

M.T.Rakhmetova^{1*}, B.T. Abykanova¹, M.B. Kairjan¹, A.A. Kuanysheva¹¹Kh. Dosmukhamedov Atyrau University,
Atyrau, Republic of Kazakhstan, Atyrau
*e-mail: maira_12_05@mail.ru**FROM ENVIRONMENTAL EDUCATION TO ECO-IDENTITY:
A MODEL FOR THE DEVELOPMENT OF ENVIRONMENTAL
COMPETENCIES IN PHYSICS STUDENTS****Abstract**

As global ecological challenges intensify, the need for comprehensive environmental education in higher education becomes critical, especially in scientific fields like physics. The purpose of the article is to develop and experimentally verify a model for the formation of eco-identity among physics students in the higher education system, as well as to evaluate its effectiveness in improving the level of environmental competence and the formation of sustainable values oriented towards the principles of sustainable development. This paper presents a model for developing ecological identity in physics students. A quasi-experimental study with 46 third-year physics students at Atyrau University (23 experimental, 23 control) was conducted to test the model. The experimental group's curriculum was enriched with the eco-identity development model, while the control group followed a traditional curriculum. Pre- and post-intervention assessments of environmental competence and ecological identity were carried out. Statistical analysis (ANOVA, t-tests) showed that the experimental group achieved significantly greater gains in environmental competence and stronger ecological self-identification than the control group. The results confirm the hypothesis that embedding a structured eco-identity model in physics education can foster deeper environmental awareness and personal identification with sustainability values. This study's findings have important implications for physics education and teacher training, demonstrating that cultivating eco-identity alongside scientific knowledge is key to preparing future educators and professionals for sustainable practice. The paper concludes with recommendations for integrating the model in broader educational contexts and suggestions for future research on sustaining eco-identity development.

Keywords: environmental education, ecological identity, environmental competence physics education, sustainable development.

Introduction

In recent decades, environmental education has gained increasing prominence in educational practice and policy worldwide. This rise is driven by the urgent need to address complex sustainability challenges through learning. Environmental education is broadly oriented toward achieving sustainable development goals, equipping students with the knowledge, skills, attitudes, and motivation for future-oriented sustainable behavior. As early as 1977, the Tbilisi Declaration defined environmental education as “a process aimed not only at disseminating knowledge, but also at fostering responsibility toward the environment” [1]. Thus, beyond imparting ecological knowledge, environmental education seeks to shape values and responsible attitudes in learners [2]. Approaches to environmental education vary widely: some emphasize immediate pro-environmental actions (e.g. teaching energy conservation and waste recycling) [3], while others focus on developing critical thinking and long-term shifts in mindset and values [4]. Programs centered on short-term behavior change (for instance, encouraging simple eco-friendly habits) can be effective [5]. Still, many educators argue that deeper transformation – cultivating an ecological worldview or identity – is necessary for lasting impact [6]. Indeed, many researchers now contend that fostering *ecological identity* should become a priority goal of environmental education, as it engenders a deeper, more internalized relationship with the environment [7]. Unlike approaches that focus exclusively on changing outward behavior or accumulating knowledge, nurturing ecological identity is about developing a person who is not only aware of environmental issues but also personally invested in the long-term well-being of the planet. Individuals with a strong ecological identity tend to view caring for the environment as integral to their self-concept, making their commitment to environmentally responsible practices more enduring.

Research confirms that environmental education can correlate with pro-environmental behavior, though the nature of this relationship is complex [8]. Paradoxically, despite growing environmental awareness in society, a significant gap often remains between awareness and action. People frequently opt for “easy” eco-friendly actions requiring minimal effort (such as recycling) while avoiding more inconvenient sacrifices (such as reducing private car use) [9]. This attitude–action gap is often attributed to competing values like convenience and social comfort, highlighting the need to cultivate a deeper environmental ethic or identity to overcome these barriers. *Ecological identity* refers to an individual’s perception of themselves in relation to nature – how connected they feel to the natural environment, and how this connection influences their values and behaviors [10]. The development of ecological identity is influenced by multiple factors including principles of deep ecology, environmental ethics, ecopsychology, and education; it evolves under cultural, social, and personal influences. Recent studies emphasize the importance of ecological identity among adults (such as environmental activists and professionals) [11], noting that its development often progresses through stages: first an awareness of environmental problems, then a belief in the possibility of positive change, and finally adoption of an active position in support of the environment. Integrating a connection to nature and personal environmental relevance into education is seen as key to promoting sustainable behavior. However, attitudes alone do not always translate into action, as contextual and psychological factors mediate behavior. Educational strategies aimed at changing environmental attitudes typically focus on four aspects: moral reasoning, raising awareness, incentives, and community influence. Of these, incentive-based approaches and leveraging social/community influence tend to be most effective in changing behavior, especially when combined with participatory, experiential learning [12]. Programs that integrate multiple approaches – for example, providing external incentives or feedback *and* engaging students in hands-on environmental activities – have been more successful in cultivating long-term pro-environmental behaviors [13]. Correspondingly, environmental education, as a field, has evolved from simply disseminating knowledge toward a holistic approach that supports the development of an ecological identity – wherein a person feels themselves to be part of nature – which is deemed crucial for long-term, responsible environmental behavior [14].

Despite these advancements in theory, there remain gaps in educational practice. In many settings, including our regional context, curricula still emphasize factual ecological knowledge or short-term activities while neglecting the deeper formation of environmental identity. In Kazakhstan, for instance, various initiatives have been launched to integrate sustainability into education – notably a national project to green the education system and orient it toward sustainable development and a “green” economy [15]. These efforts reflect a governmental and societal recognition of the importance of environmental education. However, significant challenges persist in fully implementing the principles of education for sustainable development (ESD). A major challenge is the limited awareness and understanding of ESD among educators, students, policymakers and the public, which hampers the integration of sustainability values into teaching practice [16]. This context underscores the need for more robust educational models that not only convey environmental knowledge but also actively engage and transform learners’ values and identities.

For physics students, developing an ecological identity is particularly pertinent. Physics as a discipline is closely connected to many technologies and processes – such as energy production, materials science, and industrial innovation – that have far-reaching environmental impacts [17]. Higher education institutions, as key pillars of society, play a unique role in shaping not only knowledge but also the personal development and values of future professionals. Future physicists and physics educators will be involved in areas (like power generation, engineering, and high-tech industries) where their decisions can significantly affect the environment. They must graduate with a sense of environmental responsibility ingrained in their professional identity. By fostering ecological identity among physics students, we prepare them to integrate sustainability considerations into their work – whether designing new technologies, conducting research, or teaching science in schools. Prior work suggests that strong environmental competence can

translate into the internalization of environmental values, effectively linking knowledge to identity formation. We build on this premise in the present study.

We hypothesize that implementing a structured model of eco-identity development within the physics curriculum will significantly improve students' environmental competence and foster a stronger ecological identity, compared to a traditional physics education approach without such a model. In essence, by deeply integrating environmental content and reflective practices into physics teaching, students will internalize ecological values, leading to measurable gains in both ecological knowledge and identity.

To test this hypothesis, our study is guided by the following research questions:

1. Does the proposed model of eco-identity development lead to a significant improvement in physics students' environmental competence (knowledge and skills related to ecology and sustainability) compared to a traditional curriculum?

2. Does participation in the model lead to a stronger development of ecological identity (as evidenced by students' self-perception, values, and commitments regarding the environment) compared to students who undergo traditional instruction?

3. How do the outcomes differ between students who experience the eco-identity development model and those in the control group? Specifically, what are the differences in pre- to post-intervention gains in environmental competence and ecological identity between the experimental and control groups?

Materials and methods of research

The study employed a quasi-experimental design with an experimental group and a control group to evaluate the effects of the eco-identity development model. Participants were 46 undergraduate students in their third year of the Physics Education program at Atyrau University. The sample was split evenly into two groups: 23 students in the experimental group and 23 in the control group. All participants had a similar academic background and had completed standard introductory coursework in physics and basic ecology, ensuring a comparable baseline of knowledge. None had received explicit instruction aimed at developing ecological identity before the study. The groups were taught in parallel during a single semester, with the experimental group receiving the enhanced curriculum intervention and the control group following the traditional curriculum. To minimize confounding variables, both groups were taught by the same instructor, a faculty member in physics, so that differences in teaching style were not a factor. The study was conducted over a 15-week semester, with the intervention integrated into the regular physics course schedule.

The core of this research is the development and implementation of an enhanced model for developing eco-identity in physics students. This model was adapted from a previously published framework on environmental competence and extended into a more advanced, structured form to explicitly foster ecological identity. The model is comprehensive, comprising several interrelated components and implementation strategies. In designing the model, we followed a three-stage process: (1) conceptual development of the model's structure and components, (2) determination of the implementation mechanism (i.e. how to integrate the model into teaching practice), and (3) creation of an evaluation system to gather feedback and assess student outcomes (competence and identity). The theoretical justification for the model draws on interdisciplinary research in environmental education and identity formation, allowing us to integrate key environmental principles and identity-development strategies into physics education.

Procedure

Before the intervention began, both groups (experimental and control) underwent a pre-test evaluation to establish baseline measures for the key outcomes. This pre-test included two parts: (1) an Environmental Competence Test, and (2) an Ecological Identity Survey. The environmental competence test was a written assessment (combining multiple-choice and short-answer questions) covering fundamental environmental science knowledge, environmental aspects of physics, and scenario-based problem-solving. The ecological identity survey was adapted from established environmental identity scales (such as Clayton's Environmental Identity scale [18]). The survey

produced an Eco-Identity Index for each student on a 0–50 scale. The internal consistency of the scale in the present sample was satisfactory (Cronbach's $\alpha = 0.84$), indicating acceptable reliability for research purposes.

Following the pre-test, the experimental group was taught using the proposed model, integrated throughout their physics courses for the semester. Meanwhile, the control group continued with a traditional physics curriculum. The control group's courses followed the standard syllabus, which did include some minimal coverage of environmental topics as per the national curriculum. Both groups covered the core physics content required by the program; the experimental group simply did so in a more enriched manner, whereas the control group did so in the usual manner. Importantly, the contact hours and overall workload were kept roughly equivalent between groups, so that the experimental group's gains could not be simply attributed to spending more time or effort than the control.

At the end of the semester (after approximately 15 weeks of instruction), we administered a post-test evaluation, which mirrored the pre-test. Students in both groups again took the Environmental Competence Test and the Ecological Identity Survey. This post-test allowed us to measure changes in scores from pre- to post-test in each group. We also collected the qualitative responses again by asking students to describe what environmental responsibility means to them after the course, to observe any shifts in perspective or language.

Data Analysis

The quantitative data were analyzed using both descriptive and inferential statistics. First, we computed descriptive statistics (means and standard deviations) for the environmental competence scores and ecological identity index in each group, before and after the intervention. We then assessed baseline equivalence: an independent samples *t*-test was used to verify that there was no significant difference between the experimental and control groups' pre-test scores on the competence test and identity index (confirming that any subsequent differences could be attributed to the intervention rather than pre-existing disparities). The main analysis involved comparing post-test outcomes. We performed an independent samples *t*-test on post-test competence scores between the experimental and control groups to assess whether the observed mean difference was statistically significant. Similarly, we compared the post-test ecological identity scores between the two groups using a *t*-test. To specifically address improvements within each group, we also conducted paired-sample *t*-tests for the experimental group (pre vs. post scores) and for the control group (pre vs. post) on both measures. This helped determine whether each group experienced a significant change over time and, if so, in which direction. Effect sizes (Cohen's *d*) were calculated for the key differences (experimental vs control post-test, and pre-to-post changes) to gauge the practical significance of the results. A significance level of $\alpha = 0.05$ was used for all statistical tests (with adjustments for multiple comparisons when appropriate, though in our case the comparisons were limited and focused). Additionally, we examined the relationship between environmental competence and ecological identity outcomes using Pearson's correlation coefficient. To test whether changes over time differed by group, we ran separate 2 (Time: pre-, post-test) \times 2 (Group: experimental, control) mixed-design ANOVAs for Environmental Competence and Ecological Identity. All analyses were carried out using IBM SPSS Statistics 26.

Results and their discussion

Model Description

The model is organized into four major components – *Motivational, Content, Procedural and Evaluative* – each contributing to the holistic development of students' environmental competence and identity (Figure 1).

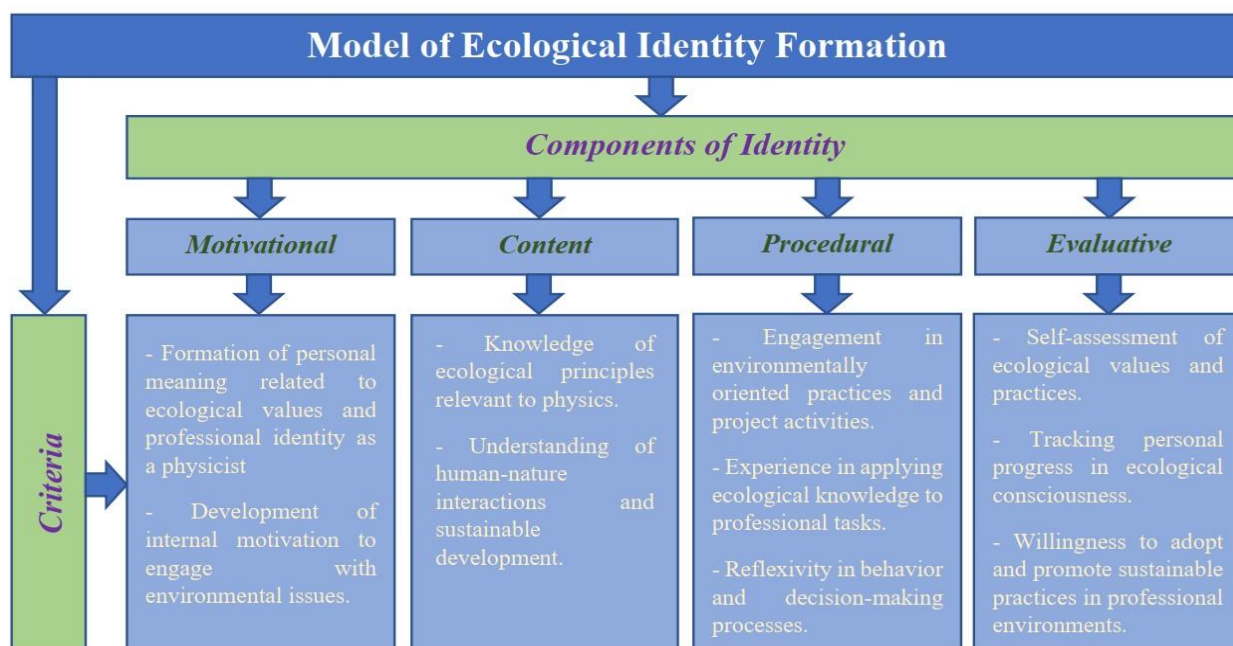


Figure 1- Model of Ecological Identity Formation

Note: Compiled by authors

The synergy of these four components creates a structured pathway for students: starting from motivation and goal-setting, through rich interdisciplinary content and active engagement, culminating in reflection and evaluation that ties it all together (Table 1). This framework was deliberately designed to guide students beyond acquiring facts, towards internalizing environmental values as part of their professional identity. The model also included an implementation mechanism that specifies the pedagogical conditions for success (e.g., a supportive classroom environment, institutional backing for field activities, etc.), and a feedback loop in which results from the evaluation component inform continuous improvement of the curriculum.

Table 1 – Components for the Model of Ecological Identity Formation

Component	Core Focus	Key Elements
Motivational-Target	<i>Values, aims, and learner motivation</i>	<ul style="list-style-type: none"> • Ecological relevance in physics and society; • Alignment with personal/professional goals; • Discussion of global/local challenges;
Content	<i>Interdisciplinary knowledge base</i>	<ul style="list-style-type: none"> • Infusion of environmental topics into Thermodynamics, Electromagnetism, Nuclear Physics, Mechanics, Optics; • Case studies (air/water pollution, energy-consumption statistics); • Targeted competencies: ecosystem literacy, tech-impact awareness, sustainable-tech know-how.
Procedural	<i>Pedagogical methods & learning activities</i>	<ul style="list-style-type: none"> • Problem-based tasks on real eco-problems; • Lab measurements (e.g., device energy efficiency, radiation background); • Field trips to renewable-energy sites; • Ethical debates (nuclear vs carbon); • Reflective diaries & group projects.
Evaluative (Control-Result)	<i>Assessment, feedback, reflection</i>	<ul style="list-style-type: none"> • Formative: quizzes, observation checklists, self-ratings; • Summative: Environmental Competence Scale, Ecological Identity Inventory; • Criteria: knowledge, awareness, self-regulation, collaboration, stewardship commitment.
Note: Compiled by authors		

At the outset of the course, students in the experimental group were introduced to the relevance of ecology in physics and society. We set clear objectives related to sustainability (e.g., understanding the environmental impact of physical processes and developing a sense of responsibility toward nature). Students engaged in discussions about global and local environmental challenges, which helped evoke their intrinsic motivation and sense of purpose. This motivational component is designed to shape values and attitudes – students reflect on why ecological issues matter to them as future physicists. By aligning educational goals with sustainability values, the motivational-target component lays the foundation for developing an eco-centric mindset in students.

We systematically infused interdisciplinary environmental knowledge into traditional topics in physics. For example, when teaching thermodynamics, we included content on energy efficiency, entropy in ecological systems, and climate change; in electromagnetism, we discussed electrical energy generation and its environmental footprint; in nuclear physics, we covered nuclear power and radiation ecology, etc. The content component ensures that students gain robust environmental knowledge and awareness in tandem with physics concepts. Key ecological competencies targeted include understanding ecosystems, recognizing the environmental implications of technological applications, knowledge of sustainable technologies, and grasping the physical principles underlying environmental processes. The content was enriched with case studies on environmental problems (such as air and water pollution data and energy consumption statistics) and on how physics-based innovations can mitigate or exacerbate these issues. By the end of the course, students in the experimental group were expected to demonstrate a deep understanding of fundamental ecological concepts and their relation to physics, thereby satisfying the criterion of ecological literacy within the physics context.

The model emphasizes active, student-centered pedagogical approaches that encourage application, analysis, and reflection. In the experimental group, we implemented a variety of interactive and experiential learning strategies: problem-based learning (solving real environmental problems using physics principles), laboratory experiments with environmental measurements (e.g. measuring energy efficiency of devices, monitoring environmental parameters like radiation or air quality), field projects (such as a field trip to a local ecological site or a renewable energy facility, followed by a project report), group discussions and debates on ethical scenarios (e.g. the trade-offs of nuclear energy vs. carbon emissions), and reflective journaling. Students were asked to maintain a reflection diary to regularly record their thoughts on how physics and environmental issues intersect, and how their own views and sense of responsibility might be evolving. Cooperative learning was encouraged through group projects addressing sustainability challenges, thereby also building teamwork skills for solving environmental problems.

Experimental Results

As expected, initial comparisons showed no significant differences between the experimental and control groups before the intervention. On the pre-test Environmental Competence assessment, the experimental group had a mean score of 59.26 (on a 0-100 scale; SD \approx 7.65), and the control group a mean of 57.10 (SD \approx 7.11). These scores are just below the minimum passing threshold of 60, indicating that, on average, both groups possessed only a basic level of environmental knowledge at the start (which is reasonable, as they had not yet undergone specialized training). A t-test confirmed that the difference in pre-test competence means was not statistically significant ($t < 1$, $p > 0.05$). Similarly, for the Ecological Identity Index, the experimental group's pre-test average was 24.42 (on a 0–50 scale; SD \approx 4.69) and the control group's was 24.81 (SD \approx 5.13), a negligible difference (statistically non-significant). These baseline results establish that the two groups were starting from a comparable point in terms of both environmental knowledge and identity orientation.

By the end of the semester, the experimental group showed markedly higher performance on both outcome measures compared to the control group. Table 2 presents the Environmental Competence Test scores (percentage scale: 0–100). It can be seen that the experimental group's

mean competence score increased substantially from pre to post, while the control group's score rose only modestly.

Table 2 – Environmental Competence Test* Scores

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	p
<i>Experimental (n = 23)</i>	59.26 ± 7.65	77.63 ± 7.45	< .001
<i>Control (n = 23)</i>	57.10 ± 7.11	61.31 ± 9.95	0.03

Note: Compiled by authors

As shown in Table 2, the experimental group's mean environmental competence score increased from 59.26 at pre-test to 77.63 at post-test, representing a gain of 18.37 points. In contrast, the control group improved from 57.10 to 61.31, a gain of 4.21 points. An independent-samples t-test on the post-test scores showed that the experimental group significantly outperformed the control group, $t(44) = 6.30$, $p < .001$, with a large effect size (Cohen's $d = 1.86$). Within-group analysis also indicated a substantial pre-post gain in the experimental group, whereas the control group showed only a modest improvement. These findings suggest that the enhanced model had a strong positive effect on students' environmental competence, likely due to the integration of interdisciplinary content, active learning, and practical application.

This suggests that merely following the standard curriculum led to a slight improvement (perhaps due to general learning or maturation), but the new model led to a much larger improvement. Every student in the experimental group scored above the passing level of 60 by the end (the lowest post-score in that group was 67). In contrast, in the control group most students remained near the minimum competence level. These results demonstrate that the enhanced model had a measurable positive impact on students' environmental competence. By integrating interdisciplinary content, active learning, and practical application, the model not only improved students' understanding of environmental principles, but also deepened their engagement with ecological problem-solving. The experimental group's higher performance suggests they gained a more robust and retained understanding of the material, consistent with the model's goals.

Table 3 presents the results for the Ecological Identity Index, derived from the survey of attitudes and self-perception regarding the environment. Again, clear differences are observed between the experimental and control groups after the intervention.

Table 3 – Ecological Identity* Scores

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	p
<i>Experimental (n = 23)</i>	24.42 ± 4.69	34.36 ± 4.94	< .001
<i>Control (n = 23)</i>	24.81 ± 5.13	27.73 ± 5.91	> 0.1

Note: Compiled by authors

Table 3 shows that the experimental group's ecological identity score increased from 24.42 at pre-test to 34.36 at post-test, whereas the control group showed a smaller increase from 24.81 to 27.73. An independent-samples t-test on the post-test identity scores indicated that the experimental group scored significantly higher than the control group, $t(44) = 4.13$, $p < .001$, with a large effect size (Cohen's $d = 1.22$). Within-group analyses further suggested that the increase in ecological identity was substantial in the experimental group, while the control group showed only a modest change. In practical terms, these results indicate that the model contributed not only to cognitive gains, but also to the internalization of ecological values and self-perceptions.

It is also illuminating to consider the relationship between gains in competence and identity. A moderate positive correlation was observed between post-test environmental competence and ecological identity ($r \approx .55$, $p < .01$), suggesting that students with stronger competence also tended to report stronger ecological identity. In other words, students who

learned more about environmental and sustainability concepts also tended to express a stronger environmental identity. The experimental group primarily drove this correlation – within that group, the correlation was even higher ($r \approx +0.65$), whereas in the control group it was weak ($r \approx +0.2$, not significant). This finding is consistent with the assumption that competence development and identity formation are interrelated. As students become more knowledgeable and skilled in addressing environmental issues, they also internalize environmental values more deeply. However, the weak correlation in the control group suggests that knowledge alone (as acquired in a traditional setting) is not always sufficient to shift identity – it was the combination of knowledge with the model’s pedagogical approach (interdisciplinary, applied, and reflective learning) that produced the strong competence–identity alignment observed in the experimental group.

To test whether changes over time differed by group, we ran separate 2 (Time: pre-, post-test) \times 2 (Group: experimental, control) mixed-design ANOVAs for Environmental Competence (Table 4) and Ecological Identity (Table 5).

Table 4 – Mixed ANOVA for Environmental Competence

Source	SS	df	MS	F	p
Time	2 158.5	1	2 158.5	150.30	< .001
Group	164.1	1	164.1	2.46	.123
Time \times Group	1 233.4	1	1 233.4	85.41	< .001
Error (Time)	632.0	44	14.36	-	-
Error (Between)	2 935.6	44	66.72	-	-

Note: Compiled by authors

A significant main effect of Time indicated that students improved overall from pre- to post-test, $F(1, 44) = 150.30$, $p < .001$, partial $\eta^2 = .77$. The Time \times Group interaction was also significant, $F(1, 44) = 85.41$, $p < .001$, partial $\eta^2 = .66$, showing that the experimental group’s gain ($\Delta = +18.37$ points) was substantially larger than the control group’s ($\Delta = +4.21$ points). No reliable main effect of Group emerged.

Table 5 – Mixed ANOVA for Ecological Identity

Source	SS	df	MS	F	p
Time	828.9	1	828.9	132.27	< .001
Group	22.1	1	22.1	3.53	.067
Time \times Group	628.5	1	628.5	100.31	< .001
Error (Time)	276.0	44	6.27	-	-
Error (Between)	274.9	44	6.25	-	-

Note: Compiled by authors

The same pattern held for identity formation. Scores rose across the sample, $F(1, 44) = 132.27$, $p < .001$, partial $\eta^2 = .75$, and the Time \times Group interaction was significant, $F(1, 44) = 100.31$, $p < .001$, partial $\eta^2 = .70$. The experimental group increased by 9.94 points compared with a 2.92-point gain in the control group. The main effect of Group did not reach significance.

Together, these analyses confirm that the intervention produced markedly greater improvements in both environmental competence and ecological identity than standard instruction, supporting the effectiveness of the proposed four-component model.

The data provided above and the statistical tests collectively answer our research questions affirmatively: Yes, the eco-identity development model significantly boosts environmental competence (RQ1) and strengthens ecological identity (RQ2) among physics students, and the outcomes for those with the model are significantly better than for those without (RQ3).

Our findings validate the hypothesis that integrating interdisciplinary content, active learning, and reflective practice into subject-specific education is a promising approach to

fostering sustainable thinking. The model's success is consistent with educational theories suggesting that meaningful learning, especially in the context of sustainability, occurs when students can connect knowledge to their own values and experiences. By moving beyond rote learning to engage students in *how* physics relates to real environmental challenges, the model encouraged a deeper form of learning. The significant gains in the experimental group's environmental competence indicate that students not only absorbed more information but also applied physics principles to environmental problems more adeptly than their peers in the control group. This can be attributed to the interdisciplinary and applied nature of the curriculum: it provided context and relevance, which are known to improve understanding and retention. The results mirror previous research that emphasizes the effectiveness of multi-faceted educational interventions [19]. For instance, programs that combine content knowledge with practical engagement and personal reflection tend to yield better outcomes in terms of behavior and attitude changes [20]. Our model combined all these elements, which likely created a synergistic effect. The interdisciplinary content gave breadth and relevance, active learning (projects, labs) built skills and personal experience, and reflective exercises helped internalize the lessons. Together, these ensured that knowledge translated into personal meaning, supporting the formation of ecological identity. This comprehensive approach reflects a shift noted in contemporary environmental education: moving from simply teaching about the environment to teaching *for* the environment – i.e., educating in ways that empower and motivate students to act for sustainability.

Despite the promising findings, the study has several limitations. First, the sample size was relatively small, which limits the generalizability of the results. Second, the intervention was implemented in a single university context; therefore, the findings should be interpreted with caution when applied to other institutional settings. Third, the quasi-experimental design did not involve random assignment of participants, which may have introduced uncontrolled group differences. Finally, ecological identity was assessed through self-report measures, which may be influenced by social desirability or response bias. Future studies should test the model with larger, more diverse samples and examine its long-term effects.

One of the most significant outcomes of this study is the measurable development of ecological identity in the experimental group. Achieving changes in identity is challenging, as identity is a deep-seated construct not easily shifted by a single course. The fact that we observed a significant increase in the ecological identity index over one semester suggests that the intervention touched students at a personal level. Students in the experimental group began to see environmental stewardship as part of their role and self-image as future physicists/educators. This outcome provides empirical support for the idea that educational environments can be intentionally designed to influence identity, not just knowledge. It reinforces arguments in the literature that identity formation should be an explicit goal of environmental education to achieve long-term commitment to sustainable behavior [21].

The context of physics education provides a unique angle on sustainability. Physics, being fundamental to understanding energy, matter, and technology, is at the heart of many environmental solutions and also problems. From renewable energy technologies to nuclear power, from climate modeling to pollution control, physics principles are integral to these fields. Therefore, forming a generation of physicists who are ecologically conscious can have a disproportionate positive impact. Our findings highlight that physics students, when educated about these connections, grasp their importance. The discussions and enthusiasm observed in the experimental group suggest that many physics students were eager to find purpose in their studies related to global challenges. This indicates an important source of student motivation of student motivation that educators can leverage – linking coursework to grand challenges can inspire students to excel and remain engaged. On the other hand, if such connections are not made, students might see physics as disconnected from society and lose interest or fail to consider the implications of their work. As our results warn, without an ingrained ecological identity, future physicists might focus solely on technical aspects and overlook the environmental consequences of their work. This could perpetuate unsustainable practices. Conversely, if sustainability values

become integral to their education, these future professionals can actively promote sustainable practices and transform potentially harmful processes into environmentally safe solutions.

Conclusion

In conclusion, this research has demonstrated the efficacy of an enhanced model for developing eco-identity among university physics students. The model – characterized by its structured framework of motivational, content, procedural, and evaluative components – significantly outperformed traditional teaching methods in both imparting environmental competence and in nurturing an ecological identity in students. The experimental group of students who experienced the model showed greater mastery of environmental knowledge (achieving higher test scores by the end of the course) and, crucially, developed a personal sense of responsibility and identification with environmental values, as evidenced by a higher ecological identity index. These outcomes were statistically significant and educationally meaningful, affirming our central hypothesis that a comprehensive, well-designed educational intervention can bridge the gap between learning about the environment and *caring* about it as part of one's identity.

The findings hold important implications for the future of physics education and for higher education's role in advancing sustainability. By integrating interdisciplinary environmental content and active learning strategies into the physics curriculum, we not only enhanced students' understanding of physics in context but also prepared them to be more conscientious scientists and citizens. This dual development of competence and identity is a hallmark of truly transformative education. The study contributes to the growing body of evidence that achieving sustainable development goals will require education systems to go beyond knowledge transmission and intentionally cultivate the values, attitudes, and identities necessary for students to engage with sustainability challenges. For universities in Kazakhstan and globally, adopting such models in science and engineering programs can produce graduates who are not only technically proficient but also ready to assume leadership roles in sustainability in their fields.

In summary, the enhanced model for developing eco-identity in physics students at Atyrau University proved to be a powerful educational innovation. It achieved a more holistic learning experience, producing students who are both knowledgeable and intrinsically motivated to apply their knowledge to environmental improvement. The future of sustainable development heavily relies on such educational transformations. This study offers a concrete step in that direction, illustrating how we can educate physicists (and, by extension, other professionals) to serve as competent stewards of the environment. By cultivating ecological identities in our students, we are investing in a future workforce that will carry the ethos of sustainability into whatever endeavors they pursue. Such educational transformations may make an important contribution to sustainability-oriented higher education.

REFERENCES

- 1 Tbilisi Declaration Intergovernmental Conference on Environmental Education, Tbilisi, USSR, 14-26 October 1977. Available at: <https://unesdoc.unesco.org/ark:/48223/pf0000032763> (accessed 07.03.2026).
- 2 Varela-Losada M., Vega-Marcote P., Pérez-Rodríguez U., Álvarez-Lires M. Going to action? A literature review on educational proposals in formal Environmental Education. Vol. 22, no. 3. 2016. P. 390–421.
- 3 Varela-Candamio L., Novo-Corti I., García-Álvarez M. T. The importance of environmental education in the determinants of green behavior: A meta-analysis approach. Journal of Cleaner Production. Vol. 170. 2018. P. 1565–1578.
- 4 Amin S., Utaya S., Bachri S., Sumarmi S., Susilo S. Effect of problem based learning on critical thinking skill and environmental attitude. Journal for the Education of Gifted Young Scientists. Vol. 8, no. 2. 2020. P. 743–755.
- 5 Ganatsios H. P., Vlastara M. K., Valeta C. A., Mpekiri S. D., Petaloudi L. M., Megaloniidou E. E. Consumer habits of forestry and natural environment students and university's environmental education on sustainability. Sustainability and Climate Change. Vol. 17. no. 1. 2024. P. 54–76.
- 6 Williams C. C., Chawla L. Environmental identity formation in nonformal environmental education programs. Environmental Education Research. Vol. 22, no. 7. 2016. P. 978–1001.
- 7 Heimlich J. E., Ardoin N. M. Understanding behavior to understand behavior change: A literature review. Environmental education research. №14 (3). 2008. P. 215-237.

- 8 Ardoin N. M., Bowers A. W., Roth N. W., Holthuis N. Environmental education and K-12 student outcomes: A review and analysis of research. *The Journal of Environmental Education*. Vol. 49, no. 1. 2018. P. 1–17.
- 9 Meyer A. Does education increase pro-environmental behavior? Evidence from Europe. *Ecological Economics*. Vol. 116. 2015. P. 108–121.
- 10 Udall A. M., De Groot J. I., De Jong S. B., Shankar A. How I see me—A meta-analysis investigating the association between identities and pro-environmental behaviour. *Frontiers in psychology*. 12. 2021. 582 p.
- 11 Martin A. R., Chen J. C., Barriers to sustainability in mature-age adult learners: working toward identity change. *Environmental Education Research*, vol. 22, no. 6, 2016. P. 849–867.
- 12 Bergman B. G., Assessing impacts of locally designed environmental education projects on students' environmental attitudes, awareness, and intention to act. *Environmental Education Research*. Vol. 22, no. 4. 2016. P. 480–503.
- 13 Nilsson A., Bergquist M., Schultz W. P. Spillover effects in environmental behaviors, across time and context: a review and research agenda. *Environmental Education Research*. Vol. 23, no. 4. 2017. P. 573–589.
- 14 O'Flaherty J., Liddy M. The impact of development education and education for sustainable development interventions: a synthesis of the research. *Environmental Education Research*. Vol. 24, no. 7, 2018. P. 1031–1049.
- 15 Seilkhan A., Aksoy A. Developing green university concepts innovations for environmental education in Kazakhstan. *Pedagogy and Psychology*. Vol. 55, no. 2. 2023. P. 63–70.
- 16 Kumar Y. A. Environmental awareness study in Kazakhstan: a critical literature review. *Kaznu Bulletin. Psychology and sociology series*. № 80(1). 2022. P. 112–127.
- 17 Imashev G., Abykanova B., Rakhmetova M., Tumysheva A., Moldasheva R., Ilyasova S., Shahimova A. Development of polytechnic knowledge and abilities in the course of studying physics. *International Journal of Environmental Science Education*. Vol. 11, no. 10. 2016. P. 3595–3606.
- 18 Clayton S., Czellar S., Nartova-Bochaver S., Skibins J. C., Salazar G., Tseng Y.C., Irkhin B., Monge-Rodriguez F. S. Cross-cultural validation of a revised environmental identity scale. *Sustainability*. Vol. 13, no. 4. 2021. 2387 p.
- 19 Semerjian L., El-Fadel M., Zurayk R., Nuwayhid I. Interdisciplinary approach to environmental education. *Journal of Professional Issues in Engineering Education and Practice*. Vol. 130, no. 3. P. 2004. P. 173–181.
- 20 Stern M. J., Powell R. B., Hill D. Environmental education program evaluation in the new millennium: What do we measure and what have we learned? *Environmental Education Research*. Vol. 20, no. 5. 2014. P. 581–611.
- 21 Payne P. Identity and environmental education. *Environmental Education Research*. Vol. 7, no. 1, 2001. P. 67–88.

ЭКОЛОГИЯЛЫҚ БІЛІМ БЕРУДЕН ЭКО-СӘЙКЕСТІККЕ ДЕЙІН: ФИЗИКА МАМАНДЫҒЫ СТУДЕНТТЕРІНІҢ ЭКОЛОГИЯЛЫҚ ҚҰЗЫРЕТТІЛІГІН ДАМУ МОДЕЛІ

Аңдатпа

Жаһандық экологиялық қиындықтардың артуы жағдайында жоғары білім беруде кешенді экологиялық оқыту, әсіресе физика сияқты жаратылыстану ғылымдары пәндерінде ерекше өзекті болып табылады. Мақаланың мақсаты - жоғары білім беру жүйесіндегі физика студенттерінің экожүйесін қалыптастыру моделін әзірлеу және эксперименттік тексеру, сондай-ақ оның экологиялық құзыреттілік деңгейін арттырудағы және тұрақты даму принциптеріне бағытталған тұрақты құндылық көзқарастарын қалыптастырудағы тиімділігін бағалау. Бұл мақалада физика студенттерінде экологиялық сәйкестікті дамыту моделі ұсынылған. Модельдің тиімділігін тексеру үшін Атырау университетінің физика мамандығы бойынша оқитын 46 үшінші курс студентінің (эксперименттік топта 23 және бақылау тобында 23) қатысуымен квазиэксперименттік зерттеу жүргізілді. Эксперименттік топта физиканы оқыту осы модельді енгізумен толықтырылды, ал бақылау тобы дәстүрлі оқу бағдарламасын пайдаланды. Экологиялық құзыреттілік және экологиялық сәйкестікті дамыту экспериментке дейін және кейін бағаланды. Статистикалық талдау (ANOVA, t-тест) бақылау тобымен салыстырғанда эксперименттік топта экологиялық құзыреттіліктің айтарлықтай артқанын және экологиялық сәйкестіктің айқынырақ дамығанын көрсетті. Нәтижелер физиканы оқытуға құрылымдалған экологиялық сәйкестікті дамыту моделін енгізу студенттердің экологиялық хабардарлығын тереңдетеді және олардың тұрақты даму құндылықтарына жеке берілгендігін нығайтады деген болжамды растайды. Мақала физиканы оқыту және мұғалімдерді даярлау үшін зерттеу нәтижелерінің салдарын талқылаумен аяқталады және модельді білім беру процесіне енгізу және экологиялық сәйкестікті дамытуды қолдау үшін болашақ зерттеулер үшін ұсыныстар берілген.

Негізгі сөздер: экологиялық білім беру, экологиялық сәйкестік, экологиялық құзыреттілік, физиканы оқыту, тұрақты даму.

ОТ ЭКОЛОГИЧЕСКОГО ОБРАЗОВАНИЯ К ЭКОИДЕНТИЧНОСТИ: МОДЕЛЬ РАЗВИТИЯ ЭКОЛОГИЧЕСКИХ КОМПЕТЕНЦИЙ У СТУДЕНТОВ- ФИЗИКОВ

Аннотация

В условиях обострения глобальных экологических проблем особенно актуальна комплексная экологическая подготовка в системе высшего образования, в частности в таких естественнонаучных дисциплинах, как физика. Цель статьи заключается в разработке и экспериментальной проверке модели формирования экоидентичности у студентов-физиков в системе высшего образования, а также в оценке ее эффективности в повышении уровня экологической компетентности и формировании устойчивых ценностных установок, ориентированных на принципы устойчивого развития. В данной статье представлена модель формирования экоидентичности у студентов-физиков. Для проверки эффективности модели было проведено квазиэкспериментальное исследование с участием 46 студентов 3-го курса специальности «Физика» Атырауского университета (23 в экспериментальной группе и 23 в контрольной). В экспериментальной группе обучение по физике дополнялось реализацией данной модели, тогда как в контрольной группе использовалась традиционная программа. Оценка уровня экологической компетентности и сформированности экоидентичности проводилась до и после эксперимента. Статистический анализ (ANOVA, t-критерий) показал, что в экспериментальной группе наблюдается значимое повышение показателей экологической компетентности и более выраженное становление экологической идентичности по сравнению с контрольной. Результаты подтверждают гипотезу о том, что внедрение структурированной модели развития экоидентичности в преподавание физики способствует углублению экологической осведомленности студентов и формированию у них личностной приверженности ценностям устойчивого развития. В завершение статьи обсуждаются значения полученных результатов для преподавания физики и подготовки будущих учителей, а также даются рекомендации по внедрению модели в образовательный процесс и последующим исследованиям по поддержанию развития экоидентичности.

Ключевые слова: экологическое образование, экологическая идентичность, экологическая компетентность, обучение физике, устойчивое развитие.

REFERENCES

- 1 Tbilisi Declaration Intergovernmental Conference on Environmental Education, Tbilisi, USSR, 14-26 October 1977. Available at: <https://unesdoc.unesco.org/ark:/48223/pf0000032763> [in English] (accessed 07.03.2026).
- 2 Varela-Losada M., Vega-Marcote P., Pérez-Rodríguez U., Álvarez-Lires M. Going to action? A literature review on educational proposals in formal Environmental Education. vol. 22, no. 3. 2016. P. 390–421. [in English]
- 3 Varela-Candamio L., Novo-Corti I., García-Álvarez M. T. The importance of environmental education in the determinants of green behavior: A meta-analysis approach. Journal of Cleaner Production. Vol. 170. 2018. P. 1565–1578. [in English]
- 4 Amin S., Utaya S., Bachri S., Sumarmi S., Susilo S. Effect of problem based learning on critical thinking skill and environmental attitude. Journal for the Education of Gifted Young Scientists. Vol. 8, no. 2. 2020. P. 743–755. [in English]
- 5 Ganatsios H. P., Vlastara M. K., Valeta C. A., Mpekiri S. D., Petaloudi L. M., Megalonidou E. E. Consumer habits of forestry and natural environment students and university's environmental education on sustainability. Sustainability and Climate Change, vol. 17, no. 1. 2024. P. 54–76. [in English]
- 6 Williams C. C., Chawla L. Environmental identity formation in nonformal environmental education programs. Environmental Education Research. Vol. 22, no. 7. 2016. P. 978–1001. [in English]
- 7 Heimlich J. E., Ardoin N. M. Understanding behavior to understand behavior change: A literature review. Environmental education research. № 14(3). 2008. P. 215-237. [in English]
- 8 Ardoin N. M., Bowers A. W., Roth N. W., Holthuis N. Environmental education and K-12 student outcomes: A review and analysis of research. The Journal of Environmental Education. Vol. 49, no. 1. 2018. P. 1–17. [in English]
- 9 Meyer A. Does education increase pro-environmental behavior? Evidence from Europe. *Ecological Economics*. Vol. 116. 2015. P. 108–121. [in English]
- 10 Udall A. M., De Groot J. I., De Jong S. B., Shankar A. How I see me—A meta-analysis investigating the association between identities and pro-environmental behaviour. *Frontiers in psychology*, 12. 2021. 582 p. [in English]
- 11 Martin A. R., Chen J. C., Barriers to sustainability in mature-age adult learners: working toward identity change. Environmental Education Research. Vol. 22, no. 6. 2016. P. 849–867. [in English]
- 12 Bergman B. G. Assessing impacts of locally designed environmental education projects on students' environmental attitudes, awareness, and intention to act. *Environmental Education Research*. Vol. 22, no. 4. 2016. P. 480–503. [in English]
- 13 Nilsson A., Bergquist M., Schultz W. P. Spillover effects in environmental behaviors, across time and context: a review and research agenda. Environmental Education Research. Vol. 23, no. 4. 2017. P. 573–589. [in English]

- 14 O’Flaherty J., Liddy M. The impact of development education and education for sustainable development interventions: a synthesis of the research. *Environmental Education Research*, vol. 24, no. 7. 2018. P.1031–1049.[in English]
- 15 Seilkhan A., Aksoy A. Developing green university concepts innovations for environmental education in Kazakhstan. *Pedagogy and Psychology*. Vol. 55, no. 2 . 2023. P. 63–70. [in English]
- 16 Kumar Y. A. Environmental awareness study in Kazakhstan: a critical literature review. *Kaznu Bulletin. Psychology and sociology series*. № 80(1). 2022. P.112–127.[in English]
- 17 Imashev G., Abykanova B., Rakhmetova M., Tumysheva A., Moldasheva R., Ilyasova S., Shahimova A. Development of polytechnic knowledge and abilities in the course of studying physics. *International Journal of Environmental Science Education*. Vol. 11, no. 10. 2016. P. 3595–3606. [in English]
- 18 Clayton S., Czellar S., Nartova-Bochaver S., Skibins J. C., Salazar G., Tseng Y.C., Irkhin B.,Monge-Rodriguez F. S. Cross-cultural validation of a revised environmental identity scale. *Sustainability*.Vol. 13, no. 4. 2021. 2387 p. [in English]
- 19 Semerjian L., El-Fadel M., Zurayk R., Nuwayhid I. Interdisciplinary approach to environmental education. *Journal of Professional Issues in Engineering Education and Practice*. Vol. 130, no. 3. 2004. P. 173–181. [in English]
- 20 Stern M. J., Powell R. B., Hill D. Environmental education program evaluation in the new millennium: What do we measure and what have we learned? *Environmental Education Research*. Vol. 20, no. 5. 2014. P. 581–611.[in English]
- 21 Payne P. Identity and environmental education. *Environmental Education Research*. Vol. 7, no. 1. 2001. P. 67–88.[in English]

Information about authors:

Mairagul Rakhmetova – **corresponding author**, master, Department of «Physics and technical disciplines», Kh.Dosmukhamedov Atyrau University, Atyrau, Republic of Kazakhstan

E-mail: maira_12_05@mail.ru

ORCID: <https://orcid.org/0000-0003-4529-0999>

Bakytgul Abykanova – candidate of pedagogical sciences, professor, Department of «Physics and technical disciplines», Kh.Dosmukhamedov Atyrau University, Atyrau, Republic of Kazakhstan

E-mail: bakitgul@list.ru

ORCID: <https://orcid.org/0000-0003-0095-3533>

Manas Kairjan - master, senior lecturer, Department of «Physics and technical disciplines», Kh.Dosmukhamedov Atyrau University, Atyrau, Republic of Kazakhstan

E-mail: ketebaev19@mail.ru

ORCID: <https://orcid.org/0009-0008-0221-0286>

Kuanysheva Assel Aitkalikyzy - 1st year master's student at Kh.Dosmukhamedov Atyrau University, Atyrau, Republic of Kazakhstan

E-mail: Akuanysheva@apec.edu.kz

ORCID: <https://orcid.org/0009-0005-1032-1961>

Информация об авторах:

Майрагуль Рахметова – **основной автор**, магистр кафедры «Физика и технические дисциплины» Атырауского университета имени Х.Досмухамедова, г. Атырау, Республика Казахстан

E-mail: maira_12_05@mail.ru

ORCID: <https://orcid.org/0000-0003-4529-0999>

Бакытгуль Абыканова – кандидат педагогических наук, профессор кафедры «Физика и технические дисциплины» Атырауского университета имени Х.Досмухамедова, г. Атырау, Республика Казахстан

E-mail: bakitgul@list.ru

ORCID: <https://orcid.org/0000-0003-0095-3533>

Манас Кайыржан - магистр, преподаватель кафедры «Физика и технические дисциплины» Атырауского университета имени Х.Досмухамедова, г. Атырау, Республика Казахстан

E-mail: ketebaev19@mail.ru

ORCID: <https://orcid.org/0009-0008-0221-0286>

Куанышева Асель Айткалиевна - магистрант 1- курса Атырауского университета имени Х.Досмухамедова, г. Атырау, Республика Казахстан

E-mail: Akuanysheva@apec.edu.kz

ORCID: <https://orcid.org/0009-0005-1032-1961>

Авторлар туралы ақпарат:

Майрагуль Рахметова – **негізгі автор**, магистр, аға оқытушы, «Физика және техникалық пәндер» кафедрасы, Х.Досмухамедова атындағы Атырау университеті, Атырау қ., Қазақстан Республикасы

E-mail: maira_12_05@mail.ru

ORCID: <https://orcid.org/0000-0003-4529-0999>

Бакытгуль Абыканова – педагогика ғылымдарының кандидаты, «Физика және техникалық пәндер» кафедрасының профессоры, Х.Досмұхамедова атындағы Атырау университеті, Атырау қ., Қазақстан Республикасы

E-mail: bakitgul@list.ru

ORCID: <https://orcid.org/0000-0003-0095-3533>

Манас Қайыржан - магистр, оқытушы, «Физика және техникалық пәндер» кафедрасы, Х.Досмұхамедова атындағы Атырау университеті, Атырау қ., Қазақстан Республикасы

E-mail: ketebaev19@mail.ru

ORCID: <https://orcid.org/0009-0008-0221-0286>

Қуанышева Әсел Айтқалиқызы - Х. Досмұхамедов атындағы Атырау университеті, 1-курс магистранты, Атырау қ., Қазақстан Республикасы

E-mail: Akuanysheva@apec.edu.kz

ORCID: <https://orcid.org/0009-0005-1032-1961>