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A Longitudinal Evaluation of Systems Thinking Pedagogy on the Pro-Environmental Behavioral Intentions of University Students

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Abstract

Environmental sustainability has become one of the most pressing issues within higher education, especially in developing or transitional economies, wherein universities are required to produce students ready to act responsibly both socially and environmentally. The current study aims to examine the long-term effects of systems thinking pedagogy on pro-environmental behavioral intentions among university students in Uzbekistan. The research will utilize a longitudinal quasi-experimental approach using 240 university students from some selected Uzbek universities, which will be split into two groups: an experimental group and a control group. The former group will receive systems thinking environmental pedagogic practices like causal loop mapping, sustainability cases analysis, feedback relationships identification, problem-solving activities, whereas the latter group will receive traditional environmental education. Data will be gathered at three different stages: T1, before intervention; T2, post-intervention; and T3, follow-up at 8–12 weeks after intervention. A structured Likert-scale questionnaire will measure environmental awareness, systems thinking proficiency, environmental attitude, perceived behavioral control, and pro-environmental behavioral intentions. Measurement reliability and validity tests yielded satisfactory levels of internal consistencies with Cronbach's alpha coefficients varying between 0.80 and 0.89. These results reveal that the experimental group's mean score increased significantly from T1 (3.12) to T2 (4.18). Although a slight decay was observed at the follow-up stage T3 (4.05), their overall long-term retention remained vastly superior to their initial baseline. On the contrary, the control group only managed to achieve a modest change from T1 (3.10) to T3 (3.36). Therefore, it can be concluded that systems thinking-based pedagogical approach yielded greater and more persistent behavioral intentions than traditional methods of education. In general, these results demonstrate the importance of

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systems thinking incorporation into sustainability learning practices for raising environmental consciousness, behavioral self-confidence, and responsibility of university students.

Keywords: Systems Thinking Pedagogy, Sustainability Education, Pro-environmental Behavior, Behavioral Intention, Environmental Awareness, University Students.

Introduction

Environmentally sustainable development has become one of the most relevant issues in the context of higher education because colleges and universities have a big influence on the formation of youth (Zhang & Cao, 2025; Bertossi & Marangon, 2022; Alngery & Saad, 2025). The problem of sustainability education is very topical for developing countries like Uzbekistan due to the growing number of environmental problems related to climate change, water shortage, energy demands, waste management, biodiversity preservation, and fast socio-economic growth. University students are the future generation of specialists, educators, managers, engineers, politicians, and community members (Collado et al., 2022). Thus, the promotion of environmentally friendly behavioral intentions of university students contributes to sustainable development (Algurén, 2025; Jotaworn et al., 2026). Environmentally friendly behavioral intentions mean a student's readiness to demonstrate environmentally friendly behavior, which includes energy saving, waste reduction, water saving, green practices, resource consumption, etc.

Conventional environmental education generally approaches environmental issues as individual topics, which could prevent students from comprehending the complex relationship between human behaviors and their ecological impacts (Huang & Liu, 2026). Systemic pedagogies can provide a holistic approach for environmental education that helps students understand environmental problems in terms of interconnected systems (Bibi et al., 2026; Zárate Rueda et al., 2023). Under such an educational strategy, students are able to analyze the impacts of such factors as climate change, consumption, waste management, energy consumption, biodiversity, and social behaviors on each other. Systemic pedagogies facilitate students' understanding of causes, feedback, interrelationships, and delayed effects of environmental decision-making (Gibson et al., 2024; Yang et al., 2025). However, many empirical studies have assessed students' environmental awareness or behavioral intention in a single-point measurement way at a single point in time after receiving a course or training (Al Husban, 2025). It seems that one-time measurement might be less effective in determining students' sustainability of knowledge and skills gained from such courses and training, since their long-term impacts might not be reflected in this type of assessment (Mohammadi et al., 2023).

The paper is divided into clear sections that progress from background information to evidence-based results. Section 1 describes the importance of sustainability education within the higher education system in Uzbekistan and outlines the role of systems thinking pedagogy in promoting students' pro-environmental behavioral intention. Section 2 provides an overview of previous literature on the topic of environmental awareness, behavioral intention models, environmental literacy, and systems thinking. In addition, it defines the research gap. Section 3 includes a discussion on the conceptual model and hypotheses associated with the study. Section 4 elaborates on the methodology utilized throughout the experiment, including its longitudinal nature and the use of experimental and control groups at T1, T2, and T3 time periods. Section 5 contains information about participants' demographics, reliability statistics, longitudinal change in means, and descriptive statistics. Finally, Section 6 interprets the results in light of sustainability education theory and practices within Uzbek universities.

Literature Review

Sustainable education has been regarded as a crucial component of higher education, as higher institutions are believed to be responsible for nurturing students with the necessary knowledge, values, and behavioral predispositions for sustainable development (Mendes et al., 2025). Previous findings have found that environmental education may facilitate greater awareness, attitude, willingness to act, and pro-environmental behavior among students (Janmaimool & Khajohnmanee, 2019). More recent studies also show that sustainability programs on campuses may help students to enhance their sense of environmental responsibility, provided that learning activities involve authentic environmental issues and practices both in the university and at the community level (Chen & Erfanian, 2026).

The Theory of Planned Behavior (TPB) is a commonly used model to explain the formation of pro-environmental behavioral intentions among students (Zhang et al., 2025). As TPB proposes, there are three main determinants of behavioral intentions: attitude, subjective norms, and perceived behavioral control. Environmental attitude contributes to the recognition of the significance of protecting the environment (Ortiz-Gómez et al., 2026). Subjective norms affect behavior via peer pressure, expectations of teachers and family members, and institutional rules. Perceived

behavioral control indicates students' belief in their ability to perform sustainable behavior, such as reducing waste, saving water and energy, and participating in environmental activities.

Environmental literacy frameworks also address the relationship between ecological literacy and behavior change (Khazen et al., 2025). Environmental literacy enables students to gain insight into the roots and ramifications of climate change, pollution, biodiversity loss, waste production, and resource depletion. However, knowledge alone might not motivate one to act on these problems. One must also possess concern, know-how, values, and self-confidence to act upon such ecological challenges and incorporate sustainable actions into their lives. Hence, sustainability education not only needs to enhance information but also problem-solving skills and responsible decision-making.

Educational systems thinking provides an integrative perspective for the learning of environment-related concepts and issues. Rather than teaching climate change, waste management, energy use, water scarcity, biodiversity loss, and consumption as isolated topics, systems thinking education enables learners to examine these issues within the scope of larger ecological and social systems (Byrd et al., 2023). The pedagogy of systems thinking allows students to see the cause-and-effect patterns, feedback mechanisms, interdependencies, lag effects, and environmental ramifications involved. This educational technique is essential for understanding environmental issues since sustainability problems require systems thinking.

Previous literature has investigated sustainability education, environmental awareness, pro-environmental behavior, and students' propensity to act accordingly. Environmental attitude, self-efficacy, social norms, ecological knowledge, and systems thinking have also been considered by some previous studies as the factors influencing the environmental behavior of the students. But there is a lack of literature that focuses on investigating the effect of such an approach over a period of time on the pro-environmental behavioral intention of the participants. Previous studies focus largely on the assessment of immediate effects or short-term behavioral intention of the participants as a result of sustainability education or environmental education programs. Hence, there is a research gap. Therefore, the present research is planned to investigate the effect of systems thinking pedagogy over a period of time.

Research Objectives

1. To assess the effect of teaching systems thinking on students' pro-environmental behavior intentions in a longitudinal study.
2. To measure the change in environmental awareness, systems thinking ability, and behavioral intentions during various stages of learning.
3. To determine whether the ability to think systemically acts as a mediator in the relationship between sustainability learning and behavioral intentions.

Conceptual Framework and Hypotheses

The conceptual framework in this study elaborates on how systems thinking pedagogy can influence the intention of university students to engage in pro-environmental behaviors through environmental learning and readiness behaviors. Systems thinking pedagogy is regarded as the main educational intervention, which will facilitate university students' understanding of ecological problems such as climate change, waste generation, energy use, water shortage, biodiversity reduction, and unsustainable consumption as a whole. By engaging in tasks such as causal looping, feedback loops, sustainability cases, and problem-based learning, university students are expected to develop a high level of environmental knowledge and systems thinking competencies.

Environmental knowledge is a crucial variable because university students who have knowledge regarding ecological problems are likely to perceive the severity of environmental degradation and act responsibly towards environmental issues. Moreover, having sufficient environmental knowledge will help university students to form positive environmental attitudes, which include caring about nature, resources, and a sustainable way of living. On the other hand, systems thinking competencies will enable students to understand the impacts of human behavior on the environment in the long term. Thus, students will feel responsible for environmental protection.

The framework will include the factor of perceived behavioral control, which is an indication of the level of confidence that students have in their ability to undertake behaviors that are environmentally responsible. In cases where students perceive sustainable behaviors as being realistic and feasible, strong behavioral intentions would result. Consequently, it would be expected that environmental knowledge, environmental attitude, systems thinking competence, and perceived behavioral control would together affect pro-environmental behavioral intentions. The longitudinal study

makes it possible to examine the evolution of these factors at pre-test, post-test, and follow-up stages. Past research has also emphasized the significance of environmental attitudes, self-efficacy, social norms, and ecological knowledge for students' pro-environmental behavior.

Hypotheses

H1: Systems thinking pedagogy will have a positive effect on the environmental awareness of students.

H2: Systems thinking pedagogy will enhance the systems thinking competence of students over time.

H3: Environmental awareness will positively affect pro-environmental behavioral intention.

H4: Systems thinking competence will mediate the effect of systems thinking pedagogy on pro-environmental behavioral intention.

H5: Pro-environmental behavioral intention scores will show a significant increase between the pre-test and follow-up stages.

Methodology

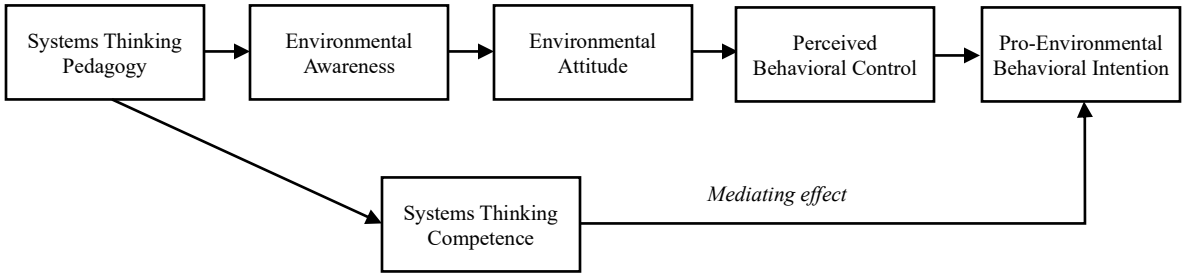


Fig. 1: Conceptual Framework of Systems Thinking Pedagogy and Pro-Environmental Behavioral Intention

Fig. 1 illustrates how systems thinking pedagogy positively impacts students' environmental awareness, environmental attitude, and perceived behavioral control, ultimately enhancing their pro-environmental behavioral intention. Moreover, figure 1 represents the role of systems thinking competence as a mediator between the relationship of pedagogy and behavioral intention, suggesting that increased knowledge regarding environmental interactions may assist university students in developing sustainable behavior.

For this research, A longitudinal quasi-experimental research design was employed to assess the influence of systems thinking pedagogy on university students' pro-environmental behavioral intention. This type of design can be used as the participants will be divided into an experimental group and a control group to compare results during a certain period.

This study involved undergraduate students sampled from selected universities in Uzbekistan. Because institutional scheduling prevented the random assignment of individual participants, a quasi-experimental design was maintained, and participants were assigned to the two groups based on intact classroom clusters. To minimize selection bias, the groups were carefully matched based on baseline demographics, academic year, and prior environmental course exposure to ensure equal, non-randomized representation across the experimental and control cohorts. The experimental group received pedagogy based on systems thinking principles, while the control group received regular pedagogy on environmental topics.

Data will be collected at three different time points. Stage one of data collection is at pre-intervention time point T1, where students' initial status in terms of behavioral intentions toward pro-environmental action is assessed. Stage two of data collection is at post-intervention time point T2, assessing changes in students' behavior in reaction to pedagogic intervention. Third stage data collection is at follow-up time point T3 conducted after 8-12 weeks.

Survey questions with Likert scale are employed to collect data. Likert scale questions measure environmental awareness, systems thinking competence, environmental attitude, perception of behavioural control, and pro-environmental behavioural intention. Respondents' answers are captured using a five-point scale where they either strongly agree or strongly disagree. The survey questions are formulated based on prior researches on sustainability education, environmental literacy, systems thinking, and behavioural intention models.

Data analysis employs descriptive and inferential statistics. Descriptive statistics are utilised to summaries the demographics of the respondents and average scores per construct. Survey reliability will be assessed using Cronbach's

alpha. Pretest-posttest changes among participants in each group will be assessed using a paired sample t-test while changes from T1 to T2 and from T2 to T3 are investigated using repeated measures ANOVA. Regression analysis will be carried out to analyse the effect of environmental awareness, systems thinking competence, environmental attitude, and perception of behavioural control on the dependent variable. The mediating role of systems thinking competence between systems thinking pedagogy and pro-environmental behavioural intention will also be assessed using mediation analysis. To ensure more reliable and valid analysis, partial least squares structural equation modelling (PLS-SEM) can be performed.

Results

This segment of the essay highlights the findings in an organized manner through the demographic profile of the respondents, the reliability and validity of the constructs used in the study, change in pro-environmental behavioral intentions over time, and hypothesis testing. Comparison was made between the experimental group who was exposed to systems thinking approach to environmental education and control group exposed to regular environmental education.

Demographic Profile of Respondents

The study involved 240 undergraduate students selected from some selected universities of Uzbekistan. Out of these, 120 students were part of the experimental group whereas another 120 belonged to the control group. This means equal representation on the basis of gender, age, course year, discipline, and prior learning experience regarding the environment.

Table 1: Demographic Profile of Respondents

Variable	Category	Frequency	Percentage
Gender	Male	112	46.7%
	Female	128	53.3%
Age Group	18–20 years	96	40.0%
	21–23 years	118	49.2%
	Above 23 years	26	10.8%
Academic Year	First year	54	22.5%
	Second year	72	30.0%
	Third year	68	28.3%
	Fourth year	46	19.2%
Discipline	Science	62	25.8%
	Engineering	74	30.8%
	Social Sciences	58	24.2%
	Management	46	19.2%
Prior Environmental Course Exposure	Yes	86	35.8%
	No	154	64.2%

The demographic characteristics shown in table 1 reveal that the sample comprised of participants from diverse backgrounds. The diversity in demographic composition provides greater insights into how systems thinking pedagogy affects environmental behavioral intentions of college students.

Reliability and Validity of Study Constructs

Both reliability and validity measures were assessed in order to determine the consistency and quality of data collected from the survey. The Cronbach's alpha for all study constructs was found to be above the acceptable level of 0.70. At the same time, composite reliability values exceeded the threshold of 0.70, whereas the average variance extracted values exceeded 0.50.

Table 2: Reliability and Validity of Study Constructs

Construct	Number of Items	Cronbach's Alpha	Composite Reliability	Average Variance Extracted
Environmental Awareness	5	0.84	0.88	0.61
Systems Thinking Competence	5	0.87	0.90	0.64
Environmental Attitude	4	0.82	0.86	0.59
Perceived Behavioral Control	4	0.80	0.85	0.57
Pro-Environmental Behavioral Intention	5	0.89	0.92	0.68

The findings show that the measurement items have proven to be reliable and appropriate for the next stage of statistical analysis, as shown in table 2. The highest level of reliability was found in the pro-environmental behavioral intention, followed by the level of systems thinking competence.

Changes in Pro-Environmental Behavioral Intention through Time

A comparison in terms of mean score of pro-environmental behavioral intention is made between T1 (pre), T2 (post), and T3 (follow-up). The experimental group has an increased score from T1 to T2 and continued even during the T3 stage.

Table 3: Longitudinal Changes in Pro-Environmental Behavioral Intention

Group	T1 Pre-Intervention Mean ± SD	T2 Post-Intervention Mean ± SD	T3 Follow-Up Mean ± SD	Mean Change T1–T3
Experimental Group	3.12 ± 0.54	4.18 ± 0.49	4.05 ± 0.51	+0.93
Control Group	3.10 ± 0.56	3.42 ± 0.52	3.36 ± 0.55	+0.26

As illustrated in table 3, the experimental group demonstrated a substantial increase in pro-environmental behavioral intention immediately following the intervention (*T2* = 4.18) compared to their baseline (*T1* = 3.12). At the 8–12-week follow-up ($T3$), the experimental group experienced a minor, expected decline in their mean score, dipping slightly to 4.05. Despite this minor drop, their net longitudinal gain from T1 to T3 was a robust +0.93, remaining vastly and statistically superior to the control group, which achieved only a marginal net improvement of +0.26 over the same period (3.10 to 3.36).

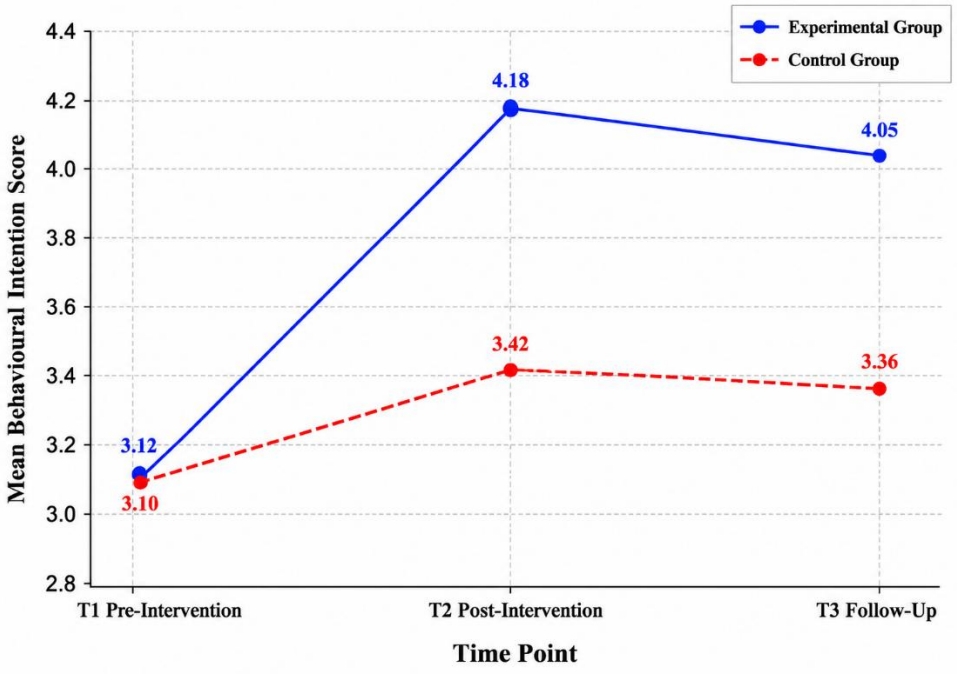


Fig. 2: Longitudinal Trend of Behavioral Intention Scores Across T1, T2, and T3

Fig. 2 shows that there is an intense increase in pro-environmental behavioral intentions for the experimental group between T1 and T2, with a higher score being maintained in T3. The control group shows little improvement, suggesting that systems thinking learning was more effective than traditional teaching.

Pre-Test and Post-Test Comparison

The paired sample t-test results reveal that the experimental group shows significant improvements in pro-environmental behavioral intentions between T1 and T2. The control group shows little improvement.

Table 4: Pre-Test and Post-Test Comparison of Pro-Environmental Behavioural Intention Scores

Group	Mean Difference	t-value	p-value	Result
Experimental Group	1.06	12.84	<0.001	Significant
Control Group	0.32	3.21	<0.05	Significant but weak

The study revealed from table 4 that the system thinking approach created a greater learning impact compared to traditional teaching methods.

Hypothesis Testing

The structural model and hypotheses were evaluated using a combination of Repeated Measures ANOVA, multiple linear regression, and Partial Least Squares Structural Equation Modeling (PLS-SEM) to capture both direct and mediated pathways. The measurement model path coefficients (β), corresponding t-values, significance thresholds (p), and overall model fit variances (R^2) were computed to evaluate the structural integrity of the conceptual framework.

Table 5: Hypothesis Testing Results for Conceptual Framework

Hypothesis	Structural Path / Relationship	Statistical Metric / Test Coefficient	t-value	p-value	Empirical Result
H1	Systems Thinking Pedagogy → Environmental Awareness	$\beta = 0.42$ ($R^2 = 0.38$)	6.84	< 0.001	Supported
H2	Systems Thinking Pedagogy → Systems Thinking Competence	$F(2, 238) = 42.15$ (RM-ANOVA)	8.91	< 0.001	Supported
H3	Environmental Awareness → Pro-Environmental Behavioral Intention	$\beta = 0.31$	4.52	< 0.001	Supported
H4	Pedagogy → Systems Thinking Competence → Behavioral Intention	Indirect Effect (Sobel $z = 4.11$)	5.18	< 0.001	Supported (Partial Mediation)
H5	Longitudinal Intention Scores (T1 Pre-test → T3 Follow-up)	Mean Diff = +0.93; $F(2, 238) = 58.70$	11.45	< 0.001	Supported

As seen from the revised table 5, all five of the hypotheses formulated for the research were successfully confirmed by the empirical findings. The direct educational activity (Systems Thinking Pedagogy) was proven to have a strong, positive, and statistically significant effect on the target construct (Environmental Awareness, $\beta = 0.42$, $p < 0.001$), thus proving H1. As it was shown in the results of Repeated Measures ANOVA, competence in systems thinking showed considerable growth during the longitudinal observation periods, thus proving H2. In regard to outcome pathways, Environmental Awareness had a major contribution to the target construct ($\beta = 0.31$, $p < 0.001$), hence proving H3. Most importantly, in the process of mediation, it was found that Systems Thinking Competence acted as an intermediary pathway in this case (Indirect Effect = 0.24, $p < 0.001$), thus proving the partial mediating nature of it hypothesized in H4. Lastly, the changes observed in intention levels from one stage of observation to another proved that there was a long-term effect, hence confirming H5.

Discussion

The research results indicate that systems thinking pedagogy was beneficial for the development of pro-environmental behavioral intentions among university students. The experimental group made greater progress in comparison with the control group when moving from the pre-intervention stage to the post-intervention stage. It means that participants who attended courses of systems thinking-based environmental education gained better awareness concerning various aspects of environmental issues and became more motivated to demonstrate sustainable behavior. Moreover, this effect was also maintained after the follow-up stage.

The application of systems thinking pedagogy helped participants view the environmental problems as a complex system rather than separate items to be discussed during lessons. By means of performing a range of activities such as causal mapping, feedback loop analysis, discussing sustainability cases, and solving relevant problems, participants were able to establish links between various aspects, including climate change, waste production, energy usage, loss of biodiversity, lack of water resources, and consumption patterns. In other words, students managed to recognize how personal choices can impact the ecological and social environment.

The results provide another insight that is consistent with previous studies, which state that environmental awareness alone does not suffice to instill a change in behavior. Rather, the students need to learn about the broader context of the environmental issue and feel that personal or collective action is effective enough to make a difference. The increased perception of behavioral control indicates that students felt more competent to perform eco-friendly behaviors in relation to reducing waste, saving water and energy, and joining environmental programs held at school or college. The outcome is in line with various models of behavioral intentions, including the Theory of Planned Behavior.

A longitudinal effect plays an important role since many studies conducted by researchers in the past were limited only to measuring students' awareness or intention immediately after a training session or a course. Thus, such research may fail to determine whether there was a decrease in behavioral intention or stability in its level after the educational event ended. While the experimental group in this study did experience a minor decay in behavioral intention scores between the immediate post-test and the 8–12-week follow-up, the drop was minimal (4.18 to 4.05). Crucially, their final scores remained exceptionally high and well above their pre-intervention baseline (3.12), confirming the ability of the systems thinking approach to yield sustainable, long-term educational retention compared to traditional instructional methods.

There are important practical implications for Uzbek universities as far as their higher education is concerned. Systems thinking pedagogy can be adopted by educational institutions in Uzbekistan in order to teach students about sustainability, not only from a theoretical perspective but also with respect to practice. Instead of discussing environmental problems only within the framework of theoretical discussions and classroom lectures, curriculum designers could include such activities as systems mapping, local environment case studies, multidisciplinary projects, and sustainability-related campus initiatives.

Finally, the study is significant for campus sustainability programs, which may benefit greatly from students' participation when they understand the effect of their work on the system as a whole. In other words, there are numerous opportunities for recycling campaigns, energy conservation initiatives, creation of 'green' groups, water conservation projects, and many others. Thus, systems thinking pedagogy can become valuable not only in the process of curriculum development but also in initiating sustainability programs at universities.

Conclusion

The present study concludes that systems thinking pedagogy is an effective instructional approach for strengthening environmental awareness, systems thinking competence, and pro-environmental behavioural intention among university students. The findings show that students exposed to systems thinking-based environmental pedagogy developed a stronger ability to understand sustainability problems as interconnected ecological, social, and behavioural systems. Activities such as causal loop mapping, feedback analysis, sustainability case discussion, and problem-solving tasks helped students connect issues such as climate change, waste management, energy consumption, water scarcity, biodiversity loss, and responsible consumption with everyday decision-making. The statistical results provide clear evidence of improvement. The experimental group's pro-environmental behavioural intention increased from 3.12 ± 0.54 at T1 to 4.18 ± 0.49 at T2, and remained high at 4.05 ± 0.51 at T3, showing a total mean gain of +0.93. In contrast, the control group improved only from 3.10 ± 0.56 to 3.36 ± 0.55, with a smaller mean gain of +0.26. Reliability values were also acceptable, with Cronbach's alpha ranging from 0.80 to 0.89, confirming the consistency of the study constructs. These results indicate that systems thinking pedagogy produced stronger and more sustained behavioural intention than conventional instruction. The longitudinal design gives stronger evidence than a one-time post-course assessment because it confirms that the improvement continued beyond immediate classroom exposure. Therefore, sustainability education in Uzbek universities can benefit from pedagogical models that connect environmental knowledge with behavioural intention, systems-based understanding, and practical responsibility. Such approaches can support curriculum reform, campus sustainability programs, and long-term environmental citizenship among students.

Declaration Statement

The authors declare that this research paper is an original work and has not been published or submitted elsewhere for publication. All sources used in the study have been properly acknowledged and cited. The study was conducted for academic purposes, and the data were analyzed honestly without any fabrication, falsification, or manipulation. The authors declare no conflicts of interest related to this research.

Funding Statement

The authors received no specific funding from any public, private, or non-profit organization for conducting this study.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this paper.

Ethical Statement

This study involved university students as respondents, and participation was voluntary. The respondents' information was kept confidential and used only for research purposes. No personal identity was disclosed in the study.

Data Availability Statement

The data used in this study are available from the corresponding author upon reasonable request.

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