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The Effect of Gamification Activities on Biodiversity Literacy

Oyunlaştırma Etkinliklerinin Biyoçeşitlilik Okuryazarlığı Üzerindeki Etkisi

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Abstract

This study aims to examine the effects of gamification-enriched teaching activities on the biodiversity literacy of 5th-grade students. A quasi-experimental design was employed in the study, with a total of 56 students in two control groups (C1: female only, C2: male only) and one mixed-gender experimental group. Gamification activities were implemented in the experimental groups for five weeks, while the control group used the traditional methods recommended in the curriculum. Data were collected using the Biodiversity Literacy Assessment Scale, and analyses were conducted using t-tests, ANOVA, and ANCOVA. Findings indicated a statistically significant increase in achievement, particularly in the mixed-class experimental group. While significant differences were limited in attitude dimensions, positive improvements were observed in the experimental groups, particularly in ethical awareness. The results demonstrate that gamification not only supports cognitive gains but also has the potential to enhance affective development. In this context, long-term, planned implementation of gamification applications in environmental education, considering classroom structure, is recommended.

Keywords: Biodiversity literacy, gamification, environmental education, middle school students

Öz

Bu çalışma, oyunlaştırma ile zenginleştirilmiş öğretim etkinliklerinin 5. sınıf öğrencilerinin biyoçeşitlilik okuryazarlığı üzerindeki etkisini incelemeyi amaçlamaktadır. Yarı deneysel desen kullanılan araştırmada iki kontrol (C1: sadece kız, C2: Sadece erkek) ve bir deney grubu olmak üzere toplam 56 öğrenci yer almıştır. Deney gruplarına 5 hafta süresince oyunlaştırma etkinlikleri uygulanmış, kontrol grubunda ise öğretim programında önerilen geleneksel yöntemler kullanılmıştır. Veriler "Biyoçeşitlilik Okuryazarlığı Değerlendirme Ölçeği" ile toplanmış ve analizlerde t-testi, ANOVA ve ANCOVA kullanılmıştır. Bulgular, özellikle karma sınıftan oluşan deney grubunda başarı düzeyinde istatistiksel olarak anlamlı artış sağlandığını göstermiştir. Tutum boyutlarında ise anlamlı farklar sınırlı olsa da deney gruplarında özellikle etik farkındalık düzeyinde olumlu gelişmeler gözlenmiştir. Sonuçlar, oyunlaştırmanın bilişsel kazanımları desteklemenin yanı sıra duyuşsal alan gelişiminde de potansiyel taşıdığını ortaya koymaktadır. Bu bağlamda, çevre eğitiminde oyunlaştırma uygulamalarının uzun vadeli, planlı ve sınıf yapısı gözetilerek uygulanması önerilmektedir.

Anahtar Kelimeler: Biyoçeşitlilik okuryazarlığı, oyunlaştırma, çevre eğitimi, ortaokul öğrencileri

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1. Introduction

The concept of biodiversity was first used during the Rio de Janeiro “Earth Summit” in the Convention on Biological Diversity (CBD) that was signed by 157 countries, including Türkiye in 1992. Biodiversity is defined as: "the variety of all living organisms that arise from terrestrial, marine, and other aquatic ecosystems and the ecological complexes to which they belong, as well as the differences within and between species" (WRI, IUCN, UNEP, 1992). The concept of biodiversity encompasses intraspecies diversity, interspecies (genetic) diversity, and ecosystem diversity (Şenel, 2015). The Earth, with all its biodiversity elements, is extraordinary (Dursun & Fent, 2022) as humans rely on the components of biodiversity for the continuation of life. Biodiversity provides almost every natural element including food, water and the air. Each component of biodiversity is valuable to society and individuals, forming the source of vital services (Nuraeni, Rustaman, & Hidayat, 2017). The quality of life individuals maintain is related to the continuity of biodiversity and the opportunities it provides. Therefore, the continuity, preservation, and transmission of biodiversity to future generations are of great importance (Balmford et al., 2002). The rapid destruction of habitats and natural resources leads to environmental problems and the extinction of endemic species valuable to the regions they inhabit (Dervişoğlu et al., 2009). Unconscious behaviours and attitudes of humans threaten biodiversity globally, resulting in increased biodiversity loss (Schneiderhan-Opel & Bogner, 2019). It has been reported that the number of species has decreased by 60% in the last forty years due to human activities (WWF, 2018). Alterations impacting 75% of the Earth's landscape suggest that wildlife and natural environments are restricted to very small regions (IPBES, 2019). The increase in biodiversity loss has become uncontrollable and a global problem (Menzel & Bogeholz, 2010). It is emphasized that raising biodiversity awareness through environmental education is one of the vital measures to prevent biodiversity loss (Barker & Elliot, 2000). If humans are the fundamental cause of increasing environmental problems and decreasing biodiversity, the necessity of educating humans is considered inevitable.

In biodiversity education, it is highlighted that individuals should fully understand all dimensions and the importance of biodiversity, as well as be aware of the consequences of its loss (Dunning, 1997). Biodiversity education is seen as crucial for preserving the existing diversity of living organisms and passing it on to future generations. Developing individuals who are knowledgeable about biodiversity, take responsibility for conservation, and are equipped to prevent species extinction are among the primary aims of biodiversity education (Mayer, 1996). In the same vain, Kassas (2002) argues that biodiversity-literate individuals must have affective, ecological, ethical, and political competencies since preventing biodiversity loss is closely related to knowledge levels, individual sensitivity, principles, ethical standards, and social dilemmas. Similarly, Menzel and Bögeholz (2006) draws attention to the multifaceted structure of training biodiversity-literate individuals. Since human activities are the main cause of rapid biodiversity loss, it is expected that educating biodiversity-literate individuals will lead to a reduction in problems. Therefore, biodiversity education starting from the early years of schooling can be seen as the key to raising biodiversity-literate individuals.

Gamification is highlighted as one of the most effective in-class practices that can be used in biodiversity education at a young age (Saleem, Noori & Ozdamli, 2021). By using information technologies that incorporate gamification elements, rich experiences can be created, and real-time interactions can be observed during the learning process. The integration of technology into education is very valuable, especially for children who are already engaged with technology. The integration of games with technology is known to increase individuals' active participation in the lesson (Gee, 2005). Therefore, according to Huotari and Hamari (2017), gamification has become an increasingly adopted approach used to influence individuals' behaviours and cognitive processes. It is described by Zicherman and Cunningham

(2011) as the use of game-inspired strategies and mechanics to actively engage participants and assist them in problem-solving. Games are appealing to all age groups, and using entertainment is a motivating source of stimulation for students at all class levels (Susi, Johannesson & Backlund, 2007; Upadhyay, 2006). In this context, gamification is important because it leverages the motivational power of games to encourage students' participation in the learning process. It is considered that gamification applications make learning environments more fun, effective, and efficient by significantly contributing to learner participation and motivation (Lee & Hammer, 2011). Gamification, which increases engagement in the learning experience, builds self-esteem, and allows for enjoyable learning, is emerging as an innovative approach in education (Werbach & Hunter, 2012). Despite being new, the positive results obtained from integrating gamification elements into education make it an attractive area for further studies.

Based on the literature reviewed, it is believed that gamification activities are an appropriate method to increase students' biodiversity literacy levels the learning experience. Therefore, it is anticipated that an experimental study incorporating gamification activities into biodiversity education will make a valuable contribution to the field. Therefore, the current study investigated the impact of gamification activities integrated into science classes on developing biodiversity-literate individuals. The objective of the study was to investigate how educational games designed with gamification techniques influence biodiversity literacy among 5th-grade students in the "Human and Environment" unit. The study sought answers for the research questions below:

1. Do the participant students' biodiversity literacy test scores before and after the intervention demonstrate statistically significant differences in the experimental group?
2. Do the participant students' biodiversity literacy test scores before and after the intervention demonstrate statistically significant differences in the control groups?
3. Do the participant students' biodiversity test scores after the intervention show differences for the control and experimental groups?

2. Method

2.1. Research Design

This research employed a quasi-experimental approach that included control groups and tests before and after the experimental process used in the study

2.2. Participants

The study involved year 5 students enrolled in a state secondary school in Diyarbakır province. The participant secondary school had mixed-gender classes as well as gender-segregated classes. In order to have both genders represented in the participant groups, two control groups and one experimental group were included in the research. One of the control groups was made up of male students (N=15), while the other included female students (N=21). One group including both male and female students (F=10, M=10) was used as the experimental group. In total, 56 students participated in the study (C1 = female only, C2 = male only, E = mixed gender).

2.3. Teaching Process

In all three groups, the "Human and Environment" unit was carried out over 5 weeks, with 4 lessons per week. In the group identified as the experimental group, which included both male and female students, activities enriched with educational games from gamification activities were implemented based on formative assessment activities designed to determine

prior learning or learning outcomes. In the control groups, teaching was carried out using the teaching methods and techniques recommended the national curriculum for science.

Examples of the activities used in the study are shown in Figure 1.

Figure 1. Screenshots from the educational game activities used

One gamification activity was prepared and applied for each week. The educational games were used as formative assessment tools to determine prior learning or the understanding acquired through the learning process. Formative assessment is a process aimed at improving education and teaching by collecting information and feedback during the process to inform instructional decisions and guide the teaching process (Black & William, 1998; Schaal, Schaal & Lude, 2015). The achievements included in the conducted teaching and the content of the educational games applied each week are shown in Table 1.

Table 1. Weekly learning outcomes and educational games applied

Week	Learning outcomes	Educational Game
1	• Examines the importance of biodiversity for the survival of natural life. • Engages in discussions about the factors that pose threats to biodiversity, using research data as a basis.	Biodiversity Maze Game
2	• Conveys the significance of the relationship between humans and the environment. • Proposes solutions for an environmental problem in the local area or the country.	"Environmental Pollution" Game
3	• Makes inferences about future environmental problems resulting from human activities.	Puzzle Game
4	• Discusses the benefits and harms in the human-environment interaction with examples.	Box Opening Game
5	Explains destructive natural events caused by natural processes. • Expresses ways to protect against destructive natural events.	"Oh No, I'm Falling!" Game

The researcher, as a science teacher, managed the instructional process for all three participant groups. During the teaching/learning process, the researcher did not act as an information provider but rather a facilitator that helped the pupils in accessing information and solving problems. The "Biodiversity Literacy Assessment Scale" was employed to examine the participant' progress.

2.4. Data Collection Tool

This study used the "Biodiversity Literacy Assessment Scale" as the instrument for collecting data. The scale was developed by the Wisconsin Environmental Education Center (1996) and adapted to Turkish by Aslan Efe & Efe (2022). The scale is composed of three sections: the first gathers demographic information, the second section contains attitude scale items, and the third part includes an achievement test. The 4-point Likert-style instrument is structured in 6 dimensions with a total of 27 items. The scale dimensions, item counts, and the reported and calculated Cronbach's alpha reliability coefficients are provided Table 2.

Table 2. Reliability values of the dimensions in the Biodiversity Literacy Assessment Scale

Scale Dimension	Numbers of items	Reported Reliability Coefficients	Calculated Reliability Coefficients
Conservation and Importance of Biodiversity	5	0,726	0,731
Ethics and Biodiversity	5	0,764	0,697
Sustainability and Biodiversity	3	0,706	0,678
Taking Precautions for Biodiversity Conservation	4	0,704	0,627
Biodiversity and Benefit	4	0,710	0,694
Importance of Species Conservation	6	0,852	0,876

The third part includes 30 multiple-choice questions aimed at measuring knowledge about biodiversity. The reliability coefficient for the achievement test in the Turkish adaptation of the Biodiversity Literacy Assessment Tool was calculated using the Spearman-Brown formula and reported as 0.822 (Efe & Efe, 2022). For the current study this coefficient value was 0.799.

2.5. Data Analysis

Parametric tests were used for analysis because the data showed a normal distribution (Kolmogorov-Smirnov: .221, p>.05) and the data were distributed homogeneously (Levene's test of homogeneity of variances, p>.05). The data collected was analysed by using SPSS 29 through one-way ANOVA for comparing independent and control groups pre and post-tests, ANCOVA for "Ethics and Biodiversity" sub-dimension of the biodiversity literacy scale and paired sample t-test for comparing groups' pre and post test scores.

3.Findings

3.1 Pre-test results for the participants' biodiversity literacy

The analysis of the three participant groups' pre-test scores for biodiversity literacy is presented in table 3.

Table 3. One-way ANOVA results for pre-test scores of the experimental and control groups

		N	M	SD	F	p	η^2
Biodiversity achievement	C1	21	6.62	2.06	2.363	.104	
	C2	15	7.27	1.91			
	E	20	8.65	4.31			
	Total	56	7.52	3.11			
Conservation and Importance of biodiversity	C1	21	2.88	.653	.252	.778	
	C2	15	2.80	.786			
	E	20	2.96	.572			
	Total	56	2.89	.655			
Sustainability and Biodiversity	C1	21	2.76	.668	.015	.985	
	C2	15	2.73	1.121			
	E	20	2.72	.751			
	Total	56	2.74	.823			

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Taking Precautions for Biodiversity Conservation	C1	21	2.86	.625	.962	.389	
	C2	15	2.65	.833			
	E	20	2.99	.705			
	Total	56	2.85	.713			
Ethics and Biodiversity	C1	21	2.55	.521	5.307	.008	.167
	C2	15	2.60	.904			
	E	20	3.16	.534			
	Total	56	2.78	.697			
Biodiversity and Benefit	C1	21	3.18	.763	3.086	.054	
	C2	15	2.70	.917			
	E	20	3.29	.475			
	Total	56	3.09	.750			
Importance of Species Conservation	C1	21	2.81	.791	2.283	.112	
	C2	15	2.50	.696			
	E	20	3.07	.817			
	Total	56	2.82	.795			

The findings shows that the three participant groups' (2 control and 1 experimental) achievement scores before the experimental process started are statistically not different ($F_{(2-53)}$= 2.363 , p=.104). Similarly, there is not any statistically important differences in this test scores for "Conservation of Biodiversity Importance" ($F_{(2-53)}$=.252 , p=.778), "Sustainability and Biodiversity" ($F_{(2-53)}$= .015 , p=.985), "Taking Precautions for Biodiversity Conservation" ($F_{(2-53)}$=.962 , p=.389), "Biodiversity and Benefit" ($F_{(2-53)}$=3.086 , p=.054), and "Importance of Species Conservation" ($F_{(2-53)}$=2.283 , p=.112) when the groups are compared. An important difference was observed in the "Ethics and Biodiversity" dimension ($F_{(2, 53)}$ = 5.307, p = .008, η^2=. 167). The table shows that C1 and C2 groups have similar mean scores which indicates both only girls and only boys groups have similar response to the sub-section of the scale, while experimental group of mixed genders have statistically significant higher scores prior to the experimental process. Therefore, ANCOVA was used for this sub-dimension to find out the if this statistically significant difference has affected the post-test scores of the participants (Table 3.).

3.1. Analysis of the participant students' test scores for biodiversity literacy:

A paired samples t-test was conducted to compare the results of the "Biodiversity Literacy Assessment Scale" (Table 4).

Table 4. Paired sample t test results of E1 group students' biodiversity literacy scores

Variable	Dimension	Test	N	M	SD	df	t	p
Achievement		Test-1	20	8.65	4.31	19	-1.424	.171
		Test-2	20	10.85	4.40			
Attitude to biodiversity	Conservation and Importance of Biodiversity	Test-1	20	2.960	.57	19	-.187	.854
		Test-2	20	2.990	.66			
	Sustainability and Biodiversity	Test-1	20	2.716	.75	19	-1.084	.292
		Test-2	20	2.933	.65			
	Taking Precautions for Biodiversity Conservation	Test-1	20	2.987	.704	19	-.911	.374
		Test-2	20	3.175	.654			
	Ethics and Biodiversity	Test-1	20	3.160	.533	19	-.186	.854
		Test-2	20	3.190	.782			
	Biodiversity and Benefit	Test-1	20	3.287	.474	19	.078	.938
		Test-2	20	3.275	.627			
	Importance of Species Conservation	Test-1	20	3.066	.817	19	-.525	.606
		Test-2	20	3.216	.809			

The analysis of students' biodiversity literacy scores show that the participant students' test scores do not differ statistically when prior to and after intervention scores for the dimensions of BA (t(20)= -1.424, p>.05), CIB (t(20): -.187, p>.05), SB (t(20): -1.084, p>.05), TAPB (t(20): -.911, p>.05), EB (t(20): -.186, p>.05), BB (t(20): .078, p>.05), and ISC (t(20): -.525, p>.05) are compared (Table 4).

Table 5 displays the analysis of the biodiversity literacy test scores for the first control group.

Table 5. C1 group students' paired t-test results

Variable	Dimension	Test	N	$\bar{X}$	SD	df	t	p
Achievement		Test-1	21	5.57	2.69	20	-1.565	.133
		Test-2	21	6.90	3.36			
Attitude to biodiversity	Conservation and Importance of Biodiversity	Test-1	21	2.88	.65	20	.339	.738
		Test-2	21	2.81	.67			
	Sustainability and Biodiversity	Test-1	21	2.76	.67	20	.797	.435
		Test-2	21	2.59	.69			
	Taking Precautions for Biodiversity Conservation	Test-1	21	2.86	.62	20	.492	.628
		Test-2	21	2.75	.58			
	Ethics and Biodiversity	Test-1	21	2.55	.52	20	-1.305	.207
		Test-2	21	2.80	.68			
	Biodiversity and Benefit	Test-1	21	3.18	.76	20	.570	.575
		Test-2	21	3.06	.67			
	Importance of Species Conservation	Test-1	21	2.81	.79	20	.479	. 637
		Test-2	21	2.68	.91			

Table 5 shows that the C1 participant students' test scores do not statistically differ for the dimensions of BA ($t_{(21)}$ = -1.565, p>.05), CIB ($t_{(21)}$: .339, p>.05), SB ($t_{(21)}$: .797, p>.05), TAPB ($t_{(21)}$: .492, p>.05), EB ($t_{(21)}$: -1.305, p>.05), BB ($t_{(21)}$: .570, p>.05), and ISC ($t_{(21)}$: .479, p>.05).

The second control group students' analysis of test scores are is presented in Table 6.

Table 6. Analysis of C2 group students' paired sample t-test results

Variable	Dimension	Test	N	X̄	SD	df	t	p
Achievement		Test-1	15	6.80	2.54	14	-1.641	.123
		Test-2	15	8.40	3.52			
Attitude to biodiversity	Conservation and Importance of Biodiversity	Test-1	15	2.80	.79	14	1.613	.129
		Test-2	15	2.29	.71			
	Sustainability and Biodiversity	Test-1	15	2.73	1.12	14	1.672	.117
		Test-2	15	2.04	.91			
	Taking Precautions for Biodiversity Conservation	Test-1	15	2.65	.83	14	.815	.429
		Test-2	15	2.43	.71			
	Ethics and Biodiversity	Test-1	15	2.60	.90	14	.565	.581
		Test-2	15	2.44	.54			
	Biodiversity and Benefit	Test-1	15	2.70	.92	14	-.270	.791
		Test-2	15	2.78	.61			
	Importance of Species Conservation	Test-1	15	2.50	.70	14	.486	.634
		Test-2	15	2.34	.93			

The table displays that students' test scores do not statistically differ for the dimensions of "BA" (t(15) = -1.641, p>.05), CIB (t(15) = 1.613, p>.05), SB (t(15) = 1.672, p>.05), TAPB (t(15) = .815, p>.05), EB (t(15) = .565, p>.05), BB (t(15) = -.270, p>.05), and ISC (t(15) = .486, p>.05).

3.2. The comparison of the experimental and control group students' post test scores

The experimental and the control group students' post-test scores are compared in Table7.

Table 7. Post-test comparisons of groups C1, C2, and E and post-hoc analysis

Dimension	Groups	N	M	SD	F	P	η^2
Biodiversity achievement	C1	21	6.67	3.66	5.530	.007	.173
	C2	15	8.40	3.52			
	E	20	10.75	4.47			
Conservation and Importance of Biodiversity	C1	21	2.81	.67	4.704	.013	.151
	C2	15	2.29	.71			
	E	20	2.99	.67			
Sustainability and Biodiversity	C1	21	2.59	.69	6.209	.004	.190
	C2	15	2.04	.91			
	E	20	2.93	.65			
Taking Precautions for Biodiversity Conservation	C1	21	2.75	.58	5.875	.005	.181
	C2	15	2.43	.71			
	E	20	3.18	.65			
Biodiversity and Benefit	C1	21	3.06	.67	2.544	.088	.088
	C2	15	2.78	.61			
	E	20	3.28	.63			
Importance of Species Conservation	C1	21	2.68	.91	4.430	.017	.143
	C2	15	2.34	.93			
	E	20	3.22	.81			

The one-way ANOVA results revealed statistically significant differences among the three groups—Control Group 1 (female), Control Group 2 (male), and the Experimental Group (mixed)—in five of the six measured post-test variables (table 7). The analysis shows that ANOVA was significant for academic achievement, $F(2, 53) = 5.53$, $p = .007$, $\eta^2 = .173$. The results indicate a large effect size which suggests the positive effect of gamification activities on biodiversity academic achievement. Post-hoc analysis was carried out to determine the source of this significance differences (table 8).

Table 8. Bonferroni Post-Hoc Comparisons for Post-Test Variables

Variable	Group I	Group J	Mean Diff (I-J)	SE	p	95% CI Lower	95% CI Upper
Biodiversity achievement	C2	E	-0.75	0.24	0.007	-1.33	-0.17
Conservation and Importance of Biodiversity	C2	E	-0.697	0.23	0.012	-1.27	-0.12
Sustainability and Biodiversity	C2	E	-0.889	0.25	0.003	-1.51	-0.26
Taking Precautions for Biodiversity Conservation	C2	E	-0.742	0.22	0.004	-1.29	-0.2
Importance of Species Conservation	C2	E	-0.872	0.30	0.016	-1.62	-0.13

Post-hoc Bonferroni comparisons showed that the experimental group scored significantly higher than Control Group 2 ($p = .012$), whereas the difference between the experimental group and Control Group 1, and between the two control groups, was not significant in terms of *Biodiversity Academic Achievement* (table 8).

The data analysis yielded a statistically significant group effect for *Conservation and Importance of Biodiversity*, $F(2, 53) = 4.70$, $p = .013$, $\eta^2 = .151$. This result indicates a large effect size (table 7). Bonferroni post-hoc analysis shows while the experimental group significantly outperformed Control Group 2 ($p = .012$), there was not any statistically significance between the experimental and the only girl control group (table 8).

Table 7 shows that group differences are significant for *Sustainability and Biodiversity* sub-section, $F(2, 53) = 6.21$, $p = .004$, $\eta^2 = .190$. This large effect size indicates the positive contribution of the instructional methodology used. Post- hoc analysis shows the significant differences stem from the difference between the experimental group and only male control group students' scale scores (table 8).

The study findings also shows significant groups differences for *Taking Precautions for Biodiversity Conservation*, $F(2, 53) = 5.88$, $p = .005$, $\eta^2 = .181$ and *Importance of Species Conservation*, $F(2, 53) = 4.43$, $p = .017$, $\eta^2 = .143$. In both subsections a large effect size indicating a positive contribution of the instructional method is evident (table 7). But the post hoc analysis shows this group differences are results of the differences between the experimental and the only male (C2) control group students' scale scores (table 8).

For the biodiversity and ethics subscale an ANCOVA was used (table 9) since there was statistically significant differences in the pre- test scores.

Table 9. ANCOVA Summary Table

Source	SS	df	MS	F	p	Partial η^2
Pre-test (Covariate)	0.350	1	0.350	0.735	0.395	0.014
Group	3.543	2	1.771	3.723	0.031	0.125
Error	24.744	52	0.476			
Total	482.560	56				

An analysis of covariance (ANCOVA) was conducted to compare the effect of group membership (C1, C2, E) on students' post-test scores in the Ethics and Biodiversity dimension while controlling for pre-test scores. The assumption of homogeneity of variances was met, as assessed by Levene's test, $F(2, 53) = 0.458$, $p = .635$. The ANCOVA results indicated a statistically significant difference between groups on the adjusted post-test scores, $F(2, 52) = 3.723$, $p = .031$, partial $\eta^2 = .125$. This suggests that group membership accounted for approximately 12.5% of the variance in post-test scores, after controlling for pre-test performance. However, the covariate (pre-test scores) was not a significant predictor, $F(1, 52) = 0.735$, $p = .395$. Effect size values above .14 indicate a moderate effect, which may have pedagogical relevance even if not statistically significant.

Table 10. Adjusted Means and Confidence Intervals

Group	Adjusted Mean	Std. Error	95% CI Lower	95% CI Upper
C1	2.83	0.15	2.519	3.138
C2	2.46	0.18	2.101	2.824
E	3.14	0.16	2.814	3.471

Adjusted mean post-test scores (table 10) were highest for group E (M = 3.14, SE = 0.16), followed by C1 (M = 2.83, SE = 0.15), and lowest for C2 (M = 2.46, SE = 0.18).

Table 11. Pairwise Comparisons (Bonferroni)

Group Comparison	Mean Difference	Std. Error	p (adj.)	95% CI Lower	95% CI Upper
C1 vs C2	0.366	0.233	0.368	-0.211	0.943
C1 vs E	-0.314	0.233	0.552	-0.891	0.263
C2 vs E	-0.680	0.249	0.026	-1.297	-0.063

Bonferroni-adjusted pairwise comparisons (table 11) revealed that the adjusted post-test score of group E was significantly higher than that of group C2, $p = .026$. The differences between E and C1 ($p = .552$), and C1 and C2 ($p = .368$) were not statistically significant.

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4.Discussion and Conclusion

This study investigated the effect of applying educational games on biodiversity literacy levels in terms of certain variables. The five-week experimental research showed that digital games as a gamification activity did not find a statistically significant contribution for enhancing students' academic achievement and attitude towards biodiversity. The study duration may have contributed to this outcome. Although significant differences were not observed when groups pre- and post- test were compared, post-test scores of the experimental and control groups showed statistically significant differences. These results align with prior research suggesting that active and collaborative learning environments can foster deeper understanding of environmental topics and promote positive attitudes toward conservation (Ardoin et al., 2020; Can, 2010; Dinçer, 2019; Dumlu Güler, 2011; Huizenga et al., 2019; Karayılan, Çakmak & Güzel, 2019; Kaya & Elgün, 2015; Monroe et al., 2019). Similarly, Babaandaç (2013) found that students supported by games in the teaching of the "Human and Environment" unit showed significantly higher academic success compared to students taught using traditional methods. Similarly, different studies reported methods and techniques that make students more active contribute to increasing environmental awareness, attitudes, and behaviours (Erten, 2003; Soner, 2006; Yıldırım, 2008; Uğulu, 2011). It also supports findings that these methods enhance sensitivity and awareness toward the environment (Soner, 2006; Cömert, 2011; Erdoğan, 2011). The most consistent pattern observed was that the experimental group significantly outperformed the male-only control group (C2) across multiple dimensions, including biodiversity achievement, conservation importance, sustainability understanding, precautionary behaviour and species conservation awareness. The mixed-gender composition of the experimental group may have also facilitated richer discussions and peer learning, which

could explain the consistently higher scores compared to the male-only group.

The findings of this study reinforce the growing body of literature suggesting that gamification can play a meaningful role in enhancing both the cognitive and affective dimensions of environmental and biodiversity education. Although within-group pre- and post-test comparisons did not yield statistically significant differences, the between-group post-test analysis revealed that the mixed-gender experimental group outperformed the male-only control group across multiple biodiversity literacy dimensions. This suggests that the gamification-based approach may be particularly effective in contexts where baseline biodiversity literacy or motivation is relatively low—especially in male-dominated learning environments.

The significant differences in post-test scores for dimensions such as Conservation and Importance of Biodiversity, Sustainability and Biodiversity, Taking Precautions for Biodiversity Conservation, and Importance of Species Conservation highlight that gamified activities can effectively foster complex, value-driven environmental competencies. These competencies extend beyond factual knowledge to include attitudes, awareness, and intended behaviours—critical components in shaping long-term pro-environmental engagement (Balmford et al., 2002; Monroe et al., 2019). Moreover, the lack of significant differences in the Biodiversity and Benefit dimension suggests that utilitarian understandings of biodiversity may not be as sensitive to instructional innovations. This could be because such knowledge is more concrete and directly relatable to everyday experiences, making it equally accessible through traditional instruction.

Interestingly, the absence of significant differences between the experimental group and the female-only control group aligns with prior research indicating that female students often begin with higher environmental awareness and pro-conservation attitudes (Zelezny et al., 2000). This finding implies that while gamification has the capacity to elevate learning outcomes, its marginal gains may vary depending on baseline attitudes and prior knowledge. In other words, gamification may act more as a levelling mechanism for underperforming groups rather than a universal booster for all learners.

From an instructional design perspective, the large effect sizes (η^2 values) observed in this study carry strong practical implications. Even in the absence of universal statistical significance across all dimensions, the magnitude of these effects suggests that gamification can produce educationally meaningful changes in biodiversity literacy—especially when designed to promote interaction, problem-solving, and collaborative learning (Huizenga et al., 2019; Werbach & Hunter, 2012).

5. Recommendations

1. The five-week intervention may have been insufficient to produce strong within-group changes. Future studies and classroom applications should consider longer-term integration of gamification, potentially spanning an entire semester, to allow for deeper conceptual change and habit formation.

2. The observed gains in male students suggest that gamification can be particularly effective for groups with lower initial biodiversity literacy or weaker environmental attitudes. Teachers might strategically employ gamification in male-dominated classrooms or with students exhibiting lower baseline scores.

3. The mixed-gender composition of the experimental group may have enhanced peer learning and discussion quality. Educators should consider structuring gamified activities to

encourage diverse group interactions, thereby leveraging different perspectives and promoting richer learning experiences.

4. Given the variation in gains between male and female students, pre-intervention assessments can guide the customisation of gamified content. Tailoring challenges to learners' initial knowledge and attitudes may maximise engagement and outcomes.

5. Qualitative follow-ups, such as student interviews, could provide insights into motivational and behavioural shifts triggered by gamified instruction.

Değerlendirme/*Evaluation*:
Çift Taraflı Kör Hakemlik Sistemi
Double Blind Refereeing System

Etik Beyan Metni/ *Ethics Declaration Text:*
Çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

It is hereby declared that scientific and ethical principles were adhered to during the preparation of this study and that all studies used are cited in the references.

Etik Bildirim/Ethics Notification: info@esosder.org

Araştırmacıların Katkı Oranı Beyanı/ *Declaration of the contribution rate of the researchers:*
Birinci yazar %60, ikinci yazar %40 oranında katkı sağlamıştır.
The first author contributed 60%, the second author 40%

Yapay Zekâ Kullanımı /Use of Artificial Intelligence:
Bu çalışmanın hazırlanma sürecinde yapay zekâ tabanlı herhangi bir araç veya uygulama kullanılmamıştır. Çalışmanın tüm içeriği, yazar(lar) tarafından bilimsel araştırma yöntemleri ve akademik etik ilkelere uygun şekilde üretilmiştir.

No artificial intelligence-based tools or applications were used in the preparation of this study. All content of the study was produced by the author(s) in accordance with scientific research methods and academic ethical principles.

Çıkar Çatışması Beyanı/ *Declaration of conflict of interest:*
Bu çalışmada herhangi bir potansiyel çıkar çatışması bulunmamaktadır.
There is no potential conflict of interest in this study.

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