data obtained from this study also revealed similar findings. The high epistemological beliefs of individuals may cause them to shape their lives regarding the information and concepts they learn. In this case, they question the information they learn about climate change from the media, the environment and the education they receive at school and structure their own beliefs according to this information (Holthuis et al., 2014; Quarderer et al., 2021). Therefore, it is an expected result that individuals with high epistemological beliefs also have high awareness of climate change.

The analysis results for the second research question of the study examined whether there was a significant difference in the Scientific Epistemological Belief Questionnnaire scores and Global Warming/Climate Change Awareness Questionnnaire scores of gifted students according to gender. The data obtained at the end of the analysis showed that the Scientific Epistemological Belief Scale scores differed significantly in favor of female students. Similarly, Topcu and Yılmaz-Tuzun (2009) stated in their study that female students had more developed epistemological beliefs than male students in their findings in which they examined the relationship between science achievement, metacognitive knowledge-organization and epistemological beliefs of primary and secondary school students. Schommer (1993) reported that there was a decline in the epistemological belief levels of female students compared to male students in the education and training process of the students in their study in which they examined the development of secondary school students' beliefs about the nature of knowledge and learning and epistemological beliefs and the effect of these beliefs on academic performance. Along with studies showing that the epistemological beliefs of male and female students differ, there are also studies showing that epistemological beliefs do not differ by gender. For example, Yli-Panula et al. (2021) stated in their research findings that high school students' epistemological beliefs on the subject of climate change did not differ by gender. Similarly, Sapancı (2012) stated in his research that examined the epistemological belief and metacognition levels of prospective teachers in terms of various variables that the level of epistemological belief did not differ by gender. Terzi (2005) examined the scientific epistemological beliefs of university students and stated that there was no significant difference between the scientific epistemological belief levels of male and female students. Topcu and Yılmaz-Tuzun (2009) mentioned that the fact that science courses in our national education system are usually in the form of presentations and that female students have more note-taking, monitoring and planning behaviors than male students may be effective in the development of epistemological beliefs. A similar situation may be the case for gifted female students. Although gifted students receive support education at Science and Art Centers, this time is limited to one hour per week and the educational environment in full-time schools may be more disadvantageous for male students than female students in terms of metacognitive achievements.

When the differences in the Global Warming/Climate Change Awareness Questionnaire scores were examined according to gender, it was seen that the mean scores for the Awareness and Behavior Change Tendency section towards the Causes and Effects of Climate Change did not differ significantly between male and female participants, while the scores obtained from the Awareness of Personal Initiatives section differed significantly in favor of female students. Ceylan et al. (2023) examined the attitudes of gifted 4th grade students towards the environment and stated that female students showed more responsible behaviors towards the environment than male students. Yıldırım and Utkugun (2023), in their study examining the interest of high school students in global warming and climate change, stated that the global warming/climate change awareness of female students differed significantly compared to male students. Sahin and Durkaya (2023) stated that the awareness level of high school students differed significantly in favor of female students in the findings of their study on global climate change awareness. Blocker and Eckberg (1997) stated that parents' sensitivity to environmental problems is effective in their behaviors in the family environment and that mothers are more sensitive to environmental problems in terms of their children's future than fathers. In the Turkish family structure the fact that girls have a closer relationship with their mothers in the family environment, female students take a more active role in family responsibilities and in addition to this the fact that male students are more involved with technology than girls in today's conditions may have affected the awareness level of gifted female about personal initiatives towards climate change.

Conclusion

This study focused on the relationship between gifted students' scientific epistemological beliefs and climate change awareness. The findings obtained from the Scientific Epistemological Belief Questionnaire scores of gifted students showed that the participating students had scientific epistemological beliefs above the average level. When the data obtained from the Global Warming/Climate Change Awareness Questionnaire which was

another data collection tool in the study was examined together with similar studies, it showed that gifted students had high levels of awareness of global warming and climate change. When the relationship between the students' Scientific Epistemological Belief Questionnaire scores and the Global Warming/Climate Change Awareness Scale scores was examined in the study, it was seen that there was a positive significant relationship between the Scientific Epistemological Belief Scale scores of the gifted students and the scores obtained from all three sections of the Global Warming/Climate Change Awareness Questionnaire. According to these findings, it is thought that the scientific epistemological beliefs of gifted students and their global warming/climate change awareness interact and that studies to be conducted to develop the scientific epistemological beliefs of gifted students will affect their climate change awareness levels. We think that when designing a curriculum for gifted students regarding global warming/climate change, studies on children's scientific epistemological beliefs can also be integrated into the content.

When the findings regarding whether there is a significant difference in the Scientific Epistemological Belief Questionnaire scores and the Global Warming/Climate Change Awareness Questionnaire scores according to gender are examined, it is seen that the Scientific Epistemological Belief Questionnaire scores differ significantly in favor of female students. When the findings regarding the differentiation of the Global Warming/Climate Change Awareness Questionnaire scores according to gender are examined, it is seen that there is a difference in the scale sections according to gender. While the mean scores regarding the Awareness of the Causes and Effects of Climate Change and Behavior Change Tendency section do not differ significantly between female and male participants, it is seen that the scores obtained from the Awareness of Personal Initiatives section differ significantly in favor of female students. Within the framework of these findings, it can be said that gifted female students have more developed scientific epistemological beliefs than male students and that the awareness levels of female students regarding personal initiatives regarding climate change are higher than male students. However the fact that the sample of this study is not sufficient to make generalizations regarding the findings is one of the limitations of the research. Another limitation is that the sample was not randomly selected. In addition, gifted eighth grade students do not attend Science and Art Center due to their preparation for the high school entrance exam, so they were not included in the study.

Recommendations

In this study, the relationship between scientific epistemological beliefs of gifted middle school students and their awareness of global warming and climate change was examined using the quantitative method. Mixed design studies can be conducted to obtain in-depth data on the scientific epistemological beliefs of gifted students. In addition, it is thought that longitudinal studies on the relationship between scientific epistemological beliefs and climate change will be important in terms of examining the change in the teaching process. In addition, a larger gifted sample can be used to examine the relationship between these two variables. The relationship between scientific epistemological beliefs and climate change awareness of gifted primary and high school students can be examined and compared with the findings of the study conducted with middle school students. The changes in scientific epistemological beliefs and climate change awareness of gifted girls and boys based on gender can be investigated in depth and the reasons for gender-based differences can be examined.

Scientific Ethics Declaration

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

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Decarbonizing K-12 Schools in the United States: Challenges, Opportunities, and Future Directions

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Abstract

K-12 schools in the United States significantly contribute to greenhouse gas emissions due to aging infrastructure, inefficient energy practices, and a heavy reliance on fossil fuels. Addressing these issues through decarbonization is not just important—it is becoming a critical initiative aimed at reducing environmental impact while simultaneously improving the educational environments we offer our students. This paper examines the current landscape of decarbonization efforts in K-12 schools, focusing on our challenges, opportunities, and emerging best practices. By analyzing existing strategies and policies at the federal, state, and local levels, this paper highlights how these efforts are supported—or, in some cases, hindered—by the frameworks in place. The benefits of decarbonization are clear: improved indoor air quality, enhanced learning conditions, and reduced operational costs, all of which contribute to a healthier and more effective educational environment. This research also delves into successful case studies, showcasing innovative approaches and replicable models in other schools nationwide.

Introduction

Given their considerable energy usage and associated carbon footprint, K-12 schools in the United States (U.S.) contribute significantly to greenhouse gas emissions. This is primarily due to outdated infrastructure, energy-inefficient practices, maintenance backlogs, and reliance on fossil fuels for heating and cooling. As a result, these factors have led to a push for decarbonization, with schools being a key area for such efforts.

These factors and myriad government funding opportunities in the U.S. have catalyzed efforts to "decarbonize" schools by removing fossil-fueled infrastructure, increasing energy efficiency, and procuring renewable energy, primarily solar or wind. Many schools view decarbonization as an opportunity to reduce operating costs, provide environmental education, and improve public health. Fully decarbonized schools provide their occupants and surrounding communities with many benefits, such as improved indoor air quality, energy savings, and visible examples of sustainable development. Many schools already serve as community hubs, making their transformation toward decarbonization a visible and impactful sustainability example for students, parents, and residents.

Specifically, this study aims to explore the current decarbonization efforts in K-12 schools across the U.S., identify the main challenges and opportunities, and provide an overview of best practices to facilitate these initiatives. This paper will explore the effectiveness of existing decarbonization strategies in K-12 schools, examining the role of federal, state, and local policies in either supporting or hindering these efforts. The objective is to offer insights into decarbonized school environments' health and educational benefits. Additionally, this paper will summarize best practices and highlight innovative case studies demonstrating the successful implementation of decarbonization projects within the K-12 educational sector.

Literature Review

State of Decarbonization Efforts in K-12 Schools

Efforts to decarbonize K-12 schools in the U.S. have gained momentum in recent years, primarily propelled by the growing recognition of their environmental impact and the availability of significant federal funding. According to the Atlas Buildings Hub (2023), substantial progress has been made in building electrification and energy efficiency improvements. Schools are increasingly adopting renewable energy sources, such as solar

panels, and implementing comprehensive retrofitting projects, such as heat pumps, thereby reducing the school's carbon footprint. Integrating renewable energy and energy efficiency measures in K-12 schools can yield substantial benefits, including lowered energy costs, improved indoor air quality, and enhanced educational opportunities for students (Iyiegbuniwe, 2014).

Practical strategies for decarbonizing K-12 schools involve leveraging the firsthand experiences of school district leaders. It is essential to provide quality data to dispel misconceptions hindering decarbonization efforts' progress and aid decision-makers. The Efficient and Healthy Schools Webinar series has contributed to this by discussing resources, best practices, and practical examples from school districts that have successfully embarked on decarbonization initiatives (Lawrence Berkeley National Laboratory, 2022). Despite the availability of guides and roadmaps, such as the Decarbonization Roadmap Guide and the Building Electrification Technology Roadmap for Schools, challenges persist in implementing decarbonization strategies. These include financial constraints, lack of technical expertise, and resistance to change within school communities (Lawrence Berkeley National Laboratory, 2023).

Benefits of Decarbonization

The benefits of decarbonizing school environments extend well beyond environmental impact. The positive outcomes are improved indoor air quality, enhanced learning conditions, and reduced operational costs. Studies have shown that students perform better academically and experience fewer health issues in well-ventilated, energy-efficient buildings (Fisk, Black, & Brunner, 2011; Haverinen-Shaughnessy, Moschandreas, & Shaughnessy, 2011; Mendell & Heath, 2005; Shendell et al., 2004; U.S. Environmental Protection Agency, 2018). Beyond environmental impacts, these benefits provide a compelling argument for adopting sustainable practices in K-12 schools.

Improved Indoor Air Quality

Research has consistently demonstrated a positive correlation between air quality and cognitive performance. A study highlighted by Trane (2023) found that students in well-ventilated classrooms demonstrated significant improvements in cognitive tasks, including concentration, problem-solving, and memory retention. Trane's study reaffirmed the Harvard T.H. Chan School of Public Health findings, which quantified that higher indoor air quality improved the cognitive function scores of students by 61% (2015). Improved air quality's positive health impacts are compelling and go beyond learning benefits. Since poor air quality is a known exacerbator of conditions such as asthma and allergies, it contributes to higher rates of absenteeism among students (Shendell et al., 2004). When decarbonization efforts install enhanced ventilation systems, this reduces allergens and pollutants, thereby decreasing respiratory-related health issues and allowing students to maintain continuous academic engagement (Harvard T.H. Chan School of Public Health, 2015).

Decarbonization efforts also involve removing onsite fossil fuel combustion, directly impacting indoor and outdoor air quality. Schools that transition away from fossil fuel-based heating and cooling systems reduce emissions of harmful pollutants such as carbon monoxide (CO) and nitrogen oxides (NOx). These pollutants are known to have adverse health effects, particularly on respiratory and cardiovascular health (Fisk et al., 2011). By eliminating the use of fossil fuels, schools not only contribute to broader climate goals but also create healthier environments. For example, schools utilizing geothermal heat pumps or solar thermal systems can achieve consistent indoor temperatures and better air quality without the drawbacks of fossil fuel combustion (Corsi et al., 2002).

Enhanced Learned Conditions

Decarbonization initiatives also significantly enhance learning conditions beyond improved air quality. Modernizing school infrastructure to incorporate sustainable design principles results in more conducive teaching and learning environments. Key components include increased natural lighting, improved acoustics, and stabilized indoor temperatures. Hathaway et al. (1992) found that students in classrooms with ample natural light scored up to 25% higher on standardized tests than those in artificially lit rooms. Natural light improves visibility and boosts mood and energy levels, improving student engagement and productivity.

Poor acoustics are common in older school buildings, leading to distractions and reduced comprehension. Decarbonization efforts often include the installation of sound-absorbing materials and the design of spaces that minimize background noise. According to the Acoustical Society of America (2014), improved classroom acoustics can enhance speech intelligibility by 25%, allowing students to understand better and retain information. Maintaining stable indoor temperatures is critical for student comfort and concentration. Environmental Protection Agency (EPA) research suggests thermal comfort impacts cognitive performance, with deviations from optimal temperature ranges leading to decreased focus and productivity (EPA, 2019). Energy-efficient HVAC systems in decarbonization projects help maintain consistent indoor temperatures, supporting sustained academic performance (Wargocki & Wyon, 2007).

Decarbonization initiatives significantly enhance learning conditions by modernizing school infrastructure to incorporate sustainable design principles, resulting in more conducive teaching and learning environments. Key components of these initiatives include increased natural lighting, improved acoustics, stabilized indoor temperatures, and the introduction of air conditioning to combat extreme heat. Natural lighting has been shown to have a profound impact on student performance. Hathaway et al. (1992) found that students in classrooms with ample natural light scored up to 25% higher on standardized tests than those in artificially lit rooms. This finding is corroborated by the Heschong Mahone Group (1999), which demonstrated that students in naturally lit classrooms performed 20-26% better on tests, and by Nicklas and Bailey (1996), who found that daylighting in classrooms improves overall student performance in reading and math. Natural light enhances visibility and boosts mood and energy levels, improving student engagement and productivity.

Improved acoustics are another critical component of decarbonization efforts. Poor acoustics, common in older school buildings, lead to distractions and reduced comprehension. The installation of sound-absorbing materials and the design of spaces that minimize background noise are often included in decarbonization projects. According to the Acoustical Society of America (2014), improved classroom acoustics can enhance speech intelligibility by 25%, allowing students to understand and retain information better. Shield and Dockrell (2003) found that poor acoustics negatively affect student performance, particularly in verbal tasks, while Klatte et al. (2010) indicated that improved acoustical environments enhance reading and math scores by 10-15%. Maintaining stable indoor temperatures is critical for student comfort and concentration. The Environmental Protection Agency (EPA, 2019) suggests thermal comfort impacts cognitive performance, with deviations from optimal temperature ranges leading to decreased focus and productivity. Energy-efficient HVAC systems help maintain consistent indoor temperatures, supporting sustained academic performance. Wargocki and Wyon (2007) found that improving classroom temperatures to optimal ranges can boost student performance by 7-15%.

Decarbonization efforts also provide the opportunity to introduce air conditioning, crucial for combating extreme heat that has increasingly led to school closures in recent years. Installing energy-efficient air conditioning systems ensures that classrooms remain conducive to learning even during heatwaves. Park et al. (2019) found that extreme heat negatively impacts student learning outcomes, decreasing performance as temperatures rise. Schools can mitigate these effects by introducing air conditioning and maintaining a stable learning environment.

Reduced Operation Costs

Beyond immediate educational benefits, decarbonization significantly reduces operational costs, which can then be redirected toward improving educational resources and programs. Decarbonized schools utilize energy-efficient systems that consume less power compared to traditional systems. The initial investment in technologies such as LED lighting, solar panels, and advanced HVAC systems is offset by long-term savings in utility bills. A National Renewable Energy Laboratory (NREL) report estimates that schools can reduce energy costs by up to 25% through these upgrades (Pless et al., 2018).

The savings from reduced energy consumption can be reallocated to support various educational initiatives. For instance, schools can invest in updated textbooks, digital learning tools, and extracurricular programs. By redirecting funds saved through energy efficiency, schools can enhance the quality of education they provide. Studies have shown that access to updated learning materials, and technology can improve student engagement and academic performance. For example, Waddell (2015) found that integrating digital classroom learning tools enhances student comprehension and interaction. The resulting financial savings can be allocated to hire additional faculty, reduce class sizes, and improve student-to-teacher ratios, enhancing overall educational quality. Darling-Hammond (2000) demonstrated that smaller class sizes lead to more individualized attention

from teachers and better student outcomes. Schools that can afford to employ more faculty can provide a more supportive learning environment, contributing to higher levels of student achievement.

Decarbonization efforts align with broader sustainability goals, fostering an environmentally responsible culture within the school community. This culture benefits the environment and instills values of sustainability and stewardship in students, preparing them to be conscientious global citizens. Sustainability education, integrated into the curriculum, has been shown to increase students' environmental awareness and responsibility (Tilbury, 1995). By embedding sustainability practices into the school's operations, students learn the importance of reducing their carbon footprint and engaging in eco-friendly behaviors. Decarbonization projects often involve the school community in the planning and implementation phases, promoting a sense of ownership and participation among students, staff, and parents. Community engagement in sustainability projects can enhance social cohesion and foster collaboration (Fisman, 2005). Students who participate in these initiatives gain practical experience and develop valuable skills beyond the classroom, such as project management, teamwork, and problem-solving.

Policy Analysis

Policy frameworks are crucial in facilitating or hindering decarbonization efforts in K-12 schools. Comprehensive policies that offer financial incentives, technical support, and regulatory guidance are essential for driving progress. This section analyzes various federal, state, and local policies and programs that impact school decarbonization efforts, using specific examples to illustrate their effectiveness.

Federal Policies

The Inflation Reduction Act (IRA), enacted in 2022, has allocated significant funding to support energy efficiency and renewable energy projects, including those in K-12 schools. This legislation incentivizes schools to adopt clean energy technologies and enhance energy efficiency. The impact of the IRA has been profound, enabling schools to undertake large-scale energy retrofits. A notable example is the Miami-Dade County Public Schools in Florida, which received a $15 million grant under the IRA to install new HVAC systems and solar panels. These upgrades have led to substantial energy savings and improved indoor air quality for the district's schools (Miami-Dade County Public Schools, 2023). However, the implementation of IRA funds is challenging. The process can be complex, primarily due to the stringent application requirements and the need for matching funds from local sources, which may only sometimes be readily available. These hurdles can complicate efforts to fully leverage the IRA's benefits, particularly for schools in underfunded districts (U.S. Department of the Treasury, 2023). The Better Buildings Challenge, launched by the U.S. Department of Energy, is designed to encourage organizations, including K-12 schools, to commit to improving their energy efficiency by at least 20% over ten years. The program offers technical assistance, resources, and recognition to participating organizations to support this ambitious goal. The impact of the Better Buildings Challenge has been significant, with the Houston Independent School District in Texas serving as a prime example.

By participating in the challenge and implementing a district-wide energy management system, the district achieved a 30% reduction in energy consumption, resulting in $1.5 million in annual energy cost savings. However, the success of the Better Buildings Challenge is contingent on several factors. The availability of technical expertise is crucial for schools to implement energy-efficient measures effectively. Additionally, the commitment of school administrators and staff to adopt and maintain these practices plays a vital role in the long-term success of energy efficiency initiatives. With strong leadership and a dedicated approach to energy management, the full potential of the Better Buildings Challenge may be easier to realize (Houston Independent School District, n.d.).

The Green Ribbon Schools Program, administered by the U.S. Department of Education, recognizes schools that have made substantial progress in reducing their environmental impact, improving health and wellness, and delivering effective sustainability education. This program highlights schools' efforts in integrating sustainability into their operations and curriculum. A notable example is the Jefferson County Public School District in Colorado, which received the Green Ribbon Schools award for its comprehensive sustainability initiatives. Among these efforts was the achievement of net-zero energy status for one of its elementary schools, accomplished through passive solar design, geothermal heating, and onsite wind energy generation. This recognition underscores the district's commitment to sustainability. It serves as a model for other schools aiming

to reduce their environmental footprint while enhancing student learning experiences (U.S. Department of Education, n.d.).

State Policies

California Clean Energy Jobs Act

The California Clean Energy Jobs Act, also known as Proposition 39, was enacted by California voters in 2012. This landmark legislation provides substantial funding to improve energy efficiency and increase the adoption of clean energy technologies in public schools and buildings. The overarching objectives of Proposition 39 include the reduction of greenhouse gas emissions, lowering energy costs, and fostering healthier, more sustainable learning environments (Table 1). The Act facilitates these goals by offering grants for energy audits, efficiency retrofits, and the installation of renewable energy systems.

Table 1. Key components of proposition 39

Component	Objective	Process/Technology	Outcome
Energy Audits and Assessments	Establish baseline energy consumption and inefficiencies	Certified energy professionals conduct audits	Reports outlining recommended improvements and projected energy savings
Energy Efficiency Upgrades	Improve energy efficiency in educational buildings	LED lighting upgrades, modernized HVAC, improved insulation	Significant reductions in energy use and operational costs
Renewable Energy Installations	Expand the use of renewable energy in schools	Solar panels, wind turbines, and other renewable systems	Decreased fossil fuel reliance and a reduced carbon footprint

The California Clean Energy Jobs Act emphasizes the state's commitment to promoting sustainability in educational settings. Through a combination of targeted financial support, comprehensive energy audits, and strategic energy efficiency measures, Proposition 39 provides a model for integrating energy-saving practices and renewable energy into schools. These efforts not only lead to significant reductions in both energy use and costs but also contribute to an enriched educational experience by raising awareness about sustainability among students. The lessons learned from California's approach offer a framework that other states can replicate to achieve similar outcomes.

The Los Angeles Unified School District's implementation of Proposition 39 highlights its success in achieving significant energy savings and advancing renewable energy adoption (Table 2). The district's efforts demonstrate how local engagement, alongside state funding and support, can result in tangible environmental and financial benefits. These initiatives offer a blueprint for scalability in other school districts facing similar challenges.

Table 2. Los Angeles Unified school district proposition 39 projects

Component	Objective	Process/Technology
Component	Implementation	Outcome
Energy Audits	Comprehensive audits across multiple campuses	Identification of energy efficiency improvements
Efficiency Upgrades	LED lighting retrofits, modernized HVAC, improved insulation	30% reduction in district-wide energy consumption
Solar Installations	Solar panels installed on school rooftops	Significant CO2 emissions reduction and generation of clean energy
Educational Initiatives	Sustainability concepts integrated into the curriculum	Increased environmental awareness and student engagement
Cost Savings	Efficiency and renewable energy measures	$5 million annual savings on energy bills
Community Involvement	Engagement with stakeholders and local communities	Increased support for sustainability initiatives
Scalability	Pilot projects expanded to other district schools	Scalable solutions adaptable to other districts
Challenges	Competitive grants and complex funding processes	Delayed implementation in some schools due to resource limitations

New York State Energy Research and Development Authority (NYSERDA) Programs

The New York State Energy Research and Development Authority (NYSERDA) leads various programs that support energy efficiency and renewable energy initiatives in K-12 schools. The Clean Energy Communities Program and the K-12 Schools Program are key components of these efforts, aimed at reducing energy consumption, lowering operational costs, and fostering healthier learning environments through energy audits, retrofits, and renewable energy projects.

Table 3. NYSERDA key components

Program	Objective	Support/Measures	Outcome
Clean Energy Communities	Promote local government adoption of clean energy practices	Grants, technical assistance, recognition	Enhanced community engagement and commitment to sustainability
K-12 Schools Program	Improve energy efficiency and renewable energy use in schools	Funding for energy audits, retrofits, and renewable installations	Reduced energy consumption, improved air quality, and increased clean energy adoption

NYSERDA's programs reflect New York State's commitment to sustainability in education by offering targeted financial and technical assistance. These efforts not only result in energy and cost savings but also enhance the learning environment and promote student engagement in sustainability practices. The experiences from case studies, such as those in the Rochester City School District, offer replicable models for other school systems aiming to implement similar programs.

Table 4. Rochester city school district NYSERDA-funded projects

Component	Implementation	Outcome
Energy Audits	Comprehensive audits in multiple school buildings	Identification of energy efficiency opportunities
Efficiency Upgrades	Installation of efficient lighting, HVAC systems, improved building envelopes	25% reduction in district-wide energy consumption
Renewable Energy	Solar panel installations on school rooftops	CO2 emissions reduced by hundreds of metric tons annually
Educational Initiatives	Integration of energy efficiency and renewable energy topics into the curriculum	Increased student engagement and hands-on learning
Cost Savings	Efficiency and renewable energy projects	$1.5 million in annual energy cost savings
Community Involvement	Engagement with stakeholders and community	Increased support for sustainability initiatives
Scalability	Successful projects replicated at other schools	Scalable solutions adaptable to other districts
Challenges	Navigating complex funding and technical expertise requirements	Delays in project implementation

Maryland Energy Administration Decarbonizing Public Schools Program

Maryland is leading efforts to decarbonize K-12 schools through comprehensive programs aimed at reducing greenhouse gas emissions and increasing the use of clean energy technologies. The Maryland Energy Administration (MEA) launched the School Decarbonization Pilot Program, which provides funding and support for energy efficiency upgrades, renewable energy installations, and sustainability education.

The Maryland School Decarbonization Pilot Program exemplifies a holistic approach to reducing energy consumption and emissions in school facilities. By funding energy audits, supporting retrofits, and promoting renewable energy adoption, Maryland schools are creating healthier and more energy-efficient learning environments. These efforts also serve as a model for how educational institutions can contribute to broader sustainability goals.

Table 5. Maryland energy administration key components

Component	Objective	Support	Outcome
Energy Audits and Assessments	Identify inefficiencies and opportunities for improvement	Funded energy audits in school facilities	Actionable areas for energy savings identified
Energy Efficiency Upgrades	Retrofit school buildings for energy efficiency	Funding for LED lighting, HVAC, and insulation upgrades	Significant reduction in energy use and operational costs
Renewable Energy Installations	Increase the use of renewable energy	Supported installations of solar panels and geothermal systems	Decreased reliance on fossil fuels and lower emissions
Educational Integration	Incorporate sustainability into the curriculum	Provided resources for hands-on learning	Increased student participation in sustainability efforts

Local Policies

Seattle Public Schools' Resource Conservation Program

Seattle Public Schools has implemented a Resource Conservation Program to reduce energy and water consumption, minimize waste, and lower greenhouse gas emissions across the district. This program involves real-time energy monitoring, student-led conservation projects, and staff training to foster a culture of sustainability within schools (Table 6). Seattle Public Schools' Resource Conservation Program demonstrates how a school district can foster long-term sustainability by engaging both students and staff in conservation efforts, achieving measurable energy and cost savings.

Table 6. Seattle public schools' resource conservation program

Component/Action	Objective	Outcome
Real-Time Energy Monitoring	Track and manage energy consumption in real time	20% reduction in district-wide energy consumption
Student-Led Conservation Projects	Engage students in sustainability initiatives	Increased student participation in energy-saving campaigns
Staff Training	Equip staff to implement conservation practices	Empowered staff contributing to $1 million in annual utility savings

Austin Energy Green Building Program

The Austin Energy Green Building Program partners with schools to promote sustainable building practices. Through financial incentives, technical assistance, and educational resources, the program supports green building projects that reduce operational costs and create healthier learning environments (Table 7). The Austin Energy Green Building Program serves as a model for integrating energy efficiency and sustainability into educational institutions, with measurable improvements in cost savings and student engagement.

Table 7. Austin energy green building program

Component/Action	Objective/Implementation	Outcome
Incentives and Funding	Encourage adoption of green building practices	Increased adoption of green building designs
Technical Assistance	Provide expertise for green building projects	Successful execution of sustainable projects
Educational Integration	Incorporate sustainability into school curricula	Enhanced student understanding of sustainability practices

Interpretation of Findings

The case studies derived from the Renew America's Schools initiative underscore the multifaceted approaches that can substantially advance the decarbonization of K-12 schools. Notably, the integration of solar installations, geothermal systems, energy-efficient retrofits, and comprehensive energy management systems emerge as efficacious strategies. Each technology contributes uniquely to energy reduction and sustainability. Furthermore, embedding these technologies into educational curricula not only maximizes their operational impact but also cultivates an ethos of environmental stewardship among students. This dual approach of technological implementation and academic integration demonstrates a robust model for sustainable educational environments, potentially setting a precedent for future initiatives.

Funding & Support

The necessity for increased federal and state funding cannot be overstated. Large-scale decarbonization projects in schools require significant financial investments that are often beyond the reach of local budgets. Programs such as Renew America's Schools serve as exemplary models, illustrating how governmental support can catalyze substantial improvements in energy efficiency and sustainability. Enhanced funding mechanisms would enable broader participation and more comprehensive project scopes, ensuring that even under-resourced schools can partake in these transformative initiatives.

Policy Frameworks

For school decarbonization efforts to be sustainable and effective, consistent and comprehensive policies at both the federal and state levels are imperative. Financial incentives, technical assistance, and transparent regulatory guidance are essential components of a supportive policy framework. Such policies should aim to lower barriers to entry for renewable energy projects, streamline approval processes, and provide ongoing support through subsidies or tax incentives. A cohesive policy environment would facilitate the widespread adoption of energy-efficient technologies and practices in educational settings.

Community Engagement

The success of decarbonization projects is often bolstered by active collaboration with local communities, businesses, and organizations. Community engagement enhances resource availability and fosters a sense of collective ownership and support for sustainability initiatives. Involving stakeholders from the outset can lead to innovative solutions, improved project outcomes, and increased public awareness. Schools that engage their communities in decarbonization efforts can leverage local expertise and resources, thereby enhancing the overall impact of their projects.

Educational Integration

Integrating decarbonization projects into school curricula provides invaluable experiential learning opportunities. Such integration helps students understand the practical applications of sustainability and fosters a culture of environmental responsibility. Curriculum development that includes hands-on projects, sustainability workshops, and interdisciplinary learning modules can significantly enhance student engagement and awareness. As future leaders and decision-makers, students who are educated in sustainability practices are more likely to advocate for and implement similar initiatives in their personal and professional lives.

Future Directions

To sustain and expand the progress achieved in school decarbonization efforts, future research and policy initiatives should focus on several critical areas. Firstly, scaling successful models is essential; other schools and districts can adopt effective strategies tailored to their specific needs by analyzing and replicating pilots and case studies that have demonstrated success. The dissemination of best practices and lessons learned will be crucial in facilitating this broader application.

Strengthening partnerships is another vital component. Building and maintaining strong relationships with utility companies, government agencies, and private sector partners will ensure decarbonization projects' long-

term sustainability. These collaborative efforts can enhance resource allocation, provide technical expertise, and support the continuous evolution of decarbonization initiatives.

Continuous improvement must also be a priority. Ongoing monitoring and evaluation of decarbonization projects will help identify best practices and areas for enhancement. Establishing continuous feedback loops will ensure that strategies remain effective and adaptable to changing circumstances, thereby maintaining momentum in achieving sustainability goals. Promoting innovation is essential for driving further reductions in energy consumption and environmental impact. Encouraging the development of new sustainable technologies and practices, supported by investment in research and development, will lead to advancements that can significantly impact school decarbonization.

Conclusion

The imperative to decarbonize K-12 schools in the United States has gained substantial momentum, driven by the dual mandates of environmental sustainability and operational efficiency. This study has highlighted the multifaceted approaches and diverse strategies employed across various districts to significantly reduce greenhouse gas emissions, enhance energy efficiency, and foster a culture of sustainability within educational settings.

The Department of Energy's Renew America's Schools initiative has demonstrated that, with adequate support, innovative approaches, and robust community engagement, K-12 schools can significantly reduce their carbon footprint. The case studies presented in this research provide valuable insights and best practices that can be emulated nationwide. By continuing to invest in and prioritize school decarbonization, we can create healthier, more sustainable learning environments for future generations. This holistic approach benefits the environment and enriches the educational experience, equipping students with the knowledge and skills to lead in a sustainable future.

Scientific Ethics Declaration

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

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The Examination of the Concept of Health Literacy through Bibliometric Analysis Method

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Abstract

The concept of health literacy has been defined by the World Health Organization for 25 years. During this period, thousands of publications related to health literacy have been produced in the literature. The aim of this study is to examine publications from the last 10 years concerning the concept of health literacy and to identify topics associated with health literacy in these studies. This article provides a general overview of research conducted on the concept of health literacy using bibliometric methods. The Web of Science (WoS) database was utilized as the data source for gathering information. Over the last 10 years, it has been determined that there have been 17,864 studies conducted on health literacy. This study has examined the distribution of these studies by year, author names, the most frequently used 20 keywords, and the relationships between these keywords. The results of the bibliometric analysis indicate that a variety of topics related to health literacy have been explored. Among these, the most prevalent ones include mental health literacy, health improvement, and mental health. In order to comprehend the concept of health literacy, it is essential to accurately identify the associated sub-concepts. Clearly elucidating the multifaceted relationship between these identified sub-concepts and health literacy is of great importance. The presence of diverse publications in the literature related to sub-concepts associated with health literacy highlights the need to examine these publications, providing a basis for planning future studies.

Introduction

The World Health Organization (WHO) defined health literacy in its Health Promotion Glossary report published in 1998 as "the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand, and use information in ways which promote and maintain good health" (WHO, 1998). Originally focusing solely on individuals' reading and comprehension skills for written information, health literacy has evolved into a concept encompassing numerous factors that affect a person's ability to access, comprehend, and utilize health information from various sources. (Batterham et al., 2016).

At least one-third of the global population experiences difficulties in perceiving health-related issues. The primary cause of these perception issues is the variation in individuals' health literacy levels (Raynor, 2012). It is acknowledged that individuals with particularly low literacy levels have a negative impact on public health and healthcare services (Berkman et al., 2010). In a study, it was found that more than one-third of American adults have limited health literacy, contributing to adverse health outcomes. Health literacy is also indicated to impact patient safety, access to healthcare, and the quality of healthcare services (Hersh et al., 2015). Although health literacy is included in many global health policies, implementing the principles of health literacy in routine practice is not easy. Individuals with low health literacy impact healthcare utilization rates and lead to worse health outcomes compared to those with higher health Literacy (Batterham et al., 2016).

Health literacy is a concept that has significant effects on individual health and public health. This topic is associated with numerous health issues. This study utilizes the Web of Science database to examine publications related to health literacy and conduct bibliometric analysis. Bibliometric analysis is a research field attracting increasing interest within the scientific community, and its importance is particularly growing with the rapid development of the internet. This analysis is becoming a fundamental methodology for evaluating research in the literature. Various articles providing a comprehensive overview of bibliometric analysis exist in many research fields, including management, economics, health, innovation, and entrepreneurship. This research will provide a foresight for future studies on health literacy. The results of the research will guide in understanding the significant issues in this field and potential solutions.

Method

Bibliometric analysis is a research method commonly used to understand global research trends in a specific field through the analysis of academic publications in databases such as WoS (Web of Science). This method typically focuses on metrics such as publication numbers, citations, and author collaborations, aiming to reveal significant trends and relationships in the output of scientific studies through statistical analysis. In this study, an analysis has been conducted on publications related to the concept of "Health Literacy" published in the last 10 years in WoS (Web of Science) using Wosvier.

Results

All categories from the core database of WoS were selected with the keyword "health literacy," and a search was conducted considering the period from 2013 to 2023 (the last 10 years). As a result of the search, 17,864 studies related to the concept of health literacy were identified. Word mining, citation analysis, and bibliometric mapping analyses were performed using the VOSviewer software. As a result of the literature review, the frequency of author keywords in publications related to the concept of health literacy is presented in the table below.

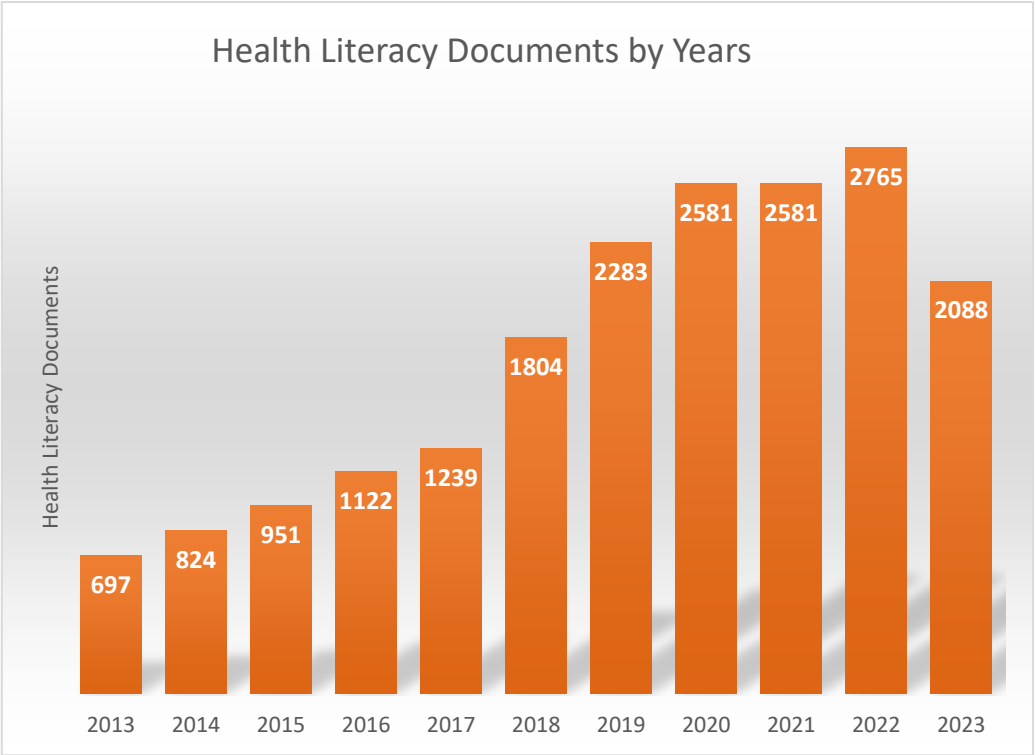

Figure 1. Health literacy documents by years

When examining the distribution of publications related to health literacy over the years, there is a notable increase in the last 5 years. It can be said that the number of studies related to health literacy has increased by more than threefold in the last 10 years. The keywords found in studies related to health literacy, their frequencies, and connection strengths are provided in Table 1.

In the examination of publications based on the concept of health literacy, the most frequently used keyword is the term 'health literacy'. The concept of mental health literacy is in the second place, while the concept of health improvement is in the third place in terms of keyword frequency. Recently, among the top 10 keywords in health literacy studies, the global COVID-19 pandemic is observed.

Figure 1 depicts other sub-keywords associated with the main keyword "health literacy". The relationships between these keywords are illustrated, showing connections both within health literacy and with other sub-keywords. On the figure, the relationships between sub-keywords have been considered, and they are depicted using different colors. These colors represent 6 groups, namely red, green, blue, navy blue, yellow, and purple.

Table 1. Author keywords associated with health literacy

	Keyword	Occurrences	Total Link Strength
1.	Health Literacy	5925	4679
2.	Mental Health Literacy	672	658
3.	Health Promotion	438	636
4.	Mental Health	507	633
5.	Patient Education	476	631
6.	Covd-19	510	610
7.	Health Education	382	538
8.	Depression	330	519
9.	Self-Management	287	403
10.	Education	320	389
11.	Knowledge	293	389
12.	Stigma	277	388
13.	Health Communication	255	386
14.	Readability	273	370
15.	Communication	287	345
16.	Public Health	257	321
17.	Adolescents	236	314
18.	Health İnformation	186	314
19.	Diabetes	219	306
20.	Ehealth	167	300

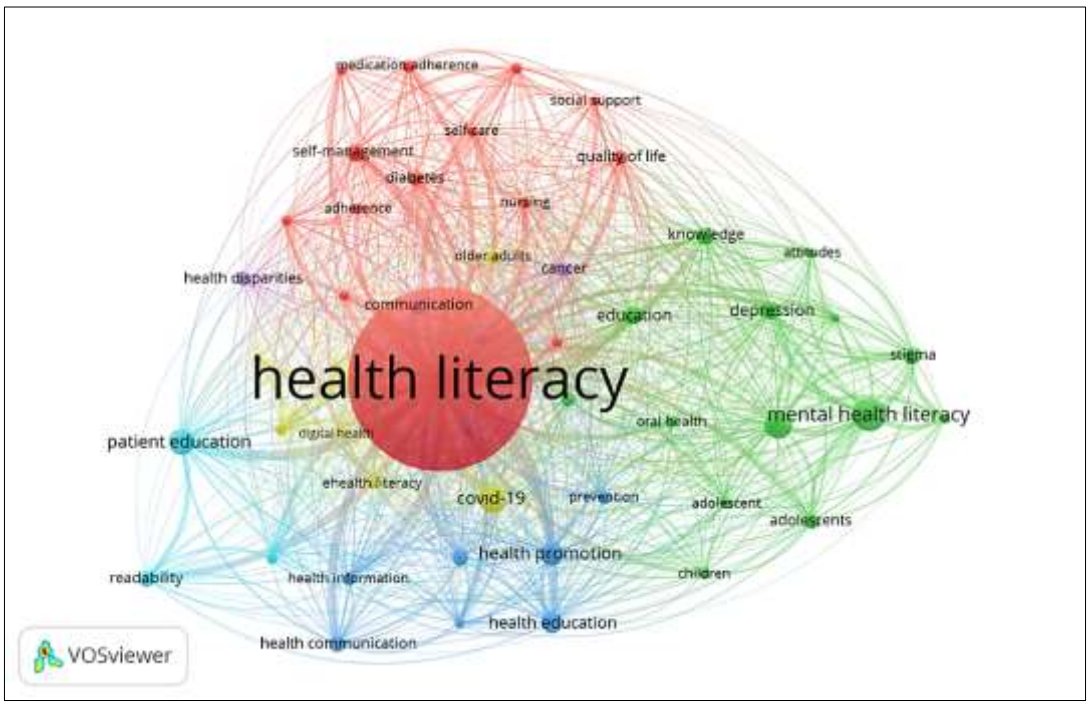

Figure 1. Health literacy author keyword frequency

In the above figure, it can be observed that six subsets are formed in association with the main concept of health literacy. These subsets are:

- Cluster 1- red: adherence, chronic disease, diabetes, health literacy, hypertension, nursing, medication adherence, primary care, quality of life, self-care, self-efficacy, self-management, social support, systematic review.
- Cluster 2- green: adolescents, anxiety, attitudes, children, depression, education, help-seeking, knowledge, mental health, mental health literacy, oral health, stigma.
- Cluster 3- navy blue: empowerment, health communication, health education, health information, health promotion, prevention, public health, social media.
- Cluster 4- yellow: covid-19, digital health, ehealth, ehealth literacy, mhealth, older adults, telemedicine.

- Cluster 5- purple: cancer, communication, health disparities, qualitative research.
- Cluster 6- blue: ınternet, patient education, readability.

In Figure 2, the relationship between the sub-keyword "mental health literacy" and other keywords is illustrated. It is observed that mental health literacy is associated with various subtopics such as depression, education, quality of life, health education, health improvement, health communication, etc.

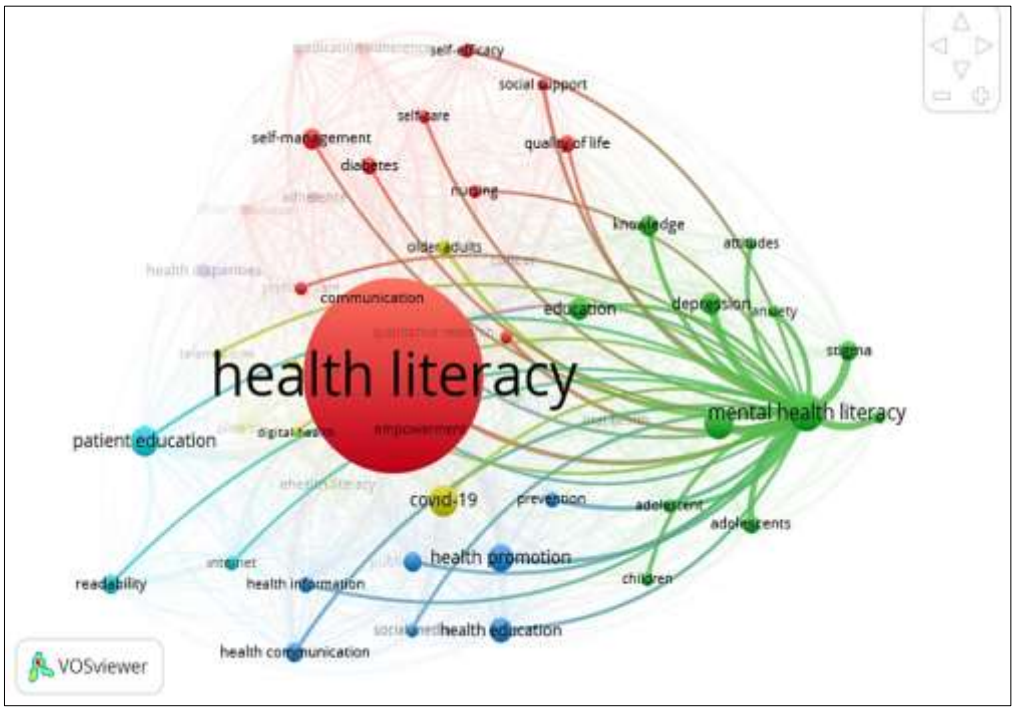

Figure 2. Mental health literacy author keyword frequency

In Figure 3, the relationship between the sub-keyword "health promotion" and other keywords is illustrated. It is observed that health promotion is associated with various subtopics such as readability, prevention, health knowledge, health education, chronic diseases, etc.

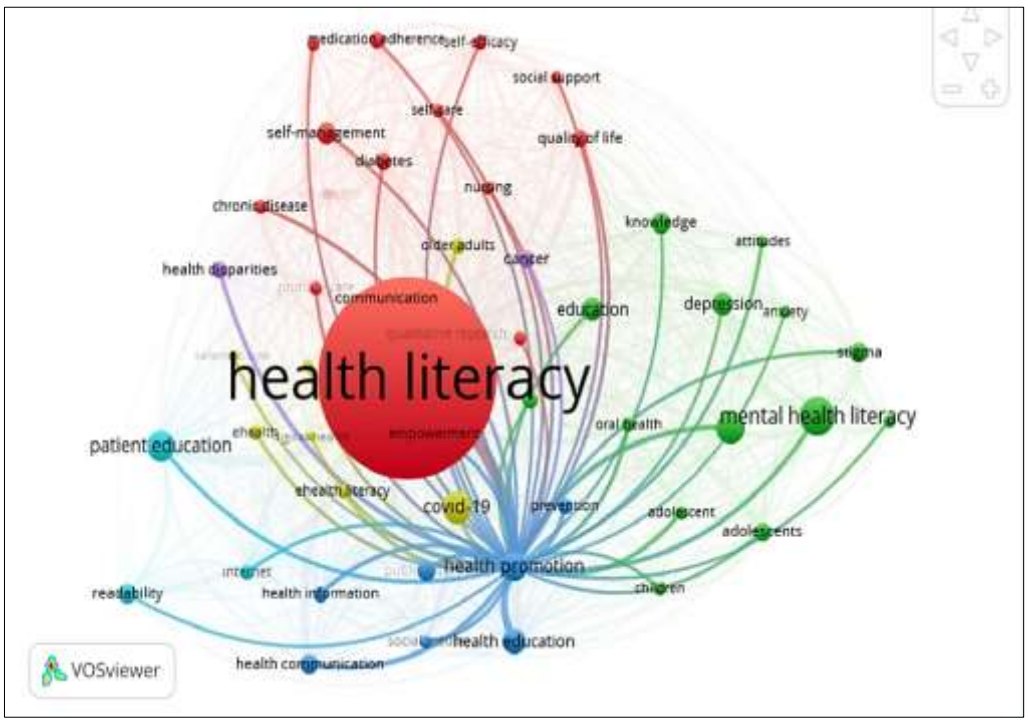

Figure 3. Health promotion author keyword frequency

In Figure 4, the relationship between the sub-keyword "mental health" and other keywords is illustrated. It is observed that mental health is associated with various subtopics such as children, adolescents, stigma, cancer, patient education, etc.

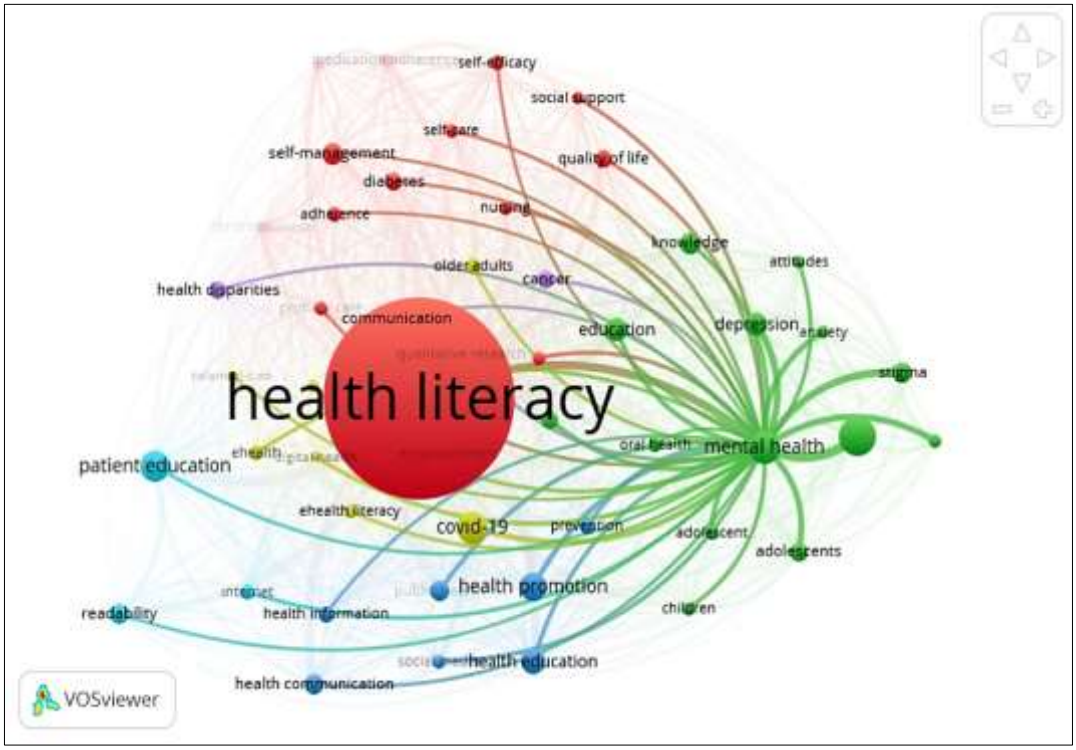

Figure 4. Mental health author keyword frequency

The relationship of the sub-keyword "patient education" with other keywords is shown in Figure 5. It is observed that patient education is associated with various subtopics such as readability, health knowledge, health education, health inequality, etc.

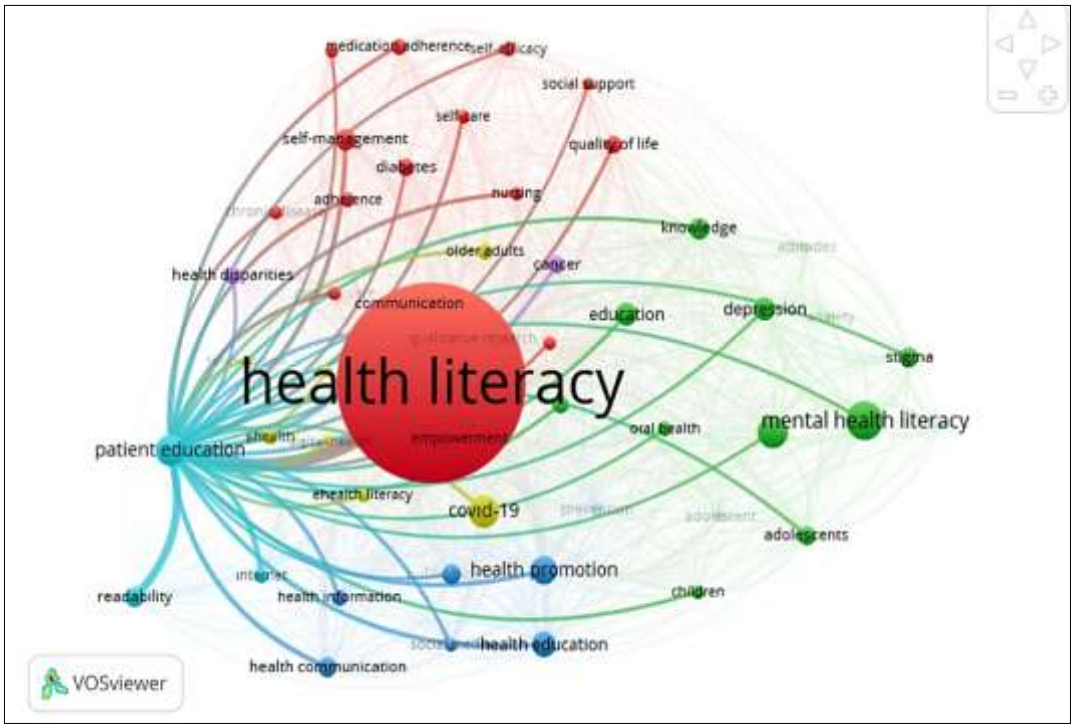

Figure 5. Patient education author keyword frequency

The relationship of the sub-keyword "Covid-19" with other keywords is depicted in Figure 6. It is observed that Covid-19 is associated with various subtopics such as self-care, social support, older adults, e-health, adherence etc.

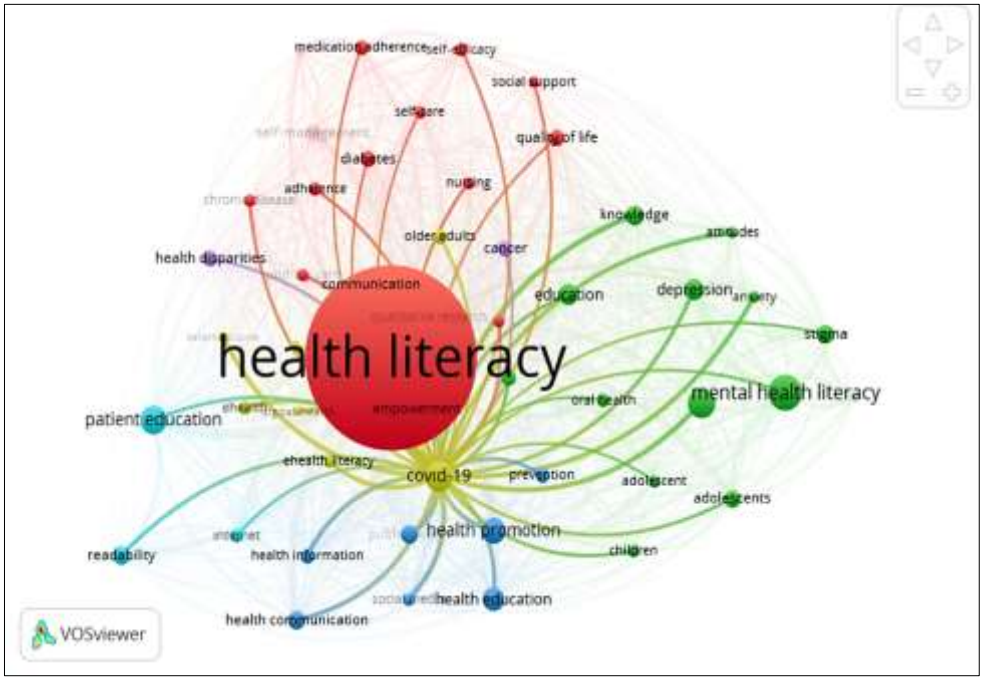

Figure 6. Covid-19 author keyword frequency

The relationship of the sub-keyword "health education" with other keywords is depicted in Figure 7. It is observed that health education is associated with various subtopics such as health promotion, e-health literacy, health communication, health disparities, Covid-19, etc.

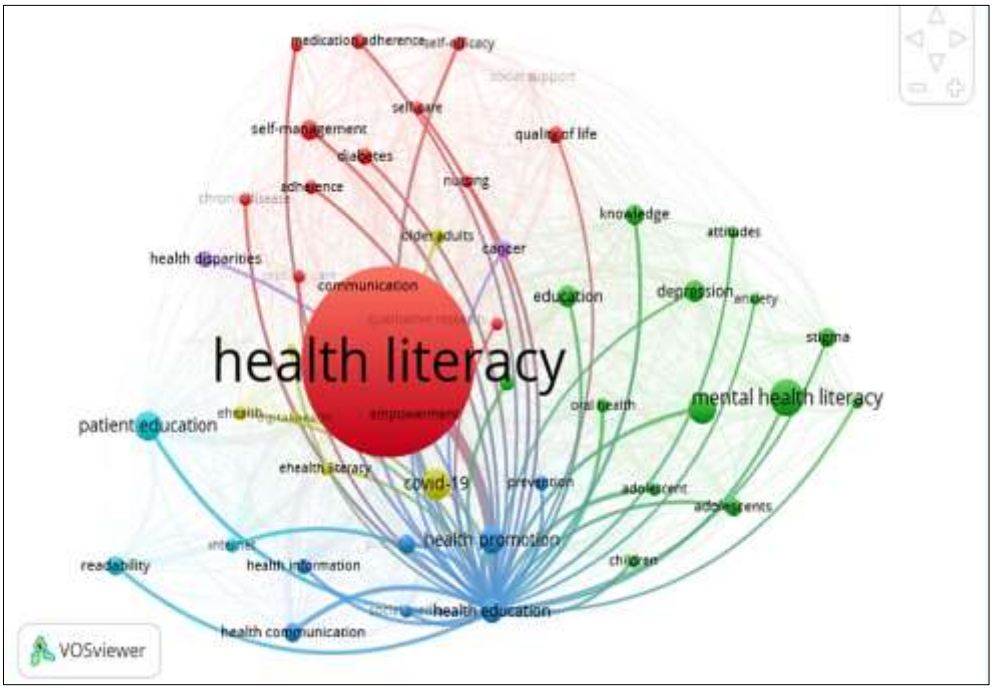

Figure 7. Health education author keyword frequency

The relationship of the sub-keyword "depression" with other keywords is depicted in Figure 8. It is observed that depression is associated with sub-factors such as stigma, anxiety, social support, adult individuals, quality of life, etc.

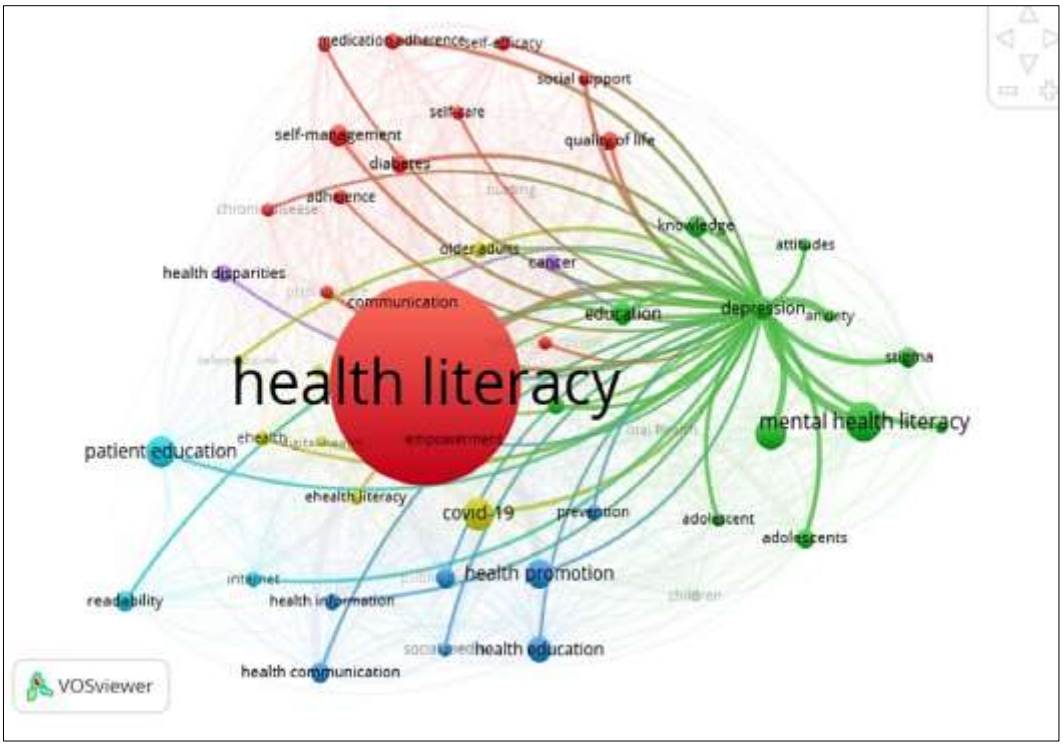

Figure 8. Depression author keyword frequency

The relationship of the sub-keyword "self-management" with other keywords is depicted in Figure 9. Self-management is observed to be associated with sub-factors such as adherence, self-care, health disparities, patient education, communication, etc

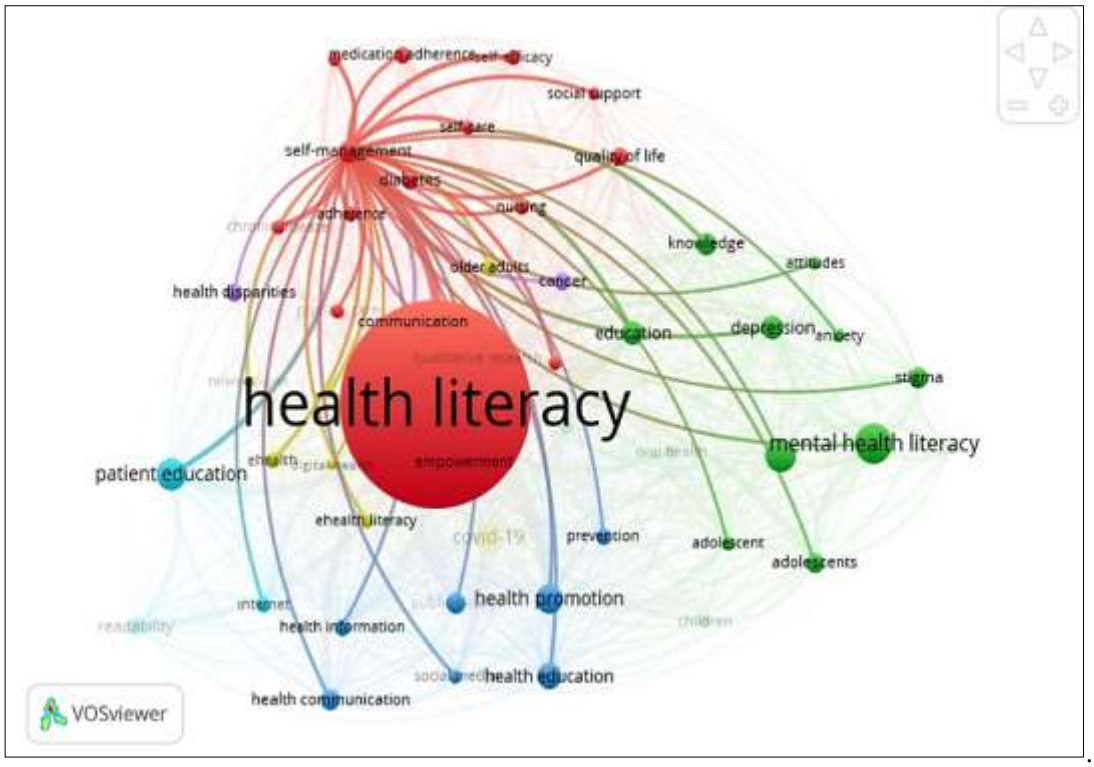

Figure 9. Self-management author keyword frequency

The relationship of the sub-keyword "education" with other keywords is depicted in Figure 10. Education is observed to be associated with sub-factors such as oral health, depression, cancer, qualitative research, nursing, diabetes, etc.

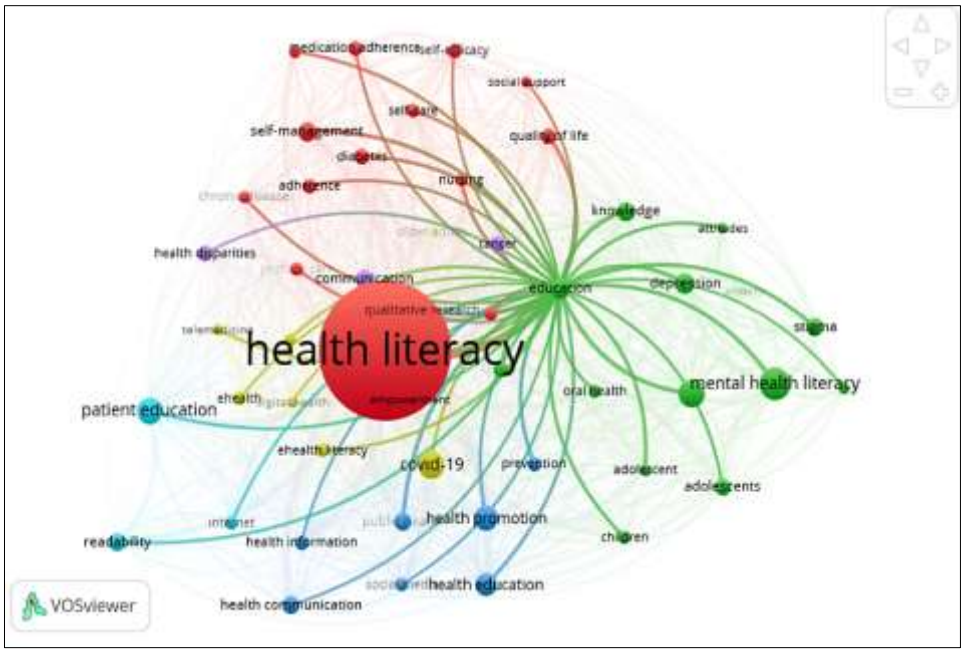

Figure 10. Education author keyword frequency

Figure 11 provides information about authors who have published articles based on the keyword "health literacy." It is observed that authors, similar to keywords, are categorized into 6 groups. Additionally, the figure highlights the citations made by authors to each other. It is notable that Wolf, Michael S. has received the most citations for his work on health literacy. Secondly, Richard H. Osborne has received the second-highest number of citations.

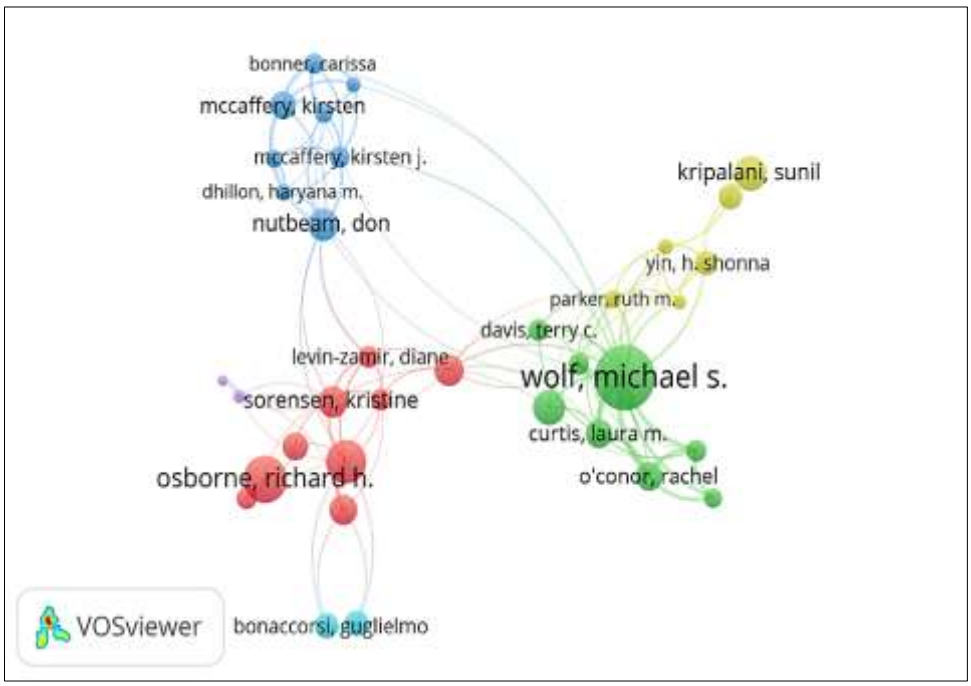

Figure 11. Authors who have used the concept of health literacy

Discussion

It has been argued that health literacy emerged as an important concept for individuals with mental health issues to overcome these negative situations (Coles & Coleman, 2010). It has been observed that many individuals with mental health disorders face difficulties in seeking treatment due to negative attitudes and perceptions (Fleary et al., 2022). The lack of sufficient information and fear of being stigmatized by society have been

explained as some of the barriers to accessing treatment (Sareen et al., 2007). In a different study, the need to improve mental health literacy was emphasised as arising from the complexity of access to services. The limited availability of studies aimed at improving mental health literacy underscores the necessity for the development and monitoring of interventions in this field (De Silva, 2020).

In a study examining the relationship between health literacy and the health behaviors of adolescents, the importance of encouraging adolescents to participate in health literacy-enhancing practices is emphasized. Improving health during adolescence helps prevent negative health outcomes in later stages of life (Park et al., 2017). In a different study, a relationship between students' health literacy and health-promoting behaviors was observed, indicating that as students' health literacy levels increased, they exhibited more health-promoting behaviors (Ozturk, 2020). Similarly, adolescents with low health literacy were found to have a lower likelihood of exhibiting health-promoting behaviors compared to other adolescents (Chang, 2011). Low health literacy is associated with deteriorating overall health, unhealthy eating, weight gain, and engaging in problematic behaviors (Park et al., 2017). Fleary et al. (2018) mentioned the importance of health literacy in imparting health-promoting behaviors to adolescents and emphasized that health literacy should be addressed in school settings. Adding a curriculum that includes basic health information and healthy lifestyle behaviors would be a positive step in increasing students' health literacy. The goal is not only to inform students but also to empower them to take responsibility for their health by developing their health knowledge and supporting their help-seeking skills (Hagell et al., 2015).

A significant relationship has been identified between all dimensions of health-promoting behaviors and health literacy (Chahardah-Cherik et al., 2018). In a study, the necessity of focusing on improving patients' health literacy and thus enhancing their health levels was emphasized (Bayati et al., 2018). In a different study examining the relationship between health literacy and individuals' health behaviors, the importance of encouraging adolescents to participate in health literacy-enhancing practices was highlighted. It has been observed that improving health prevents negative health outcomes in later stages of life (Park et al., 2017). In another study, a relationship between health literacy and health-promoting behaviors was observed, indicating that as health literacy levels increased, individuals exhibited more health-promoting behaviors (Ozturk, 2020). Fleary et al. (2018) mentioned the importance of health literacy in imparting health-promoting behaviors to students and emphasized that health literacy should be addressed in school settings. Adding a curriculum that includes basic health information and healthy lifestyle behaviors would be a positive step in increasing students' health literacy. The goal is not only to inform students but also to empower them to take responsibility for their health by developing their health knowledge and supporting their help-seeking skills (Hagell et al., 2015).

When analyzed at the societal level, mental health literacy is generally found to be insufficient (Kelly et al., 2007). Individuals with low health literacy have been observed to underutilize healthcare services, leading to a negative impact on their mental health. Additionally, previous negative experiences with healthcare services are anticipated to result in low health literacy, and this, in turn, may adversely affect their mental health (Milner, 2019).

Numerous studies have emphasized that the level of mental health literacy is lower in young people and various public policies need to be developed to eliminate this negative situation. These policies can guide young people in learning about their mental health and recognizing ways of protection (Samapıo et al., 2022). It is argued that strategies for mental health literacy should be evidence-based, designed with social awareness, developmentally appropriate, applicable throughout the lifespan, inclusive, and culturally sensitive (Gorczynski, 2021). In a different study, it is claimed that increasing mental health literacy presents some challenges and these challenges can be addressed with a carefully developed program. Mental health literacy programs should be inclusive, consider economic opportunity inequality, and address social issues such as discrimination and their impact on mental Health (Henderson, 2023).

The materials provided during the patient education process should ensure suitability for individuals with varying levels of health literacy. Ensuring the comprehensibility of forms in the patient education process enhances the patient's ability to access and utilize appropriate hospital services. Providing patients with more accessible health education materials will encourage them to actively participate in their care by fostering confidence in decision-making about their treatments (Demarco, 2010). A study conducted on patients with hearing impairment examined an issue related to the readability of educational materials. The inability of the patient to perform simple tasks to ensure the proper functioning of the hearing aid led to their return to the healthcare facility. This situation resulted in the patient experiencing loss of time, money, and disappointment (Nair, 2010). The provision of a patient education program to individuals with chronic diseases has been documented to increase their disease-specific knowledge. Patient education programs have encouraged patients

to play a more active role in their illness processes, resulting in an enhancement of their health literacy (Eckman, 2012).

The study revealed a negative relationship between health literacy and depressive tendencies in diabetic women (Hsu, 2020). It has been demonstrated that, compared to women, men in both Covid-19 positive and negative groups have higher health literacy scores. Previous studies have shown that, especially in elderly adults, men tend to have worse health outcomes (Tang, 2020). Therefore, improving health literacy can be a strategic approach to prevent and minimize the outcomes of Covid-19, particularly in men and the elderly (Do, 2020). It has been found that higher health literacy scores in individuals with Covid-19are associated with a lower probability of depression. This result is consistent with previous studies (Wang, 2020). It is also noted that higher health literacy is associated with lower Covid-19 fear and a lower probability of depression (Nguyen, 2020).

Improving health literacy through health education depends on long-term strategies and their implementation through specific efforts. The establishment of this system should begin from school age. In this way, lifelong habits, skills, and decision-making processes that can impact community health will be positively influenced (Auld, 2020). Health education is also a paramount responsibility of healthcare providers. Therefore, it is recommended to teach healthcare workers health literacy education strategies and skills to effectively communicate with patients with low health literacy levels (Bahramian, 2020). In health education provided by healthcare professionals, confirming understanding is a critical component of the training. However, validation methods are limited to questioning rather than using interactive skills such as feedback. The effectiveness of methods or tools used in health education needs to be tested with effective tools from the patient's perspective to confirm understanding of instructional materials. It is argued that establishing individual learning styles would be beneficial to enhance the effectiveness of patient education and health literacy (Kim, 2020).

There has been a relationship found between inadequate health literacy and individuals' tendencies toward depression (Hsu, 2020). In a study encompassing 224 patients in Australia, it was observed that depressive feelings were associated with low health literacy (Maneze, 2016). A study conducted in South Korea showed that individuals with low health literacy had significantly more depressive symptoms (Rhee, 2017). In a study in the United States, health literacy was found to be significantly associated with depressive symptoms (Kuczmarski, 2015). In a different study, individuals with lower health literacy were found to have 1.2 times higher odds of depression (Gazmararian, 2000).

Patients with adequate and limited health literacy showed different outcomes in self-management. Individuals with limited health literacy exhibited poorer performance in certain self-management behaviors. Reinforcement of previously taught behaviors led to greater improvement in the limited literacy group (Kim, 2004). To enhance self-management programs with a focus on empowering patients to manage their care, a system that centers on families should be implemented. Health care professionals should not only provide adaptable health literacy education programs but also create supportive environments, strengthen the social support function, and connect patients' self-management behaviors to social support resources (Chen, 2018). There were found to be significant relationships between critical health literacy and self-management behavior (Heijmans et al. 2015), but van der Heide et al. (2013) found that critical health literacy was not associated with patients' perceived abilities to perform self-management behaviors. It is emphasized that targeted self-management support activities based on patients' health literacy capacity should be developed through the collaborative participation of family, community, and the medical system (Qiu, 2020).

In a conducted study, it has been observed that obtaining an additional year of education has a positive and significant impact on health literacy for women. However, it has been found that it does not have a significant effect for men (Celidoni,2023). Low educational attainment has been found to be associated with poor overall health (Mackenbach et al., 2008), and it has been linked to a decline in physical and mental health (Lee et al., 2010). It is believed that strategies aimed at reducing inequalities in health through education may provide greater benefits than the focus on health literacy alone. Adapting health information to be more accessible, understandable, and usable by individuals facing challenges in reading and numeracy is suggested to enhance opportunities for them to protect or improve their Health (Van Der Heide, 2013).

Conclusion

Health literacy is an important concept, and when conducting studies related to this concept, it is crucial to define the sub-concepts associated with it. There are no limitations to the sub-concepts associated with health

literacy, and this concept encompasses all terms related to public health. In our literature search on health literacy using the Web of Science (WoS), it was observed that 17,864 documents were generated in the last 10 years. Among these publications, the top 5 sub-concepts most frequently studied in relation to health literacy were identified as mental health literacy, health promotion, mental health, patient education, and Covid-19.

The findings obtained within the scope of this study serve as a guide for researchers considering work in this field. By correlating the obtained results with other studies in the literature, a more comprehensive approach to the topic of health literacy has been adopted. Additionally, the insights gained will contribute to enriching the literature on health literacy and encouraging future researchers to approach the subject from different perspectives.

Recommendations

- A comprehensive analysis can be conducted on prominent themes such as mental health literacy and health promotion; for instance, the relationship between mental health literacy and general health literacy could be explored in greater depth.
- Through the expansion of keyword analyses, the interplay between emerging topics such as pandemics, climate change, and health literacy can be explored in greater depth.
- Comparative analyses of health literacy levels across different countries and their implications for healthcare systems can be undertaken, with priority given to studies investigating the influence of cultural differences on health literacy.

Scientific Ethics Declaration

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

*In addition, since the study was based on scanning open access documents in WoS, ethical approval was not required.

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An Investigation of Coding Education Practices in terms of Primary School Students' Algorithmic Thinking Skills and Students' Opinions

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Abstract

This study aims to examine the views of fourth-grade primary school students on coding education given through the Scratch program by determining the students' skills in using the program and algorithmic thinking skills. The study was conducted as a one-group study with an embedded mixed design. The study group consisted of 32 students attending the 4th grade in a primary school. The data were collected using the Algorithmic Thinking Skills Scale developed by the researcher, Semi-structured Interview Form, Student Diaries, Scratch Programming Skills Checklists and Researcher Diary. According to the quantitative results of the study, a significant difference was found between the Algorithmic Thinking Skill Scale pre-test and post-test results of the students in the experimental group. According to the results obtained from the Scratch checklists among the qualitative results of the study, it was observed that the students in the experimental group generally added the decor, characters and codes in the projects correctly. According to the student diaries among the qualitative results of the study, it was determined that students generally found the coding course and the projects done in the course enjoyable. The data obtained from the researcher's diaries also supported the student diaries. Finally, according to the student opinions among the qualitative results of the study, it was concluded that the students liked the Scratch program enjoyed making projects and did not get bored. In this context, it is recommended to provide coding education to primary school students and to teach the Scratch program to primary school students.

Introduction

Coding

In recent years, coding education has become increasingly popular, especially among young children. From kindergarten to high school, coding education or programming is implemented in both public and private schools. Teaching coding or programming to children has become more accessible with the widespread availability of coding tools that make programming more engaging during the teaching process (Erol, 2020). Coding involves the step-by-step creation of instructions that outline the processes required for a specific action to be performed using computers. In other words, it is the process of developing various solutions to existing problems by using a language that computers can understand (Yigit, 2016). It also entails the sequential execution of predefined commands and the clear articulation of tasks to be performed through computers in the form of instructions (EBA, 2024). Coding is the process of writing one or more commands on a computer system to perform a specific task. It involves converting an algorithm developed to achieve a goal into a programming language. Computer programming or coding can be explained as the development and implementation process that uses various command sets to accomplish predetermined tasks or operations on a computer, solve encountered problems, and establish the necessary interaction between humans and computers (Sayın & Seferoğlu, 2016). Research indicates that coding education enhances children's high-level thinking skills, such as approaching problems from different perspectives, thinking systematically, generating solutions, engaging in creative thinking, and establishing cause-effect relationships (Yukselturk & Altıok, 2016). Furthermore, coding education helps students develop essential skills, including analytical thinking, creativity, digital literacy, problem-solving, collaborative work and learning, process- and result-oriented thinking, spatial reasoning, and learning through hands-on experiences (Akpınar & Altun, 2014; Demirer & Sak, 2016). Children who acquire coding skills at an early age also gain experience in communication, critical thinking, and problem-solving, which are crucial for developing 21st-century skills. These skills are indispensable for the future success of our children in an increasingly digital world (Mclennan, 2017).

At the core of coding lies algorithms. In other words, knowing how to create algorithms is essential for coding. Through coding education, students are taught algorithms and are expected to use these algorithms to write codes. According to Calıskan (2020), students who receive coding education gain numerous learning opportunities, such as the ability to construct algorithms, code the created algorithms, program effectively, develop different perspectives, and use shortcuts in problem-solving.

Algorithm

An algorithm is the sequential representation of instructions required to solve a problem within a logical framework (Arı, 2016; Ercil- Cagıltay & Fal, 2016). It is a structure composed of steps that must be followed to achieve a specific goal or solve a problem (Aytekin et al., 2018; Gibson, 2012). Olsen (2000) defined an algorithm as a set of instructions designed to solve a problem.

Algorithms are not solely a phenomenon related to computers. Much like the universal language of music that resonates with the human soul, algorithms serve as a universal language for problem-solving. Although we may not always realize it, we employ algorithms in our daily lives. In other words, algorithms are akin to computational geometries that enable individuals to articulate their thoughts. They offer general solutions to problems and play a critical role in addressing everyday challenges and contributing to advancements in the technological era (Arı, 2016; Aytekin et al., 2018). Writing an algorithm is a meticulous process that demands careful attention, as every step needs to be planned in detail. An error in any step can directly impact the outcome. Therefore, certain rules must be followed when creating an algorithm. Kucukkoc (2020) outlined these rules as follows:

- All lines in the algorithm should be numbered starting from 1.
- The first line of every algorithm should begin with "1. Start."
- Every algorithm must conclude with the "Stop" command.
- Process flow directions within the algorithm should be provided using the "Git" instruction along with the line number.
- Functions or subroutines in algorithms should be named clearly with their identifying parameters.
- The steps in the algorithm should be clear, limited in number, precise, and unambiguous.
- The expressions in the algorithm should be as simple and comprehensible as possible.
- The instructions in the algorithm should not rely on any specific operating system, hardware, or programming language.

Example Algorithm

The algorithm for multiplying two numbers (e.g., $4 \times 3 = 12$) can be represented as shown in Figure 1. An algorithm is not just a tool for problem-solving; it encompasses the thinking processes through which individuals develop important skills to organize and analyze their thought patterns. In this context, algorithms are not only instructions that perform specific tasks but also tools that shape individuals' ways of thinking. The correct writing and application of an algorithm demonstrate the importance of algorithmic thinking skills. Algorithmic thinking is not just about understanding how algorithms work, but also the ability to use these processes effectively.

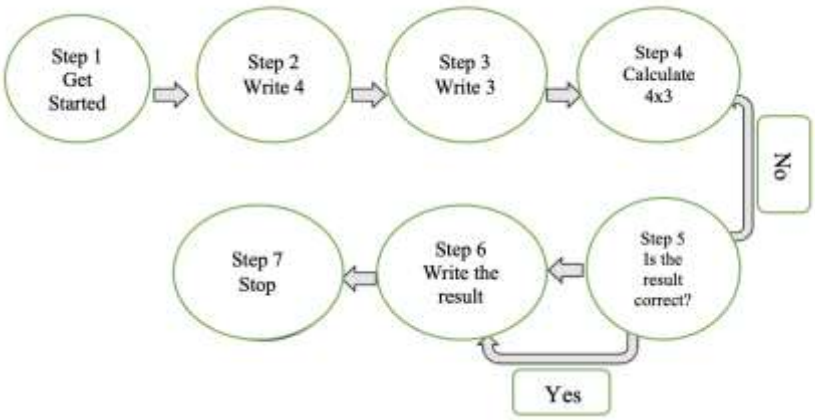


Figure 1. Multiplication of two numbers algorithm

Algorithmic Thinking Skills

According to Brown (2015), algorithmic thinking is the ability to understand, create, apply, and evaluate algorithms. Csizmadia et al. (2015) define algorithmic thinking as the ability to clearly define the steps to be taken when faced with a problem and the path to follow to reach a solution. Rather than finding a single solution to a problem, algorithmic thinking involves developing rules and instructions that can generate solutions not only for the current situation but also for similar problems, by creating various algorithms. The strength of algorithmic thinking lies in making these solutions practical. The ability to think in terms of rules and sequences to understand encountered situations or solve problems is also a key component of algorithmic thinking. The programming language used to teach algorithmic thinking skills is not sufficient for algorithmic thinking design. This is because, when teaching a programming language, too much emphasis is placed on the features of the language, and insufficient time is allocated to developing algorithmic thinking. Therefore, it would be more effective to create algorithms using code that is appropriate to the student's level, rather than focusing solely on a programming language when teaching algorithmic thinking (Futschek, 2006).

Scratch

Scratch is a programming tool that teaches programming to users between the ages of 8 and 16 while they work on projects such as stories, games, and animations (Maloney et al., 2010). The Scratch program, marketed with the slogan "Imagine, code, share," was developed by MIT's (Massachusetts Institute of Technology) Media Lab. The program is used in over 150 countries and is available in more than 40 languages. Scratch, which allows code blocks to be connected through logical steps, can be described as a program that enables real-world problem-solving (Kızılkaya & Sart, 2017). Scratch is a coding program that allows individuals or groups to design activities with code blocks in an environment that incorporates games, and then share these designed activities with other users (Scratch About, 2023). Scratch, a programming language, is the first programming tool many people learn. It is specifically designed for beginners. Scratch is an ideal program for creating games and animations, and for teaching coding while creating them. It offers both ease of use and speed. Dragging and combining pre-made code blocks in the program facilitates project creation (Dickins et al., 2016). It is easier to produce projects by combining code blocks in Scratch than with other text-based programming projects (Genc & Karakus, 2011). It has been noted that while programming projects using Scratch are both created and shared, 21st-century skills such as systematic thinking, collaborative thinking, and creative thinking are developed (Resnick et al., 2009). Additionally, since the Scratch program is game-based, lessons can become more enjoyable, motivation can increase, and students' creative thinking and problem-solving skills can be enhanced (Gezgin et al., 2017).

Because Scratch has a visual and flexible structure, it removes the barriers to programming and enables young people to create games and develop animations. Scratch's stage is similar to a real-world theater stage. It allows especially talented students to unleash and reflect on their imaginations. The software also teaches students mathematical elements, such as the coordinate system (Lee, 2011). Scratch is a tool that students can use to learn and enjoy programming, thanks to its interactive structure and fun characters. Scratch, a programming language, is a platform that can be used by both children and adults to learn coding. No additional software is needed to use Scratch, as it also works through web browsers (Demirkol, 2017). Scratch is a wonderful programming tool that allows students to design individual animations, and games, or create interactive stories using rich media tools like sound, music, and images, all within a pleasant environment, and share these projects (Cubukluoz, 2019; Yukselturk & Ucgul, 2018). Scratch makes programming fun and helps students easily learn basic algorithm concepts and programming skills (Yukselturk & Ucgul, 2018).

Scratch helps students develop creative thinking, logical reasoning, problem-solving, and collaboration skills, and contributes to their learning of computer and mathematical concepts (Su, 2019). By using Scratch, students can improve their problem-solving skills, propose different solutions to problems, and design creative activities. They can also gain experience by working on projects, participating in collaborative learning activities, and redesigning their projects (Kordaki, 2012; Resnick et al., 2009). This study aims to fill a significant gap in coding education for elementary school students. In today's world, the widespread use of technology and the necessity of acquiring digital skills from an early age have increased the importance of coding education. As a visual programming language, Scratch enables children to develop their algorithmic thinking skills, enhance their problem-solving abilities, and foster creative thinking. Therefore, investigating the feasibility of implementing coding education at earlier ages using the Scratch program will contribute to helping students adapt to technology and meet the demands of the digital age. The contributions of this study to the literature can be summarized as follows:

- *Early coding education***:** By exploring the feasibility of implementing coding education, typically offered at the middle school level, for elementary school students, the study will provide scientific data to address this gap.
- *Algorithmic thinking skills***:** The study will reveal the impact of Scratch on students' algorithmic thinking skills, offering evidence that these skills can be developed at an early age.
- *Educational practices***:** By analyzing students' perceptions and experiences during coding lessons using Scratch, the study will guide educators on how to use such programs more effectively.
- *Teacher perspectives***:** The study will examine teachers' experiences and opinions on Scratch-based coding education, offering suggestions for integrating such practices into the education system.
- *Designing their own gam***es:** By investigating students' processes of designing their own games after Scratch training, the study will highlight gains such as creative productivity and self-confidence.

This study not only demonstrates the benefits of early coding education but also serves as an essential resource for expanding coding education by contributing to education policies and curriculum development processes. The study aims to examine students' skills in using the Scratch program, their algorithmic thinking skills, and their perspectives on coding education provided through Scratch. It was conducted to determine whether coding education, typically offered at the middle school level, can be implemented at an earlier age. By teaching the Scratch program to elementary school students, the aim is to develop their coding skills, enhance their thinking abilities, teach the fundamental logic of coding, and enable them to design their games by the end of the training.

1. Does the Scratch program affect students' algorithmic thinking skills?
2. What are the students' abilities to use the Scratch program?
3. What are the students' perceptions and experiences regarding the lessons conducted using the Scratch program?
4. What are the teacher's perceptions and experiences regarding the lessons conducted using the Scratch program?
5. What are the students' opinions about coding education with Scratch?

Method

Research Design

To make the research more comprehensive, a mixed methods approach, which involves combining qualitative and quantitative data, was used. According to Johnson, Onwuegbuzie, and Turner (2007), mixed methods research is when a researcher conducts comprehensive research by integrating both qualitative and quantitative research approaches, collecting data, analyzing it, and drawing inferences. In this mixed-method study, in which we collected and analyzed both qualitative and quantitative data together, the embedded design, one of the mixed-methods designs, was used. Embedded design is a mixed methods approach in which the researcher combines traditional quantitative or qualitative data and analyzes both types of data. In an embedded design, the researcher may add a qualitative phase to a quantitative study using an experimental design, or a quantitative phase to a qualitative study using a case study. In embedded design, the phase used as support is intended to enhance the overall design (Delice, 2018; Gultekin et al., 2020). A weak experimental design was used in the quantitative dimension of the research. Among the experimental design types, a single-group pretest-posttest design was used, while a phenomenological research design was used in the qualitative dimension. The single-group pretest-posttest design is an experimental design conducted on an experimental group, which examines the effect of the independent variable through pretest and posttest measurements.

Since there is no control group in this design, it is considered a weak experimental design (Creswell & Plano-Clark, 2018). A phenomenological research design was also used in the qualitative dimension of the study. In phenomenological studies, the experiences of individuals related to the events or situations they have encountered are typically examined. The researcher conducts interviews with individuals to uncover their experiences with these events, and by analyzing the data obtained from these interviews, the researcher defines the phenomena.

Study Group

The study group consists of 32 students from the 4th grade at a school in the central district of Elazığ province during the 2022-2023 academic year. The study was conducted with a single group. The study group was

selected using convenience sampling, a method within purposive sampling. Convenience sampling is defined as selecting the sample from easily accessible and applicable units, providing speed and practicality to the study (Buyukozturk et al., 2020).

Data Collection Tools

In the study, the Algorithmic Thinking Skills Scale developed by the researcher, along with the Scratch Programming Skills Checklists, Student Diaries, Researcher Diary, and Semi-Structured Interview Form, all prepared by the researcher, were used. The reliability coefficient (α = .89) of the 'Algorithmic Thinking Skills Scale' developed by the researcher. Considering the reliability values table explained by Özdamar (2017), this coefficient is considered 'excellent in terms of reliability.' The Scratch programming checklist prepared by the researcher was created for each project taught and used individually for each student. Each step of the checklist consists of the codes found in the Scratch project. All the codes are listed in detail in the checklist. The checklist includes a column where the researcher needs to mark whether each student has executed the codes correctly or incorrectly. This allows the researcher to indicate which student made which code correct or incorrect in the relevant section. In the student diaries prepared by the researcher, students wrote their feelings, thoughts, and experiences related to the lesson of the day at the end of each class and submitted them to the researcher. In the researcher's diary, the researcher observed the process and recorded these observations to create the researcher's diary. During the process, students' attitudes and behaviors were examined in detail, and notes were taken. These notes were compiled, and the final version of the researcher's diary was created.

Implementation Process

The implementation phase of the study lasted 10 weeks (20 class hours). In the first 2 weeks (4 class hours), the Scratch program was introduced to the students. The code blocks in the program were explained in detail, separately. Game examples were shown, and students were allowed to play these games. In the remaining 8 weeks (16 class hours), games were designed with the students. Activities were planned as one game per week. In this way, students were taught 8 game design methods and were asked to design these games individually. The implementation process was carried out by the researcher, who guided the students at every stage of the process and explained the points they found difficult or could not understand.

The researcher created a teacher account on the https://scratch.mit.edu website. Then, she created a class through this account and included the students in the class. The researcher created a studio for the game designed each week and asked the students to upload their projects to this studio. Finally, the researcher examined the uploaded projects one by one and ensured that any deficiencies were addressed by notifying the students via the system. The implementation stages, the designed games, and the implementation period in the experimental group during the implementation process are shown in Table 1.

Table 1. Experimental group implementation process

Week	Implementation Phase	Implementation Duration
Week 1	Algorithm and Programming	80 min
Week 2	Introduction of Scratch Program	80 min
Week 3	Dino-Dog Project	80 min
Week 4	Ball Bouncing Project	80 min
Week 5	Star Catching Project	80 min
Week 6	Labyrinth Project	80 min
Week 7	Flying Cat Project	80 min
Week 8	Color Capture Project	80 min
Week 9	Wheel of Fortune Project	80 min
Week 10	Jumping the Barrier Project	80 min

Data Analysis

In this mixed-method study, quantitative and qualitative data were analyzed separately. Techniques such as standard deviation (SD), frequency, and percentage distributions were used to analyze the quantitative data. Before analyzing the data of the experimental group, it was checked whether the data followed a normal distribution. If the statistically insignificant value (p-value) is above .05, it indicates that the data follow a

normal distribution (Pallant, 2017). The normality data for the pretest and post-test scores of the Algorithmic Thinking Skills Scale of the experimental group are provided in the tables below. When the normality value of the Algorithmic Thinking Skills Scale pretest scores of the experimental group was examined, the p-value of significance was .361 (Table 2). This value supports the assumption of normality. According to the normality data, the pretest results of the experimental group show a normal distribution.

Table 2. Analysis results regarding the normality distribution of the pretest scores of the experimental group

		Shapiro-Wilk	
Experimental Group Pre-Test	Statistics	Sd	p
Total	.964	32	.361

Table 3. Analysis results regarding the normality distribution of the posttest scores of the experimental group

		Shapiro-Wilk	
Experimental Group Posttest	Statistics	Sd	p
Total	.721	32	.000

When the normality value of the Algorithmic Thinking Skills Scale posttest scores of the experimental group was examined, the p-value of significance was .000 (Table 3). This value violates the assumption of normality. According to the normality data, the post-test results of the experimental group do not show a normal distribution. Content analysis was used to analyze the qualitative data. Student diaries and semi-structured interview forms were coded based on the feedback received, and main themes were developed. The process was followed using checklists prepared by the researcher and supported by the researcher's diaries. The coding process used to analyze qualitative data was carried out by the researchers who prepared the transcripts of the interviews. Then, the main themes and categories relevant to the research questions were identified, and important statements in the interview data were labeled and coded according to these themes. During the coding process, main themes were divided into subcategories when necessary. The coded data was analyzed, similar statements were grouped, and relationships were established. This process ensured that the interview data were examined in a more systematic and meaningful way.

Findings

Findings Related to Quantitative Data

Wilcoxon Signed Ranks Test of Algorithmic Thinking Skill Scale Pre-Test and Post-Test Scores of the Experimental Group

It was examined whether the scores obtained from the Algorithmic Thinking Skills Scale, administered to the experimental group students before and after the application, showed a statistically significant difference. The data from the Wilcoxon Signed Ranks Test conducted for this purpose are presented in Table 4.

Table 4. Wilcoxon signed ranks test for experimental group pre-test - post-test scores

Experimental Group Pre-Test - Post Test	N	Rank Mean	Row Totals	z	p	Effect Size
Negative Sequence	7	10.14	71.00			
Positive Sequence	23	17.13	394.00	-3.331	.001	.588
Equal	2					

When Table 4 was examined, it was observed that the difference between the post-test and pre-test scores of 7 students in the experimental group was negative, the difference between the post-test and pre-test scores of 23 students was positive, and the difference between the post-test and pre-test scores of 2 students was zero. According to the data obtained, when the pre-test and post-test results of the Algorithmic Thinking Skills Scale for the experimental group students were analyzed, the z-value was found to be -3.332 and the p-value was .001 (p-value .000 < .05). Based on this, it was concluded that there was a significant difference between the pretest and posttest scores of the experimental group students' algorithmic thinking skills, favoring the posttest score. The value (r = .588) obtained from the pretest and posttest scores of the experimental group students indicates a large effect size.

Findings Related to Qualitative Data

Findings Related to Algorithm and Programming

The data of the student diaries applied to the students after the Algorithm and Programming course are given in Table 5. Since the students pointed to more than one category while expressing their opinions in their diaries, the number of opinions in the categories was higher than the number of students in the experimental group. When Table 5 was examined, it was observed that 48 of the experimental group students' feelings, thoughts, and experiences about the Algorithm and Programming course were collected in two categories: “Positive” (48 opinions) and “Negative” (8 opinions). Under the positive category, codes were grouped into 5 subheadings, and under the negative category, codes were grouped into 2 subheadings.

Table 5. Student diaries on the introduction of algorithms and programming

Category / Code		f
Positive		48
	It was a lot of fun	15
	I'm so excited	12
	It was very nice to command	10
	It was fun to execute commands	6
	It was very striking.	5
Negative		8
	At first, I didn't know what to do	5
	I was afraid of not being able to say the right commands	3

When the opinions in the positive category were analyzed in detail in the table, it was found that 15 students expressed that the lesson was very fun, 12 students were very excited, 10 students enjoyed giving commands, 6 students found it enjoyable to apply the commands, and 5 students stated that the lesson was very remarkable. When the opinions in the negative category were analyzed in detail, 5 students expressed that they did not know what to do at first, and 3 students were afraid of not being able to give the correct commands.

> *S2: "The lesson was very fun. Especially giving commands was very enjoyable."*
> *S5: "I was very excited when our teacher came to the lesson with a toothbrush and toothpaste. When we started the lesson, I did not know what to do at first. I thought what if I gave the commands wrong. But it was not as I feared, I had a lot of fun."*
> *S10: "The lesson was very fun. I enjoyed giving commands and practicing the given commands."*

The researcher's diary of the Algorithm and Programming course contains the following statements:

> *"When I entered the classroom with a toothbrush and toothpaste, the students paid attention. It was clear from their eyes that they were wondering what I was going to do with what I had. When I started to explain the lesson, they were listening to me with curious eyes. They were very surprised when they learned what an algorithm was. They loved realizing that the actions they do in daily life are algorithms. They were very impatient to stand up at the blackboard and give commands and follow them. They were very happy at the end of the lesson."*

Findings Related to the Introduction of Scratch Program

The data of the Student Diaries applied to the students after the Introduction of Scratch Program course are given in Table 6. When Table 6 was examined, it was observed that 53 of the experimental group students' feelings, thoughts, and experiences about the Scratch Program were gathered under three categories: “As an Entertainment Tool” (f=53), “From an Educational Perspective” (f=17), and “From a Time Perspective” (f=3). Under the category "As an Entertainment Tool," the codes were grouped into 5 subheadings; under the category "From an Educational Perspective," the codes were grouped into 3 subheadings; and under the category "In Terms of Time," the codes were grouped into 2 subheadings. When the opinions in the "As an Entertainment Tool" category were examined in detail, 21 students expressed that it was very entertaining, 16 students described it as very beautiful, 8 students said it was very loved, 7 students were very excited, and 1 student stated that the lesson was very special. When the opinions in the "From an Educational Perspective" category were examined in detail, 8 students expressed that they learned how to make games, 7 students thought that the program was educational, and 2 students considered it a good program to improve themselves. When the

opinions in the "In Terms of Time" category were examined in detail, 2 students expressed that it was a bit challenging at first, and 1 student mentioned that they could not fully understand some of the codes.

> *S7: "Scratch program is very nice. It is very fun to make games. It is very enjoyable to write the codes."*
> *S15: "I was very excited when I met the Scratch program. The program is very fun. I am very excited to make games with this program. I am glad I met this program."*
> *S20: "It is a very nice program, but I still don't understand some codes. I don't know how to do them, but it is a very good program to improve ourselves."*

Table 6. Student diaries on the introduction of the Scratch program

Category / Code		f
As a means of entertainment		53
	It's a lot of fun	21
	It was very beautiful	16
	I like it a lot	8
	I'm so excited	7
	It was very special	1
Educational aspects		17
	Learning to make games	8
	Educational	7
	Good for self-improvement	2
In terms of time		3
	A Little Tricky	2
	I don't fully understand some codes	1

The following statements are also included in the researcher's diary of the Introducing Scratch Program course:

> *"The students seem to enjoy going to the computer lab. I observed that they were very excited when we introduced the Scratch Program today. The main page of the program and the code sections attracted the attention of the children. They constantly asked questions about the program. There are so many things they are curious about. They want to learn everything in one day. The lessons look like they will be very enjoyable.''*

Table 7. Checklist for the Dino-Puppy Project

Codes	Added by (f)	Did not add (f)
Decorations added 3 scenes	31	1
Dog 1 added his puppet	31	1
Added Dinosaur 4 puppet	28	4
Bat added his puppet	32	-
For the bat puppet	32	-
 added the code.		
For the Dinosaur 4 puppet	32	-
 added the code		
For Dog 1 puppet	32	-
 added the code		

Findings of the Dino-Dog Project

Data on the checklist applied for the Dino-Dog Project are given in Table 7. When the checklist of the Dino-Dog Project in Table 7 was examined, it was observed that 31 students in the experimental group added decorations to 3 scenes, 1 student affected a different scene, 31 students added the Dog 1 puppet, 1 student added a different puppet, 28 students added the Dinosaur 4 puppet, 4 students added a different puppet, and all students added the Bat puppet. When the code blocks were analyzed, it was found that all students wrote the correct codes for the Bat, Dinosaur 4, and Dog 1 puppets. Analyzing the data in the Movements Checklist revealed that all students added the codes correctly, and only a few students used different props and puppets in the scenes.

Table 8. Student diaries related to the Dino-Dog Project

Category / Code		f
As a means of entertainment		54
	It was beautiful	28
	It was a lot of fun	20
	New projects excite me	3
	I lost track of time	2
	I want to code every day	1
	It's fun to watch my project	1
	The characters were chirpy	1
Educational aspects		6
	Educational	3
	I learned codes with the project	1
	Looks like an algorithm	1
	I made small mistakes at the beginning	1
In terms of time		3
	It didn't take much effort	2
	It took some time to write the code	1

The data of the Student Diaries applied to the students after the Dino-Dog Project lesson are given in Table 8. When Table 8 is examined, it is observed that 54 of the experimental group students' feelings, thoughts, and experiences about the Dino-Foam project were categorized under three headings: “As a Means of Entertainment” (f=54), “From an Educational Perspective” (f=6), and “From a Time Perspective” (f=3). Under the category "As a Means of Entertainment," the codes were grouped into 7 subheadings; under the category "From an Educational Perspective," the codes were grouped into 4 subheadings; and under the category "In Terms of Time," the codes were grouped into 2 subheadings. When the opinions under the "As a Means of Entertainment" category were examined in detail, 28 students expressed that it was very beautiful, 20 students said it was very entertaining, 3 students were excited to do new projects, 2 students did not understand how time passed, 1 student wanted to code every day, 1 student enjoyed watching the project, and 1 student thought the characters were chirpy. When the opinions in the "Educational Perspective" category were analyzed in detail, 3 students stated that it was educational, 1 student learned the codes with the help of the project, 1 student thought the project was similar to an algorithm, and 1 student mentioned that they could make small mistakes at first but later write correct codes. When the opinions in the "In Terms of Time" category were analyzed in detail, 2 students said it did not take much effort, and 1 student said it took some time to write the codes.

> *S20: "It was very nice and fun. Writing code is very good, I liked it very much. It is very fun to make the puppets talk."*
> *S25: "The Dino-Dog project was very fun. I liked it a lot. I did it with a lot of love and fun. I think it was a fun and beautiful project."*
> *S18: "Dino-Dog was very fun and writing code was also very fun. It was very easy to write code. It was very enjoyable to watch the project I made, even if it was short. I did it in a short time because it was easy."*

In the researcher's diary of the Dino-Dog Project lesson, the following statements were made:

> *"The students were very excited again on the way to the laboratory. When I told them about the project, they started to listen to me with curiosity and excitement. While I was explaining the sample application, they were worried that they could do the same process, but when they started doing the project, they realized that there was nothing to worry about. They had a lot of fun*

writing the codes during the lesson. They laughed a lot when they played their last project. The happiness of having accomplished a project was visible in their eyes."

Findings of the Ball Bouncing Project

The data belonging to the checklist applied for the Ball Bouncing Project are given in Table 9.

Table 9. Checklist for the Ball Bouncing Project

Codes	Added by (f)	Did not add (f)
Decorations added 2 scenes	31	1
Baseball added his dummy	23	9
Puppet 1 drew his puppet himself	32	-
Puppet 2 drew his puppet himself	32	-
For the Baseball puppet	32	-
 added the code block.		
For puppet 2 puppet	32	-
 added the code block		

When the checklist of the Ball Bouncing Project in Table 9 was examined, it was observed that 31 students in the experimental group added the scene of the props 2, 1 student affected a different scene, 23 students added the Baseball puppet, 9 students added a different puppet, and all students drew Puppet 1 and Puppet 2 correctly. When the code blocks were analyzed, it was found that all students wrote the correct codes for the Baseball and Puppet 2 puppets. Analyzing the data in the Movements Checklist revealed that all students added the codes correctly; however, a few students used a different stage, and especially 9 students used other ball puppets instead of the baseball puppet. Data from the Student Diaries, which were applied to the students after the Ball Bouncing Project lesson, are provided in Table 10.

Table 10.Student diaries related to the Ball Bouncing Project

Category / Code		f
As a means of entertainment		44
	It's a lot of fun	22
	It was very beautiful	9
	I like the game very much	6
	I saw that I could accomplish something	2
	I enjoy writing code very much	2
	It was remarkable	1
	The game was adventurous	1
	I played a lot when the game ended	1
In terms of difficulty		19
	I had some difficulty writing code	10
	Very easy	7
	It was very easy when I got used to writing code	1
	It was not a hassle	1

When Table 10 was examined, it was observed that 44 of the experimental group students' feelings, thoughts, and experiences about the ball-bouncing project were categorized under two headings: "As a Means of Entertainment," while 19 were categorized under "In Terms of Difficulty." Under the category "As a Means of Entertainment," the codes were grouped into 8 subheadings, and under the category "In Terms of Difficulty," the codes were grouped into 4 subheadings. When the opinions in the "As a Means of Entertainment" category were examined in detail, 22 students expressed that it was very entertaining, 9 students said it was very beautiful, 6

students liked the game very much, 2 students felt they could achieve something, 2 students enjoyed writing code very much, 1 student found it remarkable, 1 student described it as adventurous, and 1 student mentioned they played a lot when they finished the game. When the opinions in the "In Terms of Difficulty" category were analyzed in detail, 10 students mentioned having some difficulty in writing code, 7 students said it was very easy, 1 student said it became easy once they got used to writing code, and 1 student said it was not challenging.

> *S11: "Ball bouncing was very nice. I had some difficulties while making it at home, but I played with it a lot after the game was finished. I had a lot of fun. I am very happy that I learned Scratch."*
> *S31: "I had a lot of fun making the game but it was a bit challenging. Although the Ball Bouncing game was challenging, I think it was still a fun game."*
> *S20: "Ball bouncing was very fun. It was fun, beautiful and easy. I liked it very much. The pleasure of this game is different."*

The researcher's diary for the Ball Bouncing Project lesson includes the following statements:

> *"The students were very excited again on the way to the laboratory. They were very happy when I told them about the project. When I played the project I had prepared before, they watched me with amazement. Then a few students also played. They seemed very enjoyable. When I started writing the codes, they had difficulty at first. They thought they couldn't do it, but when I helped them, they did it easily. We finished the project and they played the game they made during the rest of the lesson. There was laughter, anger, and shouting in the class. They said they enjoyed it very much. They even insisted that we play one more lesson."*

Findings of the Star Catching Project

Data on the checklist applied for the Star Capture Project are given in Table 11. When the checklist of the Star Catching Project in Table 24 was examined, it was observed that all of the students in the experimental group affected the Space scene, the Robot puppet, the Starfish puppet, the duration variable, and the score variable. When the code blocks were analyzed, it was found that all students wrote the correct codes for the Robot and Starfish puppets. Analyzing the data in the Movements Checklist revealed that all students added the puppets and codes correctly. This indicates that the students had a clearer understanding of the Scratch program.

Table 11. Checklist for the Annual Catching Project

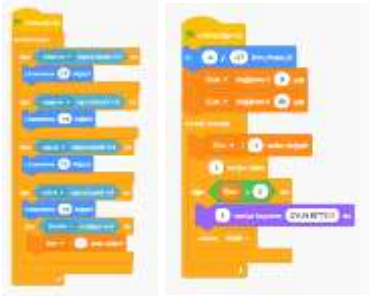
Codes	Added by (f)	Did not add (f)
Added the Space scene	32	-
He added the robot puppet	32	-
Starfish added his puppet	32	-
Added score variable	32	-
Added duration variable	32	-
For the robot puppet  added the code block	32	-
For the Starfish puppet  added the code block	32	-

Table 12. Student diaries related to the Star Catching Project

Category / Code		f
As a means of entertainment		50
	It's fun	16
	I had no difficulty in making it	11
	It was beautiful	11
	I like it a lot	9
	I always want to do it	1
	It wasn't very exciting	1
	It was a bit boring	1
In terms of difficulty		12
	I had some difficulty	8
	The codes were long	3
	At first, it seemed strange, but then I understood	1

Data from the Student Diaries applied to the students after the Star Catching Project lesson are given in Table 12.When Table 12 was examined, it was found that the feelings, thoughts, and experiences of 50 experimental group students regarding the Star Catching project were categorized under two headings: “As a Means of Entertainment” (f=50) and “In Terms of Difficulty” (f=12). Under the “As a Means of Entertainment” category, the codes were grouped into 7 subheadings, while under the “In Terms of Difficulty” category, the codes were grouped into 3 subheadings. Detailed analysis of the opinions in the “As a Means of Entertainment” category revealed that 16 students found the project fun, 11 had no difficulty doing it, 11 thought it was very beautiful, 9 liked it very much, 1 always wanted to do coding, 1 thought the game was not very exciting, and 1 thought it was a little boring. Detailed analysis of the opinions in the “In Terms of Difficulty” category showed that 8 students thought it was a little difficult, 3 thought the codes were long, and 1 found the game strange at first but understood it later.

> *S14: "Although I had a little difficulty, it was very good. I like to play the game after making it. I have a lot of fun while playing, I enjoy doing it very much. I am glad that we make games. I want to do it all the time."*
> *S9: "It is a little difficult to make a game, but it is very fun and very good to play. It is like downloading a game and playing it."*
> *S10: "The project we did today was very good. I had some difficulties while doing it, but the end was very good. We played a perfect game. I thank my teacher very much."*

The researcher's diary of the Star Capture Project lesson also contains the following statements:

> *"The students were very excited again on the way to the laboratory. They were very happy when I told them about the project. They were very happy when I played the project I prepared for them. I explained how to write the codes. This time they found the codes a bit long and started asking if they could do it. They had a hard time at first, but when they understood the logic, they did it easily. After finishing the project, they started to play the game they made as in other lessons. I think this is the most enjoyable part of the lesson. Both the happiness of accomplishing something and the joy of playing the game they made..."*

Findings of the Labyrinth Project

Data on the checklist applied for the Labyrinth Project are given in Table 13. When the checklist of the Labyrinth Project in Table 13 was examined, it was found that all of the students in the experimental group affected the labyrinth image from the computer, the Giga puppet, the Penguin 2 puppet, and the duration variable. Analysis of the code blocks revealed that all of the students wrote the correct codes for the Giga puppet. Further analysis of the checklist data showed that all of the students added the puppets and codes correctly. This indicates that the students have gained a clearer understanding of the Scratch program.

Data from the Student Diaries applied to the students after the Labyrinth Project lesson are given in Table 14. When Table 14 was examined, it was found that 44 of the experimental group students' feelings, thoughts, and experiences about the Labyrinth project were categorized under "As a Means of Entertainment," while 19 students' opinions were categorized under "In Terms of Difficulty." Under the "As a Means of Entertainment"

category, the codes were grouped into 7 subheadings, and under the "In Terms of Difficulty" category, they were grouped into 4 subheadings.

Table 13. Checklist for the Labyrinth Project

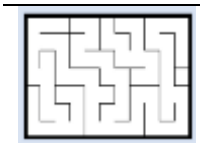
Codes	Added by (f)	Did not add (f)
 added the image from the computer	32	-
Giga added his dummy	32	-
Penguin 2 has added his puppet	32	-
Added duration variable	32	-
For the Giga puppet	32	-
 added the code block.		

Table 14. Student diaries related to the Labyrinth Project

Category / Code	f
As a means of entertainment	44
It was very beautiful	21
It was a lot of fun	13
It's fun to play the games I make	2
One of my favorite projects	2
Remarkable	2
I wish Scratch would never end	2
Beyond perfect	2
In terms of difficulty	19
It was a little hard to play	9
I had some difficulty	8
Pro player level	1
I had no difficulty in making it, it was easy	1

Upon analyzing the opinions in the “As a Means of Entertainment” category in detail, 21 students expressed that it was very beautiful, 13 found it very entertaining, 2 enjoyed playing the games they created, 2 considered it one of their favorite projects, 2 found it remarkable, 1 did not want the Scratch lesson to end, and 1 considered it beyond perfect. When the opinions in the "In Terms of Difficulty" category were examined in detail, 9 students reported that playing the game was a bit difficult, 8 experienced some difficulty in writing the codes, 1 stated that the game was at a pro-player level, and 1 mentioned that they did not have difficulty in making the game and found it easy.

> *S3: "The game was fun. It was very nice. I had a lot of fun. I think it was a good project. I didn't have any difficulty doing it, I think it was easy."*
> *S30: "It was very nice to make the maze game. Giga and Penguin were very cute. I had a little difficulty catching Giga in the maze, but the game was very nice. I am glad my teacher made us do it."*
> *S20: "The maze project is one of my favorite projects. It is a nice project. But I had a little bit of difficulty when I played it because it went back to the beginning when it said black lines. Still, it's a nice project, it's fun."*

In the researcher's diary of the Labyrinth Project lesson, the following statements were made:

"They are very happy when we go to the laboratory every week. They were very surprised when I told them about the project. They started to say how we were going to do it. When they played the project for the first time, they constantly burned out and got very angry. They listened attentively to the project and immediately grasped how to do it. Now it doesn't take time to make a game like before. The children have now grasped the logic. They also got to know the program well. We finished the project together and it was time to play with the games we made. Since this game requires high precision, they constantly hit the edges of the maze and went back to the beginning. Although this made them a little angry, they told us how much they liked the game when they returned to the classroom."

Findings of the Flying Cat Project

Table 15. Checklist for the Flying Cat Project

Codes	Added by (f)	Did not add (f)
Added the Blue Sky scene	32	-
Cat Flying added his puppet	32	-
Added Buildings dummy	32	-
Dragon added his puppet	32	-
Donut added his puppet	32	-
Added the Donut variable	32	-
Added the variable Can	32	-
For the Cat Flying puppet  added the code block.	32	-
For Buildings puppet  added the code block	32	-
For the Dragon puppet  added the code block	32	-
For the donut puppet  added the code block	32	-

The data belonging to the checklist applied for the Flying Cat Project are given in Table 15. When examining the checklist of the Flying Cat Project in Table 15, it was observed that all of the students in the experimental

group added the Blue Sky scene, Cat Flying puppet, Buildings puppet, Giga puppet, Dragon puppet, Donut puppet, Donut variable, and Can variable. Upon analyzing the code blocks, it was found that all of the students correctly wrote the codes for the Cat Flying, Buildings, Dragon, and Donut puppets. Furthermore, when the data in the checklist were examined, it was determined that all students added the puppets and codes correctly. This indicates that there are no longer any aspects of the Scratch program that students are unable to understand and that the program has been sufficiently comprehended. Data from the Student Diaries applied to the students after the Flying Cat Project lesson are given in Table 16.

Table 16. Student diaries related to the Flying Cat Project

Category / Code		f
As a means of entertainment		43
	It's so beautiful	19
	It's a lot of fun	14
	I played a lot	4
	Scratch lessons don't end	2
	I like it a lot	1
	One of my favorite projects	1
	It was like real games	1
	The movement of the buildings was spectacular	1
In terms of difficulty		13
	I had no difficulty in making it	8
	I had some difficulty	4
	The codes are a bit long	1

When Table 16 was examined, it was observed that 43 of the experimental group students' feelings, thoughts, and experiences about the Flying Cat project were categorized under "As a Means of Entertainment," while 13 were categorized under "In Terms of Difficulty." Under the category "As a Means of Entertainment," the codes were grouped into 8 subheadings, and under the category "In Terms of Difficulty," the codes were grouped into 3 subheadings. Upon a detailed analysis of the opinions in the "As a Means of Entertainment" category, 19 students expressed that it is very beautiful, 14 found it very entertaining, 4 played a lot with the game they created, 2 did not want the Scratch lessons to end, 1 liked the project very much, 1 considered it one of their favorite projects, 1 felt it was like real games, and 1 found the movement of the buildings eye-catching. When the opinions in the "In Terms of Difficulty" category were examined, 8 students reported having no difficulty in making the project, 4 experienced some difficulty, and 1 felt that the codes were a bit long.

> *S32: "The flying cat game was like real games. It was one of the most beautiful things. I played a lot. The dragon moves and I always miss it. It was as fun to make as it was to play."*
> *S2: "It is a very nice project. The codes are a bit long but it is very fun. I made the game and played it for an hour."*
> *S9: "The flying cat was very beautiful. The movement of the buildings in the game was eye-catching. The cat seemed to fly. It was fun to catch the spawns and escape from the dragon. I am glad my teacher made us do it."*

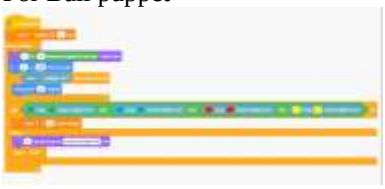
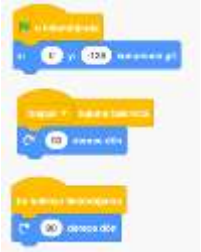
The researcher's diary of the Flying Cat Project lesson includes the following statements:

> *"They were very happy when we went to the laboratory this week. They were very curious about the project. The name of the airplane cat excited them. They had a lot of fun playing the project I did. They said it was very easy to play this project. I don't know, maybe they got used to Scratch... The codes were a bit long, but they didn't have any difficulty in writing them. Now they are doing projects in a shorter time. This makes me so happy. I am proud to see my students using the Scratch program. After finishing the project today, we had more time to play the game. The children played the game until the end of the lesson. They told each other the scores they got from the game. The lesson was very enjoyable. Children leave the Scratch lessons very happy and having fun."*

Findings of the Color Capture Project

Data on the checklist applied for the Color Capture Project are given in Table 17.

Table 17. Checklist for the Color Capture Project

Codes	Added by (f)	Did not add (f)
Added Blue Sky 2 scene	32	-
Ball added his puppet	32	-
 Color puppet uploaded from computer	32	-
Added score variable	32	-
For Ball puppet	32	-
 added the code block.		
For color puppet	32	-
 added the code block		

When the checklist of the Color Capture Project in Table 17 was examined, it was found that all of the students in the experimental group added the Blue Sky 2 scene, and the Ball puppet, uploaded the Color puppet from the computer and added the Score variable. Upon analyzing the code blocks, it was observed that all of the students correctly wrote the codes for the Ball and Color puppets. A further examination of the data in the checklist revealed that all of the students correctly added the puppets and codes. This indicates that the Scratch program is now more clearly understood by the students. The data of the Student Diaries applied to the students after the Color Capture Project lesson are given in Table 18.

Table 18. Student diaries related to the Labyrinth Project

Category / Code		f
As a means of entertainment		43
	Beautiful	15
	It's a lot of fun	14
	I like it a lot	5
	I didn't like it very much	2
	It was boring	2
	Remarkable	1
	Like a brain teaser	1
	These codes are important for my future games	1
	My favorite project	1
	Like a real game	1
In terms of difficulty		13
	The codes were easy to write	6
	It was a bit difficult	4
	I had a hard time downloading the color puppet	3

When Table 18 was examined, it was found that the feelings, thoughts, and experiences of 43 experimental group students regarding the Color Capture project were gathered under two categories: “As a Means of Entertainment” and “In Terms of Difficulty,” with 13 opinions falling under the latter. Under the category "As a Fun Tool," the codes were grouped under 10 subheadings, while under the category "In Terms of Difficulty," the codes were grouped under 3 subheadings. Upon examining the opinions in the “As a Means of Entertainment” category in detail, 15 students found it beautiful, 14 thought it was very entertaining, 5 liked the project very much, 2 did not like it very much, 1 found it boring, 1 found it remarkable, 1 likened it to an intelligence game, 1 believed the codes were important for future games, 1 considered it their favorite project, and 1 thought it was

like a real game. In the “In Terms of Difficulty” category, 6 students thought it was easy to write the codes, 4 found it a little difficult, and 3 had difficulty in downloading the color puppet.

> *S25: "It took a very short time, but I had a hard time loading it. I liked it very much. I like projects like this very much. I always want to do it."*
> *S2: "I had a hard time downloading the color puppet and I didn't like the game very much, but the game was still good. I think these codes are important for the games I will make in the future."*
> *S9: "I think it was very fun. I enjoyed doing it and I liked it very much. I would like to make games similar to the color capture game. It was very easy and I have fun doing it."*

The following statements are also included in the researcher's diary of the Color Capture Project lesson:

> *"When they first heard about the color capture project, they didn't make much sense. When they started playing the game I made, they generally enjoyed it. However, I also had bored students. They said that the ball landed too fast and that they could not change colors immediately and that they were bored because of this. I noticed that they had fun when they started to write the codes themselves. There was a problem in the beginning about downloading the color puppet from the computer, but then they easily solved it. When they finished the project and started to play, they were very happy again. There was the happiness of doing another project. When they left the laboratory, they said they had a lot of fun again."*

Table 19. Checklist for the Wheel of Fortune Project

Codes	Added by (f)	Did not add (f)
Decorations added 1 scene	32	-
 Added the Wheel of Fortune puppet	32	-
Puppet 1 drew his puppet himself	32	-
Giga added his dummy	32	-
Added score variable	32	-
For the passionflower puppet  added the code block.	32	-
For the Giga puppet  added the code block.	32	-
For Puppet 1 puppet  added the code block.	32	-

Findings Related to the Wheel of Fortune Project

Data on the checklist applied for the Wheel of Fortune Project are given in Table 19. When the checklist of the Wheel of Fortune Project in Table 19 was examined, it was observed that all the students in the experimental group added the Props 1 scene, the Wheel of Fortune puppet, the Giga puppet, the score variable, and independently drew the Puppet 1 puppet. An analysis of the code blocks revealed that all students correctly coded the Wheel of Fortune, Giga, and Puppet 1 puppets. The data in the checklist confirmed that all students accurately added the required puppets and codes. This indicates that the students have developed a clear understanding of the Scratch program. Data on the Student Diaries applied to students after the Wheel of Fortune Project lesson are given in Table 20.

Table 20. Student diaries on the Wheel of Fortune Project

Category / Code	f
As a means of entertainment	35
It was very beautiful	20
It's a lot of fun	10
It was the best game so far	4
It was boring to play	1
In terms of difficulty	13
The codes were easy	7
A little bit tricky	4
The codes were long	2

When Table 20 was examined, it was observed that 35 of the experimental group students' opinions about the Wheel of Fortune project were categorized under "As a Means of Entertainment," while 13 were categorized under "In Terms of Difficulty." In the "As a Means of Entertainment" category, the codes were grouped into 4 subheadings, and in the "In Terms of Difficulty" category, the codes were grouped into 3 subheadings. Detailed analysis of the “As a Means of Entertainment” category revealed that 20 students found the project very beautiful, 10 found it very entertaining, 4 considered it the best game they had created so far, and 1 found playing the game boring. In the “In Terms of Difficulty” category, 7 students found it easy to write the codes, 4 felt that creating the game was somewhat challenging, and 2 thought the codes were lengthy.

> *S27: "I think it was very good. I had a lot of fun doing it. I always want to do it. I hope all my projects will be complete. Because I had a lot of fun. It is very fun to make games similar to the Wheel of Fortune. I think it was very easy."*
> *S18: "Wheel of Fortune was a very nice project. The more I turned it, the more points I got. Wheel of Fortune was colorful. I got 1000 only once and I was very happy."*
> *S13: "The codes were long. It was fun and beautiful. It was easy and I didn't have any difficulty in doing it. I liked the game. It was a bit long but it was still good."*

The researcher's diary of the Wheel of Fortune Project lesson includes the following statements:

> *"The Wheel of Fortune project was one of the projects that attracted the attention of the students. They said that they saw this game a lot on the internet. But they expressed that they did not know how to do it. They were very happy when they started writing the codes. They had no difficulty in writing codes this week. Only because the codes were a bit long, did they start to ask when it would be over. I think they were a bit bored... When the game was over, they started playing again. They didn't like the fact that luck was very important in this game. Sometimes they were bankrupt all the time. But they still seemed to have a lot of fun and were happy. The process went very well. Now we are coming to the end of our application. The children don't want the Scratch lessons to end..."*

Findings of the Jumping from Obstacle Project

The data belonging to the checklist applied for the Jumping from the Barrier Project are given in Table 21. When examining the checklist of the Jumping Through Obstacles Project in Table 21, it was observed that all students in the experimental group included the Boardwalk scene, the Pico Walking puppet, the Tree 1 puppet, and the following Block puppets: Block-G, Block-A, Block-M, Block-M, Block-E, Block-O, Block-V, Block-E, Block-R, as well as the Score variable.

Table 21. Checklist for the Jumping the Hurdle Project

Codes	Added by (f)	Did not add (f)
Boardwalk scene added	32	-
Pico Walking added his puppet	32	-
Tree 1 added his dummy	32	-
Block-G added his dummy	32	-
Block A added his dummy	32	-
Block M added his dummy	32	-
Block E added his dummy	32	-
Block-O added his dummy	32	-
Block V added his dummy	32	-
Block E added his dummy	32	-
Block-R added his dummy	32	-
Added score variable	32	-
For the Pico Walking puppet	32	-
 added the code block.		
For Tree 1 puppet	32	-
 added the code block		
For Block-G puppet	32	-
 added the code block		
For Block-A puppet	32	-
 added the code block		
For Block-M puppet	32	-
 added the code block		
For Block-E puppet	32	-
 added the code block		
For Block-O puppet	32	-

 added the code block For Block-V puppet	32	-
 added the code block For Block-E puppet	32	-
 added the code block For Block-R puppet	32	-
 added the code block		

Analysis of the code blocks revealed that all students correctly wrote the codes for Pico Walking, Tree 1, and all Block puppets. The checklist data indicated that all students successfully added the required puppets and codes. The detailed selection and completion of this project demonstrated the students' advanced understanding of the program. The inclusion of all puppets and accurately written codes confirms that the Scratch program has been comprehensively understood by the students. The data of the Student Diaries applied to the students after the Jumping through Obstacles lesson are given in Table 22.

Table 22. Student diaries related to jumping over obstacles

Category / Code		f
As a means of entertainment		49
	It was a lot of fun	26
	It was very beautiful	13
	The game was adventurous	4
	I was very excited when I played	2
	It was remarkable	1
	I enjoyed doing it	1
	It was like real games	1
	It was my best project	1
In terms of difficulty		19
	The codes were too long	16
	I got tired of writing the code	2
	I had no difficulty writing the code	1

When Table 22 was examined, it was found that the opinions of 49 experimental group students about the Jumping Through Obstacles project were grouped under two categories: “As a Means of Entertainment” and “In Terms of Difficulty.” Under the “As a Means of Entertainment” category, 26 students described the project as very entertaining, 13 found it very beautiful, 4 thought it was adventurous, 2 felt very excited while playing, and 1 student each remarked that it was remarkable, enjoyable to create, similar to real games, and the best project they had ever done. Under the “In Terms of Difficulty” category, 16 students expressed that the game's codes were too long, 2 felt tired while writing the codes, and 1 reported no difficulty in writing them. Overall, while the project was widely regarded as engaging and enjoyable, the length of the codes posed a challenge for some students, suggesting room for simplifying or better pacing the exercises.

> *S31: "The game was very good. It was very enjoyable to play, but the codes were very long. I got tired while writing the codes but it was worth it."*

S10: "I did not have any difficulty in making the game. It was like real games. I enjoyed it very much."
S32: "I was very excited while playing the game because it is necessary not to touch the obstacles while jumping over them. It was the best project I have ever done. I am glad that our teacher taught us this game."

The following statements are also included in the researcher's diary of the Jumping from the Barrier Project lesson:

"The children were both very happy and a little sad this week. Because this week we are doing the last Scratch lesson. They wished it would not end. We finished our application with a project worthy of the last week. The children were very surprised when they saw the codes because the codes were long. They started to say that we couldn't do it, but when they started writing the codes, they realized that the codes were not difficult even though they were long. Now they have a good grasp of the codes. They can even do long codes. This is a great happiness for me because I cannot tell you how happy it made me to have given a training that I have been thinking about for years and most importantly to see that it was learned by the students. When the children finished the project, they started to play. Playing with the game was more fun than writing the codes. They played with great pleasure. At the end of the lesson, they left very happy again, just like the other weeks. We have completed our last week without any problems and in a pleasant way."

Findings Related to Student Opinions

The students in the experimental group were asked, “What kind of program do you think Scratch is?” The categories, codes, and their frequency values, based on the students' responses, are presented in Table 23.

Table 23. Ideas about the Scratch Program

Category / Code		f
Emotionally		36
	It's a lot of fun	12
	It was very beautiful	8
	Magnificent	7
	Super for making games	4
	Coding is exciting	3
	It's great.	2
Cognitive aspects		9
	A program that teaches codes	4
	A program that improves our intelligence	2
	A program that teaches algorithms	2
	People think they are informaticians	1

When the feelings, thoughts, and experiences of the experimental group students about the Scratch program were analyzed as shown in Table 23, it was found that 36 opinions were categorized as "Emotional" and 9 as "Cognitive." Under the "Emotional" category, the codes were grouped into six subheadings, while under the "Cognitive" category, the codes were grouped into four subheadings. In the "Emotional Perspective" category, 12 students stated that Scratch is very fun, 8 described it as very beautiful, 7 found it magnificent, 4 expressed that making games is super, 3 mentioned that coding is exciting, and 2 referred to it as great. In the "Cognitive Perspective" category, 4 students remarked that Scratch is a program that teaches coding, 2 highlighted it as a program that develops intelligence, 2 considered it as a program that teaches algorithms, and 1 student mentioned that using Scratch makes them feel like an informatician while writing code.

S8: "It is a very fun program. I enjoyed doing it very much."
S5: "It was very nice and coding excites you. While coding, you think you are a cognitive scientist."
S15: "Scratch is a program that teaches codes. It is both very fun and very enjoyable."

The experimental group students were asked the question, “Did you like the Scratch program? Why?” The categories, codes, and their frequency values derived from the students' responses are presented in Table 24.

Table 24. Liking the Scratch Program

Category / Code		f
Yes		38
	It's fun	19
	I learned to code	7
	We made a game	6
	It was easy	2
	My dream has come true	1
	I felt like a scientist while making a game	1
	I was proud of myself when I learned about the program	1
	It develops our imagination	1

When Table 24 was examined, it was observed that 38 student opinions fell under the “Yes” category regarding their liking for the Scratch program, reflecting their feelings, thoughts, and experiences. The codes within the “Yes” category were organized into eight subheadings. A detailed analysis of the "Yes" responses revealed that 19 students found the program fun, 7 students appreciated learning coding, 6 students enjoyed creating games, 2 students found the program easy, and 1 student expressed that the program made their dream of learning coding come true. Additionally, 1 student mentioned feeling like a scientist while creating games, another student felt proud upon mastering the program, and 1 student believed that the program helped develop their imagination.

> *S20: "I liked the Scratch program because it contains algorithms. I had no difficulty in writing the codes. I participated because it was fun. I was proud of myself when I wrote all the codes correctly. At the same time, when I knew and wrote the codes, it was as if I entered the digital world."*
> *S17: "Yes, I liked it because we can make games. We do coding. It is fun and we learn how to make games."*
> *S30: "I liked the Scratch program very much because I felt like a scientist while making the games. I was in the air, in short, making games was really fun."*

The students in the experimental group were asked the question, "How did you feel while making games with Scratch?". The categories/codes and their frequency values obtained from the students' responses are provided in Table 25.

Table 25. Feelings while making games with Scratch

Category / Code		f
Emotionally		45
	I enjoyed it very much	21
	I'm so happy	16
	I'm so excited	5
	I was scared at the beginning but it didn't happen as I feared	2
	I'm not bored	1
It was the best time of my life		1
I relax while coding.		1
I have a new hobby		1

When Table 25 was examined, it was seen that 45 of the experimental group students' opinions were grouped into 4 categories: "Emotionally," 1 as "The Best Time of My Life," 1 as "I Relax While Writing Code," and 1 as "Acquiring a New Hobby." Under the "Emotionally" category, the codes were grouped into 5 subheadings. When the opinions in the "Emotionally" category are examined in detail, 21 of the student's opinions were that they enjoyed it very much, 16 were very happy, 5 were very excited, 2 were afraid at the beginning but it was not as they feared, and 1 was not bored.

> *S32: "I had fun, I enjoyed it, I felt warm inside as if the characters were real while doing the project. I felt very good, I was relaxing while writing code."*
> *S12: "I was excited when I was making a game with Scratch because I had questions in my mind such as can I succeed or did you write the codes correctly? At the end of the game, if I succeeded, if the game was correct, I was very happy."*
> *S5: "I felt very excited when I made my first game with Scratch. I was very happy when I played my first game. It was one of the happiest moments of my life.”*

When the experimental group students were asked, “Which project did you enjoy doing the most? Why?”, the categories/codes and their frequency values obtained as a result of the answers received from the students are provided in Table 26.

Table 26. The most enjoyable projects

Category / Code		f
Ball Bouncing		14
	It was as much fun as real games	7
	It was beautiful	5
	It was easy	1
	Because it's my own game	1
I like them all		11
	They were all beautiful	4
	I enjoyed doing it all	3
	They were all fun	2
	Educational	1
	Improving our intelligence	1
Wheel of Fortune		10
	It was a lot of fun	6
	It was colorful	1
	We made the game that everyone loved	1
	It was like the games I played on the internet	1
	Because I wrote the code myself	1
Dino Dog		8
	The characters were funny	4
	Dialogues were good	2
	It was fun	2
Labyrinth		6
	It was fun	3
	The voice in the game was delightful	2
	It was very beautiful	2
Star Chasing		2
	It was very enjoyable	2
Color Capture		2
	It was a lot of fun	1
	It was exciting	1

When the feelings, thoughts, and experiences of the experimental group students regarding the projects they enjoyed were examined, it was found that 14 of the students' opinions were gathered under 7 categories, including “Ball Bouncing Project,” 11 under “I liked it all,” 10 under “Wheel of Fortune Project,” 8 under “Dino Foam Project,” 6 under “Labyrinth Project,” 2 under “Star Chasing Project,” and 2 under “Color Catching Project.” Under the “Ball Bouncing Project” category, the codes were grouped under 4 subheadings. When examined in detail, 7 of the students found it as fun as real games, 5 thought it was beautiful, 1 found it easy, and 1 appreciated having their own game. Under the “I Like It All” category, the codes were grouped under 5 subheadings. Detailed analysis showed that 4 students felt all the projects were beautiful, 3 enjoyed doing all of them, 2 found all of them fun, 1 thought they were educational, and 1 felt they enhanced their intelligence. In the “Wheel of Fortune Project” category, the codes were grouped under 5 subheadings. Detailed analysis revealed that 6 students found it very entertaining, 1 thought it was colorful, 1 made a game that everyone loved, 1 felt it resembled internet games, and 1 wrote the code themselves. Under the “Dino-Dog Project” category, the codes were grouped under 3 subheadings. 4 students found the characters funny, 2 appreciated the dialogues, and 2 enjoyed the project overall. In the "Labyrinth Project" category, the codes were grouped under 3 subheadings. Detailed analysis revealed that 3 students found it fun, 2 enjoyed the sound of the game, and 2 thought it was beautiful. Under the “Star Chasing Project” category, the codes were grouped under 1 subheading. 2 students found it very enjoyable. In the “Color Catching Project” category, the codes were grouped under 2 subheadings. 1 student found it very fun, and 1 found it exciting.

> *S19: "I enjoyed the Ball Bouncing game the most because the ball was bouncing and we were trying not to drop it and lose it. It was as fun as real games."*
> *S8: "I enjoyed doing all the games and they were fun. The reason is that it is educational and improves your intelligence."*

S21: "Wheel of Fortune because it is enjoyable like the games on the internet and we make the game that everyone loves. It is very enjoyable"

It seems like you're referring to Table 27, but I don't have the specific details from that table. If you'd like, you can share the data or key points from Table 27, and I can help you structure or analyze the information.

Table 27. Difficulties in creating projects with Scratch

Category / Code		f
I had some difficulty.		14
	I struggled with some projects	4
	When codes are long	3
	Locating code blocks is a bit tricky	3
	When I load something from the computer	2
	Hard to generate code	2
No difficulty at all		10
	It was easy	5
	I enjoyed it very much	2
	My teacher's guidance was good	1
	It was fun to play	1
	It was fun	1
Difficulty		8
	In my first projects	4
	The codes were sometimes confusing	2
	I was having a hard time downloading it from my computer	1
	There was a lot of work to be done	1

When the feelings, thoughts, and experiences of the experimental group students regarding the difficulties they faced in creating projects with Scratch were analyzed in Table 27, it was found that 14 of the students' opinions were grouped under the category "I had some difficulty," 10 of them under "I had no difficulty," and 8 of them under "I had difficulty." The codes under the "I had some difficulty" category were grouped under 5 subheadings, the codes under the "I had no difficulty" category were grouped under 5 subheadings, and the codes under the "I had difficulty" category were grouped under 4 subheadings. In the "I had some difficulty" category, 4 students reported difficulty with certain projects, 3 mentioned difficulty when the codes were long, 3 found it challenging to locate code blocks, 2 struggled when loading files from the computer, and 2 found it hard to create codes. In the "I had no difficulty" category, 5 students felt that the projects were easy, 2 enjoyed them greatly, 1 appreciated the teacher's guidance, 1 found making games enjoyable, and 1 found it fun. In the "I had difficulty" category, 4 students reported difficulty with their first projects, 2 felt the codes were sometimes complicated, 1 had difficulty downloading files from the computer, and 1 found the tasks had too many operations to complete.

S15: "I did not have any difficulty in making a game with Scratch because the codes and characters were easy. Since I did the codes carefully, I did not make any mistakes."
S24: "Yes, I had difficulty in some projects, but in general it was easy. Even though it was difficult, I liked it very much."
S31: "Yes, it was difficult because choosing the characters, making their codes one by one, downloading the background from the computer and downloading it to Scratch... there is a lot to do."

Conclusion and Discussion

According to the results of the Algorithmic Thinking Skill Scale, which was developed to examine the effect of the Scratch program on coding education for 4th-grade primary school students, a significant difference was found between the post-test and pre-test scores of the experimental group, with post-test scores being higher. This indicates that the Scratch program had a significant impact on the algorithmic thinking skills of primary school students. When reviewing the literature, it was noted that few studies have specifically addressed the effect of the Scratch program on algorithmic thinking skills. For example, Bahar (2023) found that Scratch applications had a significant impact on algorithmic thinking, critical thinking, and creativity, but did not significantly affect problem-solving skills. Similarly, Cakıcı and Ozdemir (2022) concluded that coding education without computers led to a statistically significant improvement in students' problem-solving and

algorithmic thinking skills. The findings from these studies are consistent with the results of this study, supporting the idea that Scratch programming positively influences algorithmic thinking skills.

According to the results of the checklists for the Scratch lessons and the projects developed, it was concluded that some of the students in the experimental group initially misplaced certain puppets and decorations in their first projects. However, as they became more familiar with the program, all students were able to complete the projects. This suggests that with practice and experience, the students' understanding and skills in using Scratch improved, enabling them to finish the tasks accurately.

According to the results obtained from the student diaries regarding the Scratch lessons and the projects developed, the opinions of the experimental group students were generally positive. They expressed that they found the projects fun, and they liked the projects very much. The students reported that they enjoyed writing code and did not experience difficulty in completing the projects. Additionally, they mentioned that they would like to continue with Scratch lessons. The students also stated that playing the games they created was highly enjoyable, as it gave them a sense of accomplishment. They found the projects remarkable and expressed excitement while playing the games they developed.

According to the results obtained from the students' opinions about the Scratch program, the experimental group of students expressed that the Scratch program was very fun, visually beautiful, and wonderful. They stated that making games was an exciting and enjoyable experience. The students mentioned feeling very happy and excited while working with Scratch, although some initially felt scared, they found it less challenging than they anticipated. They enjoyed the process very much and expressed that they liked all the projects. Additionally, the majority of the students reported not facing difficulty in creating the projects. When reviewing the literature, it is noted that there are limited studies on primary school students' opinions about the Scratch program. For instance, Yurtbakan (2022) found that gifted students viewed the Scratch program as fun during the qualitative phase of their study. Ozturk (2021) reported that middle school students found games designed with Scratch interesting, visually appealing, and entertaining. Similarly, Cubukluoz (2019) concluded that students found games created using Scratch to be interesting and fun. The findings from these studies are consistent with the results of this study.

Recommendations

In this study, where the teaching of the Scratch program was conducted, it was observed that elementary school students easily learned to use the Scratch program. Therefore, coding education can be provided to elementary school students, and the Scratch program can be taught. The Scratch program can be taught over a longer period, giving students more opportunities to create games. Students can be encouraged to make different games using the Scratch program. The Scratch program can also be taught to 3rd-grade elementary school students, and teachers can use Scratch activities to increase students' interest and motivation in the lesson. The effects of coding education on other cognitive skills can be examined, and due to the lack of sufficient studies on coding education in elementary schools in the literature, researchers can focus on this area. Additionally, the Ministry of National Education can include coding education in the elementary school curriculum.

Scientific Ethics Declaration

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

*In this study, ethical approval was obtained from the Social and Human Sciences Research Ethics Committee of Inonu University with the approval number 2022/14-8, dated 30.06.2022.

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Development of Science Process Skills and Learning Achievement Using Flipped Classroom Learning Management through Inquiry-Based Learning for Grade 8 Students

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Abstract

The objectives of this research are: (1) to develop a flipped classroom learning plan using inquiry-based learning on the topic of substance separation for Grade 8 students, to achieve effectiveness according to the 75/75 criteria; (2) to compare science process skills and learning achievement before and after implementing the developed learning plan. The study included 45 Grade 8 students from a high school in Khon Kaen Province, Thailand, during the second semester of the 2022 academic year. The students were chosen using cluster random sampling. The research tools included: (1) six flipped classroom learning management through inquiry-based learning on the topic of mixture separation, totaling 11 hours; (2) a multiple-choice test with 30 questions on the topic of mixture separation to measure learning achievement; and (3) a multiple-choice test with 30 questions to assess science process skills. The statistical analysis includes mean, percentage, standard deviation, and hypothesis testing with Hotelling's T-Square. The research findings were: (1) the flipped classroom learning plan using inquiry-based learning had an effectiveness of 89.2/77.5; (2) the learning achievement and science process skills of students after implementing the developed learning plans were significantly higher than before, with statistical significance at the .05 level.

Introduction

In modern education, developing science process skills and improving learning outcomes are essential objectives, especially in secondary school science teaching. With technological advancements and pedagogical strategies, educators are increasingly adopting innovative approaches to enhance student engagement and understanding. Two such approaches, flipped classroom learning and inquiry-based learning, have gained attention due to their ability to reshape traditional approaches to teaching science. The flipped classroom model, which shifts direct instruction outside the classroom and utilizes class time for interactive activities, has increased student engagement and achievement (Egara & Mosimege, 2024; Jonathan Bergmann, 2012; Yu et al., 2023). On the other hand, inquiry-based learning (IBL) emphasizes student-driven exploration and problem-solving, which are essential for developing scientific process skills (Gillies, 2023; Hmelo-Silver, 2004). Combined, these approaches offer a promising framework for enhancing secondary school students' understanding of complex scientific concepts such as separation of mixture.

The flipped classroom model has become accepted for its ability to create a more interactive and engaging learning environment. Bergmann and Sams (2012) (Jonathan Bergmann, 2012) describe this approach as a reversal of traditional teaching methods, where students first encounter new content through pre-class materials such as videos and then apply their understanding during in-class activities. This model facilitates deeper engagement and allows teachers to provide more personalized support during class. According to a meta-analysis(Jensen et al., 2015; Lazonder & Harmsen, 2016), the flipped classroom approach can significantly improve student learning outcomes and engagement, particularly when combined with active learning strategies. Inquiry-based learning (IBL) focuses on students actively exploring scientific questions and problems, which fosters critical thinking and a deeper understanding of scientific concepts (Sucilestari & Arizona, 2020). Students develop essential scientific process skills by engaging in hands-on investigations and discussions, such as hypothesizing, experimenting, and analyzing data (Hmelo-Silver, 2004). Research indicates that IBL can enhance students' ability to apply scientific principles and improve their problem-solving skills (Antonio & Prudente, 2023). Scientific process skills, including observation, measurement, experimentation, and analysis, are crucial for students' science understanding and investigation ability (Gizaw & Sorsa, 2023). These skills are often developed through inquiry-based approaches emphasizing active participation and critical thinking. Many

research highlights that students who engage in inquiry-based activities demonstrate better mastery of scientific process skills than those who receive traditional instruction (Bordin, Said, Sabil, & Arshad, 2022; Minner et al., 2010; Orkwiszewski, 2009; Wilson et al., 2010).

Separation techniques in science, including filtration, distillation, and chromatography, are fundamental in chemistry education. These techniques provide practical applications of scientific principles and are critical for students to master as they form the basis for more advanced scientific inquiry (Miranda, 2021). By integrating the flipped classroom model with inquiry-based learning, educators can create an environment that not only introduces these techniques effectively but also encourages students to engage in their application and understanding actively. This combination can potentially lead to improved scientific process skills and better learning outcomes, aligning with current educational goals for science instruction (Dellatola et al., 2020; Lage et al., 2000; Love et al., 2016). Combining flipped classroom methods with inquiry-based learning can provide a robust framework for developing scientific process skills. For instance, the pre-class content in a flipped classroom can introduce theoretical concepts related to substance separation. At the same time, in-class inquiry-based activities allow students to apply these concepts through experiments and problem-solving tasks. This approach not only reinforces theoretical knowledge but also enhances practical skills and fosters a deeper understanding of the subject matter (Loizou & Lee, 2020)

Despite the potential benefits of integrating flipped classroom and inquiry-based learning approaches, there remains a gap in understanding how these methods specifically impact the development of scientific process skills and learning outcomes in the context of substance separation for secondary school students. Previous research has separately highlighted the effectiveness of flipped classrooms and inquiry-based learning (Ogunleye et al., 2024; Potvin et al., 2017; Scott & Friesen, 2013; Yu et al., 2023). Still, there is limited empirical evidence on their combined impact in the specific context of teaching mixture separation techniques. Additionally, while both approaches have been shown to enhance student engagement and performance in various subjects, their effectiveness in developing scientific process skills and improving learning outcomes in secondary school chemistry remains underexplored.

This research examines how integrating flipped classroom learning with inquiry-based approaches affects secondary school students' development of scientific process skills and their learning outcomes in the context of mixture separation. By examining this combination, the study seeks to provide insights into its effectiveness and practical implications for enhancing science education. **The objectives of this work include:** 1) To develop an effective flipped classroom learning management plan using inquiry-based learning on mixture separation for Grade 8 students to achieve the 75/75 criteria and 2) To compare learning achievement and science process skills of students before and after implementing the developed learning plans.

Method

Population and Sample

The population includes 11 classes, totaling 495 Grade 8 students in regular classrooms (non-special ability) during the second semester of the 2022 academic year at a high school in Khon Kaen Province, Thailand. The sample was selected through random cluster sampling, comprised of a single class of 45 students.

Research Tools

1) The flipped classroom learning management plan using inquiry-based learning on the topic of mixture separation for Grade 8 students consists of 6 plans totaling 11 hours, as follows:

Learning plan 1: Evaporation - 1 hour
Learning plan 2: Crystallization - 3 hours
Learning plan 3: Distillation - 1 hour
Learning plan 4: Solvent Extraction - 2 hours
Learning plan 5: Paper Chromatography - 1 hour
Learning plan 6: Mixture Separation in Daily Life - 3 hours

Each plan was reviewed by five experts, receiving an average score of 4.89 out of 5. The evaluation summary highlights a high level of quality and suitability.

2) A multiple-choice test with 30 questions on mixture separation to measure learning achievement. The item objective congruence (IOC) values for the items range from 0.60 to 1.00, with a discrimination index between 0.25 and 0.67. The reliability, assessed using the Lovett method, is 0.94.
3) The science process skills test is a 30-question multiple-choice assessment. The IOC values range from 0.60 to 1.00, with difficulty levels between 0.52 and 0.79 and discrimination indices from 0.21 to 0.36. The test has an overall reliability score of 0.97.

Data Collection

The researcher collected data using the following steps: (1) clarified the details of the procedures in the sample classroom, (2) conducted a pre-test with the sample group using both the achievement test and the science process skills test, (3) implemented the developed learning plan, following each plan sequentially and recording scores during the lessons, (4) after completing six learning plans, conducted a post-test using the same achievement test and science process skills test as used in the pre-test.

Statistics and Data Analysis

In analyzing the data using the following statistical methods: (1) basic statistics, including percentages, means, and standard deviations to analyze the data, (2) to assess the quality of research tools, the objective congruence (IOC) for **content validity** which involves expert judgment to determine if the tool covers all relevant content. The effectiveness of the learning plans was evaluated against the 75/75 criteria using the E1/E2 formula. Discrimination power for individual items was analyzed using Brennan's B-Index method. The reliability of the achievement test was measured using Lovett's formula. Difficulty (p) and discrimination (r) indices were calculated. The reliability of the entire test was assessed using the Kuder-Richardson Formula KR-20, (3) statistics for hypothesis testing to compare science process skills and learning achievement before and after the implementation, the Multivariate Paired Hotelling's T-Square test was used.

Results and Discussion

Effectiveness of the Learning Management Plans

The effectiveness of the learning management plans was assessed using E1/E2. E1 is process effectiveness measured by evaluating the scores from the class activity and the final quizzes of the learning plans, which indicate knowledge (Knowledge: K) and process skills (Process: P). E2 is outcome effectiveness measured using the achievement test scores, compared against the 75/75 criteria, as shown in Table 1.

Table 1. Effectiveness of the developed learning plans

Items	Full Score	$\bar{X}$	S.D.	p
E_1	600	535.47	22.81	89.25
E_2	30	23.24	3.23	77.48
E_1/E_2 = 89.25/77.48				

From Table 1, it is found that the flipped classroom learning management plan using inquiry-based learning on the topic of mixture separation for Grade 8 students has an effectiveness score of 89.25/77.48, which meets the established criteria of 75/75.

Comparison of Student Learning Achievement Before and After Implementing the Learning Plans

Hypothesis testing for Hotelling's T-Square statistic was evaluated using three approaches:
1) Ensuring that each population follows a multivariate normal distribution and accounting for outliers, results shown in Table 2
2) Verifying initial assumptions about correlation, result shown in Table 3
3) Verifying initial assumptions concerning variance using box's test of equality of covariance matrices, result shown in Table 4

Table 2 Preliminary assumptions for multivariate normal distribution and outliers

Items	Minimum	Maximum	Mean	S.D.
Mahalanobis Distance	0.137	11.814	3.911	2.666
critical values used for comparison df = 2, χ^2 = 13.82				

From Table 2, the overall data analysis using the maximum value of Mahalanobis Distance yielded a value of 11.814, less than the critical value (χ^2 = 13.82). This indicates that there are no multivariate outliers, and it can be concluded that the distribution of the analyzed data approximates a multivariate normal distribution.

Table 3 Examination of variable correlations before and after implementing the learning management.

Dependent Variables	Scientific Process Skills	Learning Outcomes
Scientific process skills (before), r_{xy}	1.00	0.259*
Learning outcomes (before), r_{xy}		1.00
Scientific process skills (after), r_{xy}	1.00	0.544**
Learning outcomes (after), r_{xy}		1.00

From Table 3, verifying initial assumptions about correlation, it was found that the analysis of the correlation coefficients between scientific process skills and learning outcomes before and after implementing the learning management shows a positive and statistically significant correlation at the .05 level.

Table 4. Verifying initial assumptions concerning variance.

Box's M	F	df1	df2	p
3.261	1.060	3	1393920.000	.365

From Table 4, the analysis of the box's M or box's test of equality of covariance matrices showed a value of 3.261, with an F value of 1.060 and a probability (Prob) of 0.365, which is greater than 0.05. This indicates that the population variance-covariance matrices (homogeneity of variance-covariance matrices) are equal.

From these results, the analysis indicates that the data distribution approximates a multivariate normal distribution. The correlation checks for dependent variables, both before and after the learning management using the flipped classroom with inquiry-based learning on substance separation for Grade 8 students, show that all variables are correlated. Additionally, the variance-covariance matrices are equal. As a result, using multivariate analysis of variance or Hotelling's T-Square is considered suitable for analysis.

Comparing Scientific Process Skills and Learning Outcomes Before and After Implementing the Learning Management

The results showed that students' science process skills and learning outcomes were significantly higher after the implementation of the developed learning plan, with statistical significance at the .05 level, as show in Table 5

Table 5. Comparing scientific process skills and learning outcomes before and after implementing the learning management.

Independent variables	before		after		T^2	F	p
	$\bar{x}$	S.D	$\bar{x}$	S.D			
Scientific process skills	16.91	3.27	23.16	3.84	372.299	177.688	0.00
learning outcomes	11.80	2.79	23.24	3.26			

The results indicate significant improvements in both scientific process skills and learning outcomes after implementing the developed learning management. Specifically, the mean score for scientific process skills increased from 16.91 (SD = 3.27) before the implementation to 23.16 (SD = 3.84) afterward, yielding a Hotelling's T^2 value of 372.299 and an F-value of 177.688, with a p-value of 0.00, demonstrating vital statistical significance. Similarly, learning outcomes showed a notable improvement, with the mean score increasing from 11.80 (SD = 2.79) to 23.24 (SD = 3.26). These findings suggest that the implemented strategies effectively enhanced students' skills and knowledge, supporting the efficacy of the educational approach used. The results of developing science process skills and academic achievement through the use of an inquiry-based flipped classroom learning approach on the topic of mixture separation for Grade 8 students can be discussed as follows:

1. The inquiry-based flipped classroom learning management on the topic of mixture separation for Grade 8 students shows an effectiveness of 89.25/77.48, meeting the criteria of 75/75. This means that students achieved an average score of 89.25% from the combined assessments during the inquiry-based flipped classroom, with the scores equally weighted between 50:50 for the activity logs and the post-test. The average post-test academic achievement score was 77.48%, meeting the specified criteria. It can be observed that the inquiry-based flipped classroom learning plan effectively enhances both science process skills and learning achievement. This approach can be implemented efficiently by transitioning from traditional lecture-based instruction to a method where students learn independently and engage in activities together in the classroom. This shift increases interaction between teachers and students and among students themselves. By using technology in learning management, instructors can save time on lessons, allowing them more time to collaborate with students and engage in interactive learning activities. The inquiry-based flipped classroom learning approach emphasizes student-centered learning. Students study the content at home through online systems, videos, or other online resources the teacher provides before attending class. The teacher's role is to offer guidance and answer questions during classroom activities. Students define problems independently based on given scenarios, which enhances their understanding and allows them to apply the knowledge they gained before class in designing their research to find answers. Additionally, the study found the inquiry-based flipped classroom learning plan on the topic of mixture separation for Grade 8 students was effective, with scores of 89.25/77.48. However, it was noted that the E1 and E2 scores differed by more than 5%, which indicates an imbalance between the student activities and the post-test exam. For example, if the E1 score is higher than the E2 score, it may imply that the tasks given were easier than the teaching content. This indicates that the mixture separation activity logs and the post-test scores used to measure process skills and learning achievement were not balanced. Therefore, to improve the difficulty of the post-test exam, more questions should be added, focusing more on analytical thinking or including open-ended questions (Loizou & Lee, 2020; Ramadhansyah, 2021; Schallert et al., 2022).

2. Students who engaged in the inquiry-based flipped classroom learning on the topic of mixture separation for Grade 8 show significantly higher science process skills and learning achievement after the learning implementation, with statistical significance at the .05 level. Several studies have demonstrated the effectiveness of inquiry-based flipped classroom models in enhancing students' science process skills and learning achievement. For example, a study involving Grade 9 students in the Philippines found that students in the flipped classroom environment, which integrated inquiry-based learning, showed significant improvements in their conceptual understanding and science process skills compared to traditional teaching methods. Moreover, the combination of the flipped classroom and inquiry-based approaches has been particularly effective in STEM education, enabling students to engage more deeply with scientific concepts through active learning and exploration during class time. This has been shown to promote not only a better understanding of scientific topics but also higher achievement levels in various subjects, including science and mathematics (Rusnilawati et al., 2023; Tan et al., 2020). The application of these models, particularly in mixture separation, allows for efficient use of class time for inquiry and problem-solving, significantly improving students' learning outcomes with statistical significance at the 0.05 level. This is consistent with the research by Rafon and Mistades (Rafon-Paghubasan & Mistades, 2020), who found that when students studied prepared materials independently, class time was effectively utilized for collaborative activities like problem-solving and active discussions. This student-centered method promoted deeper comprehension, encouraging learners to explore topics independently and engage in group discussion, ultimately boosting their academic success and interaction skills. The approach enhanced both individual accountability and group collaboration, allowing for a more interactive and productive learning environment.

3. Considering individual scores, some students show improved learning achievement and science process skills after the implementation. However, despite progress, their post-learning scores remained below the class average. This could be due to the diversity and differences among students. Students may face challenges such as limited access to technology, affecting their ability to engage with pre-class materials in a flipped classroom model fully. Additionally, varying levels of prior knowledge, study habits, and learning skills can influence how effectively they process new information, leading to disparities in performance even after making progress. These factors highlight the need for differentiated support. Therefore, teachers should consider incorporating various learning styles or teaching techniques that are more diverse and appropriate, possibly increasing the time for learning pre-class materials to support student learning better.

Conclusion

In conclusion, the inquiry-based flipped classroom model is appropriate for teaching and learning. It focuses on student-centered learning, uses technology as a medium for education, and helps prepare students before

engaging in classroom activities. This approach ensures that students have ample time to participate in activities and engage thoroughly in the learning process, enabling them to build their knowledge through hands-on experience. The teacher acts as a facilitator and guide, which helps ensure that the effectiveness of the science learning plan meets the set criteria and effectively enhances both scientific process skills and academic achievement.

Recommendations

Suggestions for implementation of the developed inquiry-based flipped classroom model or recommendations for future research are as follows:

1) Since the learning process involves experimental skills and the use of scientific glassware, students should be provided with additional training in the primary use of laboratory equipment to ensure they are well-prepared for experiments.
2) During the research process, it was observed that students initially experienced confusion when working in groups and were slow in dividing tasks, which made each activity step time-consuming. Therefore, teachers should encourage them to recognize the roles of group members, task division, discussion, and collaborative learning. While students are engaged in group activities, teachers should prompt them to help and consult with others and carefully observe their group working.
3) The inquiry-based flipped classroom model integrates learning both in and out of the classroom. Therefore, teachers should create a variety of easily accessible instructional resources, such as visual aids, interactive infographics, digital flashcards**, e-books, or** podcasts**,** to engage students' interests and address their individual differences.
4) Teachers should provide immediate feedback on students' activities to ensure students are aware of their individual and group performance. Positive reinforcement should be encouraged when students successfully and promptly complete learning activities, boosting their enthusiasm and motivation for learning.
5) The inquiry-based flipped classroom model should be applied in other learning units to promote ongoing student learning improvement.
6) It would be beneficial to examine the integration of the inquiry-based flipped classroom model with other teaching methods, such as combining it with problem-based learning.
7) It is advisable to study the inquiry-based flipped classroom model with other dependent variables, such as analytical thinking or attitudes toward learning science.

Scientific Ethics Declaration

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

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