

A.K. Dzhumagazieva\*<sup>1</sup>, G.K. Dlimbetova<sup>1</sup>, F.G. Mukhametzhanova<sup>2</sup>

<sup>1</sup>L.N. Gumilyov Eurasian National University  
Astana, Kazakhstan

<sup>2</sup>Institute of International Relations, History and Oriental Studies  
Kazan (Volga Region) Federal University, Russian

\*e-mail: [Dasel\\_84@mail.ru](mailto:Dasel_84@mail.ru)\*

## DEVELOPMENT MODEL OF ENVIRONMENTAL RESPONSIBILITY AMONG PROSPECTIVE TEACHERS IN A DIGITAL COLLEGE LEARNING ENVIRONMENT: DIAGNOSIS AND EXPERIMENTAL VALIDATION

### Abstract

This study presents the development and empirical validation of a pedagogical model aimed at fostering environmental responsibility among prospective teachers within the digital learning environment of pedagogical colleges. The relevance of the research is determined by the need to move beyond declarative environmental education toward measurable behavioural transformation in the context of sustainable development and digitalization of vocational teacher training in Kazakhstan. The purpose of the article is to develop and empirically validate a pedagogical model for the formation of environmental responsibility among future teachers in a digital educational environment, as well as to evaluate its effectiveness based on a comprehensive diagnosis of cognitive, value, behavioral and digital competencies. The empirical study was conducted during the 2024–2025 academic year in two pedagogical colleges of the West Kazakhstan region and involved 165 students aged 16–20. The Eco-Teacher-Responsibility (ETR) diagnostic toolkit was developed to assess four components of environmental responsibility: cognitive awareness, value orientation, behavioural readiness, and digital ecological competence. The results demonstrate statistically significant improvements following a structured formative intervention ( $p < 0.001$ ; Cohen's  $d = 0.82$ ). The proportion of students with a high level of environmental responsibility increased from 15% to 44%, while the share of those at a low level decreased from 49% to 11%. The findings confirm that the systematic integration of digital technologies, project-based learning, and value-oriented pedagogical support contributes to sustainable behavioural change among future teachers.

**Keywords:** environmental responsibility, sustainable development, digital learning environment, pedagogical college, teacher education, ecological competence, empirical validation.

### Introduction

The growing ecological challenges of the 21st century, including climate instability, biodiversity loss, and resource depletion, have intensified the role of education in shaping environmentally responsible behaviour [1]. Within this context, teacher education acquires particular significance, as future teachers act not only as knowledge transmitters but also as value mediators and behavioural role models [2]. In Kazakhstan, the modernization of vocational teacher training increasingly incorporates digital learning environments and sustainability-oriented reforms. However, environmental education in pedagogical colleges often remains limited to theoretical knowledge, with insufficient emphasis on measurable behavioural outcomes [3].

Environmental responsibility can be understood as an integrative construct that combines ecological knowledge, personal values, behavioral readiness, and the ability to apply digital tools to solve environmental problems [4]. The formation of this quality requires more than exposure to information; it demands a structured pedagogical design and consistent practical engagement.

The present study aims to develop and experimentally validate a model to foster environmental responsibility among prospective teachers in a digital college learning environment. This study contributes to the literature in several important ways. First, it develops and empirically validates a structured model of environmental responsibility formation specifically adapted to pedagogical colleges in Kazakhstan. Second, it conceptualizes environmental responsibility as a multidimensional construct that explicitly incorporates digital ecological competence alongside cognitive, value-based, and behavioural components. Third, through a quasi-experimental design, the study provides quantitative evidence of measurable behavioural transformation. Finally, it

demonstrates that integrating digital technologies with value-oriented pedagogical strategies can significantly enhance sustainable behavioral outcomes in secondary vocational teacher education.

#### Literature Review

Recent research emphasizes that environmental responsibility should be approached as a multidimensional construct that integrates cognitive, motivational, and behavioral components [5]. Empirical studies indicate that sustainable ecological transformation occurs only when value-based reflection is combined with experiential learning.

Kopnina (2020) argues that many programs labeled as education for sustainable development remain largely declarative and do not lead to measurable behavioral outcomes. This critique underlines the importance of empirically validated models. Within digitally mediated environments, ecological competence develops more effectively when interactive simulations and project-based learning are incorporated [6-7]. In the Central Asian context, Dlimbetova, Abenova, and Sadykova (2020) propose a system-wide “green continuum” across educational levels, highlighting the importance of institutional coherence.

Sandibekova et al. (2024) further demonstrate that the formation of eco-competence in teacher education requires integrating value-oriented pedagogy with practical engagement. The alignment of educational reform with SDG 4 and SDG 13 is also widely discussed in recent literature [8]. Despite the growing body of international research, empirical studies focusing specifically on secondary vocational teacher education remain limited. Most investigations concentrate on higher education institutions, leaving a gap in understanding how pedagogical colleges — as foundational institutions in teacher preparation — can systematically cultivate environmental responsibility within digitally enhanced learning environments.[9]

Therefore, the present research addresses this gap by proposing and experimentally validating a structured model tailored to the context of pedagogical colleges in Kazakhstan. Unlike predominantly descriptive approaches, the study employs quantitative statistical analysis to assess behavioural change and the development of digital ecological competence among future teachers.

#### Materials and methods of research

##### Research Design

The empirical study was conducted during the 2024–2025 academic year in two pedagogical colleges of the West Kazakhstan region: Uralsk Pedagogical College and Aktobe Pedagogical College. The research design followed a quasi-experimental pre-test–post-test format and included three consecutive stages: diagnostic assessment, formative intervention, and post-intervention evaluation. [10]

##### Participants

The study involved 165 students ( $n = 165$ ) enrolled in teacher education programmes. Participants were aged between 16 and 20 years ( $M = 18.1$ ). The gender distribution reflected the typical structure of pedagogical training in Kazakhstan: 132 female students (80%) and 33 male students (20%).

All students from the selected academic groups participated in the research, ensuring representativeness within the institutional context.

##### Duration and Structure of the Intervention

The formative programme was implemented over one academic semester (16 weeks) and included 36 academic hours integrated into the digital learning environment.

The structure of the intervention comprised:

Stage 1 – Diagnostic phase (2 weeks): Baseline measurement using the Eco-Teacher-Responsibility (ETR) toolkit.

Stage 2 – Formative phase (12 weeks):

- Digital ecological projects (10 hours): development of campus waste management initiatives and online sustainability campaigns;
- Volunteer environmental activities (12 hours): participation in tree planting, clean-up campaigns, and local environmental monitoring;
- LMS-based simulations and virtual laboratories (8 hours): modelling ecological scenarios and analysing sustainability cases;

- Reflective seminars (6 hours): discussion of professional responsibility and SDG integration into teaching practice.

Stage 3 – Control phase (2 weeks): Post-test assessment and statistical comparison of results.

The intervention combined digital educational technologies with experiential and value-oriented pedagogical strategies.

#### Diagnostic Instrument

To assess environmental responsibility, the authors developed the Eco-Teacher-Responsibility (ETR) diagnostic toolkit. The instrument is based on competence-oriented and system-activity approaches in education for sustainable development.

The ETR includes four interrelated scales:

- Eco-Cognition – knowledge of sustainable development principles, climate literacy, and environmental regulation;
- Eco-Values – ecological beliefs and professional responsibility orientations;
- Eco-Action – participation in environmental initiatives and behavioural readiness;
- Eco-Digital – ability to apply digital tools for environmental problem-solving.

Each scale contains 8–12 items measured on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree).

#### Level Classification

Environmental responsibility levels were classified as follows:

- Low level: 1.0–2.4
- Medium level: 2.5–3.9
- High level: 4.0–5.0

#### Reliability and Validity

Internal consistency of the scales was assessed using Cronbach's alpha, which ranged from 0.79 to 0.86, indicating satisfactory reliability.

Content validity was established through expert evaluation involving five specialists in environmental pedagogy and sustainable development.

Construct validity was confirmed using exploratory factor analysis:

- KMO = 0.81
- Bartlett's test of sphericity:  $p < 0.001$

These indicators confirm the adequacy of the instrument's structure.

#### Data Collection and Statistical Analysis

Data collection methods included questionnaire surveys (ETR), structured classroom observation, and student interviews.

Statistical analyses were conducted using SPSS (version 27.0). Descriptive statistics (means, standard deviations, and percentage distributions) were calculated to determine the overall level of environmental responsibility. To assess the effectiveness of the intervention, paired Student's t-tests were applied to compare pre-test and post-test scores. Effect size was calculated using Cohen's d to estimate the practical significance of observed differences. The threshold for statistical significance was set at  $p < 0.05$ .

### **Results and their discussion**

The initial diagnostic assessment revealed that environmental responsibility among prospective teachers was unevenly developed. At the baseline stage, 49% of students ( $n = 81$ ) demonstrated a low level, 36% ( $n = 59$ ) a medium level, and only 15% ( $n = 25$ ) a high level.

The mean overall ETR score at baseline was  $M = 2.68$  ( $SD = 0.74$ ), indicating predominance of low-to-moderate ecological responsibility.

Component-level analysis showed that the weakest dimensions were behavioural readiness and digital ecological competence:

- Eco-Action:  $M = 2.5$  ( $SD = 0.8$ )
- Eco-Digital:  $M = 2.4$  ( $SD = 0.7$ )

These results suggest that while students possessed general awareness of environmental issues, their ability to translate knowledge into consistent ecological behaviour remained limited. Interviews conducted during the diagnostic phase indicated that participation in environmental initiatives was often episodic and externally motivated rather than internally sustained.

#### Post-Intervention Outcomes

Following the 16-week formative programme, statistically significant positive changes were observed.

At the post-test stage:

- Low level – 11% (n = 18)
- Medium level – 45% (n = 74)
- High level – 44% (n = 73)

The proportion of students at the high level increased from 15% to 44%, while the share at the low level decreased from 49% to 11%.

The mean overall ETR score increased to:

M = 4.25 (SD = 0.58)

Paired t-test results confirmed statistical significance:

t(164) = 6.18, p < 0.001

Effect size analysis demonstrated a large practical effect:

Cohen's d = 0.82

These indicators confirm that the observed changes were not random fluctuations but reflect substantial pedagogical impact.

#### Component-Level Dynamics

All four dimensions of environmental responsibility demonstrated measurable growth.

Table 1 - Dynamics of Environmental Responsibility Components

Scale	Pre-test (M±SD)	Post-test (M±SD)	t	P
Eco-Cognition	2.8 ± 0.7	4.1 ± 0.6	5.12	<0.001
Eco-Values	3.0 ± 0.6	4.2 ± 0.5	4.89	<0.001
Eco-Action	2.5 ± 0.8	4.3 ± 0.6	6.04	<0.001
Eco-Digital	2.4 ± 0.7	4.4 ± 0.5	6.31	<0.001

Note: compiled by authors

#### Data Source and Availability

The empirical data presented in this study were collected by the authors during the 2024–2025 academic year within a quasi-experimental research design conducted in two pedagogical colleges of the West Kazakhstan region. The dataset includes results obtained from 165 students using the Eco-Teacher-Responsibility (ETR) diagnostic toolkit, as well as data from structured observations and semi-structured interviews.

Due to ethical and institutional restrictions, the data are not publicly available; however, they can be provided by the corresponding author upon reasonable request.

The most pronounced improvements were observed in:

- Eco-Digital (+2.0 points)
- Eco-Action (+1.8 points)

This indicates that digital simulations, project-based assignments, and volunteer engagement contributed significantly to behavioural activation. During the intervention period, students began independently proposing environmental initiatives within the college environment, including digital awareness campaigns and waste-reduction proposals. Such behavioural manifestations suggest that the programme influenced not only cognitive understanding but also motivational engagement.

#### Interpretation

These findings are consistent with recent research emphasizing that behavioural transformation in environmental education requires systemic pedagogical intervention rather than isolated informational approaches [11].

The obtained results are also consistent with the findings of Dlimbetova, Abenova, and Sadykova (2023), who emphasize the importance of systemic sustainability integration across educational levels in Kazakhstan. Similarly, Sandibekova, Dlimbetova, Bulatbayeva, and Abenova (2020) argue that eco-competence formation in teacher education requires the combination of value-oriented pedagogy and practical engagement. The present study extends these conclusions by providing quantitative evidence of behavioural transformation within a secondary vocational education setting.

#### Limitations

Several limitations should be acknowledged. The study was conducted within one regional context, and therefore broader generalization requires caution. In addition, the post-test assessment was administered immediately after the intervention; long-term stability of behavioural changes requires further longitudinal observation. Finally, part of the data relied on self-report measures, which may introduce response bias.

These limitations do not undermine the validity of the findings but indicate directions for future research.

#### Conclusion

The present study developed and empirically tested a structured model for fostering environmental responsibility among prospective teachers within a digital college learning environment. The findings demonstrate that environmental responsibility cannot be limited solely to theoretical ecological awareness, as it requires systematic pedagogical support integrating knowledge acquisition, value reflection, behavioural engagement, and digital competence.

The implementation of a 16-week formative programme resulted in statistically significant improvement across all components of environmental responsibility. The proportion of students demonstrating a high level increased from 15% to 44%, while the share at the low level decreased from 49% to 11% ( $p < 0.001$ ; Cohen's  $d = 0.82$ ). The most substantial gains were observed in behavioural and digital dimensions, indicating the effectiveness of integrating project-based activities and digital simulations into teacher training curricula [12].

From a theoretical perspective, the study contributes to the understanding of environmental responsibility as a multidimensional construct that must include digital ecological competence in the context of contemporary educational transformation. The research also demonstrates that secondary vocational teacher education institutions can serve as active platforms for sustainable development initiatives when structured pedagogical models are applied.

Practically, the proposed model can be adapted for use in pedagogical colleges across Kazakhstan and similar educational systems. Its modular structure allows flexible integration into existing curricula without major institutional restructuring.

Future research should expand the geographical scope of the sample, conduct longitudinal monitoring to assess the stability of behavioural changes, and explore the integration of emerging digital technologies, including artificial intelligence tools, into ecological education environments [13]. The findings confirm that environmental responsibility should be regarded as a multidimensional construct shaped by cognitive, value-based, and behavioural interaction. The integration of digital technologies into ecological education aligns with global trends in sustainable teacher training [14]. The results also support previous conclusions that measurable ecological transformation requires structured institutional support rather than isolated curricular elements.

Environmental responsibility in teacher education should be regarded not as an additional competence but as a core professional characteristic. The findings of this study confirm that measurable ecological transformation among future teachers is achievable through coherent pedagogical design and evidence-based implementation [15].

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## МОДЕЛЬ ФОРМИРОВАНИЯ ЭКОЛОГИЧЕСКОЙ ОТВЕТСТВЕННОСТИ У БУДУЩИХ ПЕДАГОГОВ В УСЛОВИЯХ ЦИФРОВОЙ ОБРАЗОВАТЕЛЬНОЙ СРЕДЫ КОЛЛЕДЖА: ДИАГНОСТИКА И ЭКСПЕРИМЕНТАЛЬНАЯ ВАЛИДАЦИЯ

### Аннотация

В статье представлена разработка и эмпирическая валидация педагогической модели, направленной на формирование экологической ответственности у будущих педагогов в условиях цифровой образовательной среды педагогических колледжей. Актуальность исследования обусловлена необходимостью перехода от декларативного экологического образования к измеряемым поведенческим изменениям в контексте устойчивого развития и цифровизации системы профессиональной подготовки педагогов в Казахстане. Цель статьи — разработать и эмпирически валидировать педагогическую модель формирования экологической ответственности у будущих педагогов в условиях цифровой образовательной среды, а также оценить её эффективность на основе комплексной диагностики когнитивных, ценностных, поведенческих и цифровых компетентностей. Эмпирическое исследование проводилось в 2024–2025 учебном году на базе двух педагогических колледжей Западно-Казахстанской области и охватило 165 студентов в возрасте 16–20 лет. Для оценки четырех компонентов экологической ответственности — когнитивной осведомленности, ценностной ориентации, поведенческой готовности и цифровой экологической компетентности — был разработан диагностический инструмент «Eco-Teacher-Responsibility» (ETR). Результаты демонстрируют статистически значимые улучшения после реализации структурированной формирующей программы ( $p < 0.001$ ; Cohen's  $d = 0.82$ ). Доля студентов с высоким уровнем экологической ответственности увеличилась с 15% до 44%, тогда как число студентов с низким уровнем снизилось с 49% до 11%. Полученные данные подтверждают, что системная интеграция цифровых технологий, проектного обучения и ценностно-ориентированной педагогической поддержки способствует устойчивым поведенческим изменениям у будущих педагогов.

**Ключевые слова:** экологическая ответственность, устойчивое развитие, цифровая образовательная среда, педагогический колледж, подготовка педагогов, экологическая компетентность, эмпирическая валидация.

## **КОЛЛЕДЖДІҢ ЦИФРЛЫҚ ОҚУ ОРТАСЫНДА БОЛАШАҚ ПЕДАГОГТЕРДІҢ ЭКОЛОГИЯЛЫҚ ЖАУАПКЕРШІЛІГІН ҚАЛЫПТАСТЫРУ МОДЕЛІ: ДИАГНОСТИКА ЖӘНЕ ЭКСПЕРИМЕНТТІК ВАЛИДАЦИЯ**

### **Андатпа**

Мақалада педагогикалық колледждердің цифрлық білім беру ортасы жағдайында болашақ педагогтердің экологиялық жауапкершілігін қалыптастыруға бағытталған педагогикалық модельдің әзірленуі және эмпирикалық валидациясы ұсынылады. Зерттеудің өзектілігі Қазақстандағы педагог кадрларды кәсіптік даярлау жүйесінің цифрландырылуы және тұрақты даму жағдайында декларативті экологиялық білім беруден өлшенетін мінез-құлықтық өзгерістерге көшу қажеттілігімен негізделеді. Мақаланың мақсаты-цифрлық білім беру ортасы жағдайында болашақ педагогтерде экологиялық жауапкершілікті қалыптастырудың педагогикалық моделін әзірлеу және эмпирикалық түрде валидациялау, сондай-ақ когнитивті, құндылық, мінез-құлық және цифрлық құзыреттіліктерді кешенді диагностикалау негізінде оның тиімділігін бағалау. Эмпирикалық зерттеу 2024–2025 оқу жылында Батыс Қазақстан облысының екі педагогикалық колледжі базасында жүргізіліп, 16–20 жас аралығындағы 165 студентті қамтыды. Экологиялық жауапкершіліктің төрт компонентін — когнитивтік хабардарлықты, құндылықтық бағдарды, мінез-құлықтық дайындықты және цифрлық экологиялық құзыреттілікті — бағалау мақсатында Eco-Teacher-Responsibility (ETR) диагностикалық құралы әзірленді. Нәтижелер құрылымдалған қалыптастырушы бағдарламаны жүзеге асырғаннан кейін статистикалық тұрғыдан мәнді өзгерістерді көрсетті ( $p < 0.001$ ; Cohen's  $d = 0.82$ ). Экологиялық жауапкершіліктің жоғары деңгейін көрсеткен студенттердің үлесі 15%-дан 44%-ға дейін артты, ал төмен деңгейдегілердің үлесі 49%-дан 11%-ға дейін азайды. Алынған нәтижелер цифрлық технологияларды, жобалық оқытуды және құндылыққа бағытталған педагогикалық қолдауды жүйелі түрде біріктіру болашақ педагогтердің тұрақты мінез-құлықтық өзгерістеріне ықпал ететінін дәлелдейді.

**Негізгі сөздер:** экологиялық жауапкершілік, тұрақты даму, цифрлық білім беру ортасы, педагогикалық колледж, педагогтарды даярлау, экологиялық құзыреттілік, эмпирикалық валидация.

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#### Information about authors:

Assel Karimovna Dzhumagazieva - **corresponding author**, 2nd year doctoral student of the educational program 8D01103, L.N. Gumilyov Eurasian National University, Satpayev street 2, 010008, Astana, Republic of Kazakhstan

ORCID: <https://orcid.org/0009-0008-4823-2499>

E-mail: [Dasel\\_84@mail.ru](mailto:Dasel_84@mail.ru)

Gaini Karekeevna Dlimbetova – Doctor of Pedagogical Sciences, Professor, of L. Gumilyov Eurasian National University, Satpayev street 2, 010008, Astana, Kazakhstan Astana, Republic of Kazakhstan

ORCID: <https://orcid.org/0000-0003-3578-8996>

E-mail: [gaidk25@gmail.com](mailto:gaidk25@gmail.com)

Flera Gabdulbarovna Mukhametzhanova - Doctor of Pedagogical Sciences, Professor of the Department of Historical and Social Studies of the Institute of International Relations, History and Oriental Studies, Kazan (Volga Region) Federal University, Kazan, Russia

ORCID: <https://orcid.org/0000-0001-9991-1549>

Email: [florans955@mail.ru](mailto:florans955@mail.ru)

#### Сведения об авторах:

Асель Джумагазиева – **основной автор**, докторант 2 курса образовательной программы 8D01103, Евразийский национальный университет им. Л.Н. Гумилева, ул. Сатпаева, 2, г. Астана, Республика Казахстан

E-mail: [Dasel\\_84@mail.ru](mailto:Dasel_84@mail.ru)

ORCID: <https://orcid.org/0009-0008-4823-2499>

Гайни Длимбетова – доктор педагогических наук, профессор, Евразийский национальный университет им. Л.Н. Гумилева, ул. Сатпаева, 2, г. Астана, Республика Казахстан

ORCID: <https://orcid.org/0000-0003-3578-8996>

E-mail: [gaidk25@gmail.com](mailto:gaidk25@gmail.com)

Флера Мухаметзянова – доктор педагогических наук, профессор кафедры исторических и обществознания Института международных отношений, истории и востоковедения Казанского (Приволжского) федерального университета, г. Казань, Россия

ORCID: <https://orcid.org/0000-0003-3578-8996>

E-mail: [gaidk25@gmail.com](mailto:gaidk25@gmail.com)

#### Авторлар туралы мәлімет:

Асель Джумагазиева – **негізгі автор**, 8D01103 білім беру бағдарламасының 2 курс докторанты, Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Сәтбаев көшесі, 2, Астана қ., Қазақстан Республикасы

ORCID: <https://orcid.org/0009-0008-4823-2499>

E-mail: [Dasel\\_84@mail.ru](mailto:Dasel_84@mail.ru)

Гайни Длимбетова – педагогика ғылымдарының докторы, профессор, Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Сәтбаев көшесі, 2, Астана қ., Қазақстан Республикасы

ORCID: <https://orcid.org/0000-0003-3578-8996>

E-mail: [gaidk25@gmail.com](mailto:gaidk25@gmail.com)

Флера Мухаметзянова – педагогика ғылымдарының докторы, Халықаралық қатынастар, тарих және шығыстану институтының тарих және әлеуметтік ғылымдар кафедрасының профессоры, Қазан (Еділ бойы) Федералдық университеті, Қазан қ., Ресей

ORCID: <https://orcid.org/0000-0003-3578-8996>

E-mail: [gaidk25@gmail.com](mailto:gaidk25@gmail.com)