Ecological-pedagogical competency formation in the training of biology teachers at Kazakhstani universities

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ABSTRACT: In an era of ecological disasters and increasing anthropogenic pressure on natural ecosystems, the task of forming not only professional but also ecological-pedagogical competencies among future biology teachers becomes especially relevant. In this article, the authors analyse methods and approaches for integrating ecological-pedagogical competencies into the educational process for students enrolled in biology teacher training programmes at Kazakhstani universities. Modern education requires biology teachers to possess not only in-depth knowledge in biology and ecology, but also the ability to apply this knowledge to cultivate ecological awareness among students. The study employs both qualitative and quantitative analysis methods, including surveys, interviews with faculty and students, and a review of the curricula of leading universities in Kazakhstan.. The research findings indicate that incorporating ecological-pedagogical components into biology teacher training programmes enhances ecological awareness levels and prepares future teachers to foster ecological culture among school students.

INTRODUCTION

In the context of globalisation and the intensifying environmental issues of the modern world, the task of cultivating not only professional knowledge but also ecological-pedagogical competencies among students - future biology teachers - has become especially urgent [1]. According to the research of Shapran, universities play a key role in developing ecological competency in students [2]. He argues that universities create conditions that foster the formation of a sustainable ecological mind-set, an awareness of one's responsibility for environmental issues, and an understanding of the impact on the environment in professional, social and daily life [2]. Ecological and pedagogical competencies imply the ability to carry out the educational process in such a way that it contributes to the formation of students' holistic perception of nature, understanding the need for its conservation and rational use of natural resources [3].

The significance of this task is driven by a number of factors, including the worsening environmental conditions globally, the reduction of biodiversity, climate change, and other global challenges that demand immediate and effective responses from the educational system. In this context, as Ponomarenko notes, the training of biology teachers with a high level of ecological-pedagogical competency is not only relevant but also a strategically important task [4]. According to Khrolenko, the development of ecological competency among university students is a continuous process of their active engagement in environmental conservation activities, which includes acquiring practical experience in preserving and improving the environment, as well as cultivating ecologically significant personal qualities, such as empathy, compassion and environmental awareness [5].

The challenge of integrating ecological-pedagogical competencies into the training process for students in the biology teacher training specialty encompasses multiple aspects, from curriculum design and teaching methodologies to the practical application of acquired knowledge and skills in educational practice. Approaches to addressing this issue should be comprehensive and include changes in both the content of education and the methods of its delivery. In the view of the authors of this article, one of the key competencies is the development of ecological literacy, which enables future teachers to effectively teach ecological principles and foster a responsible attitude toward the environment among schoolchildren. It is also essential to apply theoretical knowledge in practice, helping students gain a deeper understanding of ecological processes and equipping them to solve real-world environmental problems. This can be achieved through methods, such as practical exercises, projects and case studies.

The competency of integrating ecological aspects into pedagogical activities empowers teachers to incorporate ecological topics into school curricula, thereby illustrating the interconnection between humans and nature, and emphasising the importance of sustainable resource use. Additionally, research and analytical competencies play a critical role, allowing students to participate in scientific research, which develops their skills in environmental monitoring and analysis.

Finally, digital technology skills enable the use of modern tools to expand the possibilities of ecological education and self-learning, which is increasingly essential in the face of global environmental challenges. Collectively, these competencies contribute to the formation of highly qualified teachers who can impart profound ecological knowledge to students and foster a responsible attitude toward nature.

Recent studies indicate that the effectiveness of the educational process significantly depends on the level of teacher preparation, their ability to integrate ecological knowledge into the general educational context, and their capacity to develop necessary competencies among students [6-9]. Therefore, this article focuses on analysing existing methods and approaches to training biology teachers, with an emphasis on developing their ecological-pedagogical competencies, drawing upon the research of several scholars in this field of knowledge [10-12].

To achieve these objectives, the authors of this article used data collected from analyses of curricula at leading universities, surveys and interviews with faculty and students, as well as a review of scientific literature on this topic. Thus, the article presents a comprehensive study aimed at identifying and analysing key aspects of ecological-pedagogical competency formation in the training of biology teachers.

METHODS

As part of the study, a comprehensive analysis was conducted on the current curricula of leading higher education institutions in Kazakhstan, specifically *Korkyt Ata* Kyzylorda University and Bolashak Kyzylorda University, which offer educational programmes in the field of biology teacher training. A targeted sample was used for the survey. The research included a survey of two groups of students enrolled in the biology teacher training programme. The first group consisted of students in the junior years (1st-2nd year), while the second group included students in the senior years (3rd-4th year). A total of 80 students participated in the survey, with 40 respondents in each group. The selection ensured an equal distribution of respondents across groups: 40 junior students and 40 senior students.

This division allowed for a comparison of the level of ecological-pedagogical competencies and awareness among students at different stages of their studies, as well as an assessment of the development dynamics of these competencies throughout their university education based on the biology programme at *Korkyt Ata* Kyzylorda University and Bolashak Kyzylorda University.

The study focused on the core courses of the biology educational programme, encompassing general biology subjects, such as General Biology, Ecology, and Methods of Teaching Biology, as well as specialised subjects aimed at developing ecological and pedagogical competencies, such as Biodiversity, Field Study Methods, and Pedagogy.

Data collection was conducted during the 2021-2022 academic year using a survey method with standardised questionnaires provided to students. The survey was carried out in person at the universities, ensuring high data reliability and completeness.

The analytical process involved both qualitative and quantitative research methods. Qualitative analysis included a thematic review of the curricula texts and interviews, aimed at identifying key concepts, teaching approaches and methods for developing ecological-pedagogical competencies. For quantitative analysis, statistical methods were used to process survey data, focusing on students' satisfaction with the quality and content of their education and assessing their level of ecological awareness.

Curriculum Analysis

To evaluate the content aspects of the curricula, the authors selected leading universities in Kazakhstan that implement biology teacher training programmes. The analysis was conducted based on several criteria: the presence and volume of ecological subjects in the curriculum, integration of ecological topics into general biology courses, use of interdisciplinary approaches and project-based activities to develop ecological-pedagogical competencies. Additionally, they considered the availability of specialised courses and seminars aimed at teaching ecology and promoting ecological awareness among school students.

Surveys and Interviews

The surveys and interviews with faculty and students aimed to investigate their perceptions of the effectiveness of current training programmes and to gather suggestions for improving the learning process. Specialised questionnaires were developed, including questions on satisfaction with the content and teaching methods, as well as suggestions for incorporating new approaches and technologies into the curriculum. Deeper understanding of participants' beliefs and expectations about biology teacher preparation in an ecological setting was made possible by the interviews.

For students' convenience, surveys were conducted on-line using the Google Forms platform. In contrast, interviews were held in person, allowing for a more in-depth exploration of the opinions and expectations of participants in the educational process. The respondents for both the surveys and interviews were students from *Korkyt Ata* Kyzylorda University and Bolashak Kyzylorda University, specialising in biology teacher training. A random sampling method

was applied to select students from the 1st to 4th years for the surveys. For the interviews, students were chosen based on their academic experience, including those actively involved in ecological projects and those without such experience. Additionally, faculty members overseeing ecological aspects in the training of biology teachers were invited to participate in the interviews.

The survey questionnaire incorporated the following core questions:

1. Self-assessment of knowledge in ecology and biology: *How do you assess your current knowledge in ecology and biology?* The answers were supposed to be on a five-point scale from *very low* to *very high*.

2. Perception of the integration of environmental education into the educational process: *In your opinion, is there enough attention paid to environmental education in the curriculum?* The answer options included: *yes, probably yes, probably no, no,* and *undecided*.

3. Assessment of teaching methods: *Which methods of teaching ecology and biology do you consider the most effective?* Respondents could choose several options from the suggested ones: lectures, seminars, practical classes, project work, field research, on-line courses.

4. Participation in ecological activities: *Have you participated in ecological projects or research as part of the educational process?* Possible answers: *yes, no* and *plan to in the future*.

5. Suggestions for improving training: *What aspects or elements should be added or modified in the biology teacher training programme to strengthen environmental and pedagogical competency?* This question suggested an open answer where students could express their opinions and suggestions.

This structure of the questionnaire allowed to get a comprehensive understanding of the current state and needs of students in the field of environmental and pedagogical education. The analysis of the answers to the questions made it possible to identify both the strengths of the existing training system and aspects that needed to be amended and improved. Special attention was paid to students' suggestions for improving the educational process, which allowed to form a number of recommendations for the introduction of innovative methods and approaches into the educational programme.

The surveys and interviews were conducted from October to December to engage students during the peak of the academic term. During the interviews, respondents shared several significant observations, such as: *I believe the curriculum lacks practical outdoor activities to study ecology beyond textbooks. Integrating modern technologies, such as ecological process simulators, could make learning more engaging and illustrative. I would like to see more project-based work focused on solving real ecological problems in the region.*

RESULTS

The study's findings, which are based on a survey of junior and senior students enrolled in the training of biology teachers' specialisation, highlight crucial aspects of the development of pedagogical and ecological competency. The analysis of the respondents' answers provided insights into the progression of essential knowledge and skills, while also highlighting the main challenges and needs in environmental education for students.

Analysis of Self-Assessment in Ecology and Biology Knowledge

Junior-year students typically rated their knowledge in ecology and biology as average or below average. This indicates the need to strengthen the focus on ecological education at the initial stages of training, which may enhance material retention and foster a lasting interest in the subject. In contrast, senior-year students demonstrated a significantly higher level of knowledge, reflecting a positive learning trend and the effectiveness of acquiring specialised knowledge over the course of their studies [5].

The results of self-assessment of knowledge in ecology and biology by students involved in the current research is demonstrated in Table 1 and Figure 1.

Table 1: Self-assessment of knowledge in ecology and biology.

Group	Very low	Low	Average	High	Very high
1st-2nd year	5%	15%	40%	30%	10%
3rd-4th year	2%	8%	25%	40%	25%

According to Table 1 and Figure 1, data analysis reveals a significant improvement in self-assessed knowledge as students advance from junior to senior years, indicating the effectiveness of training within the chosen specialisation.

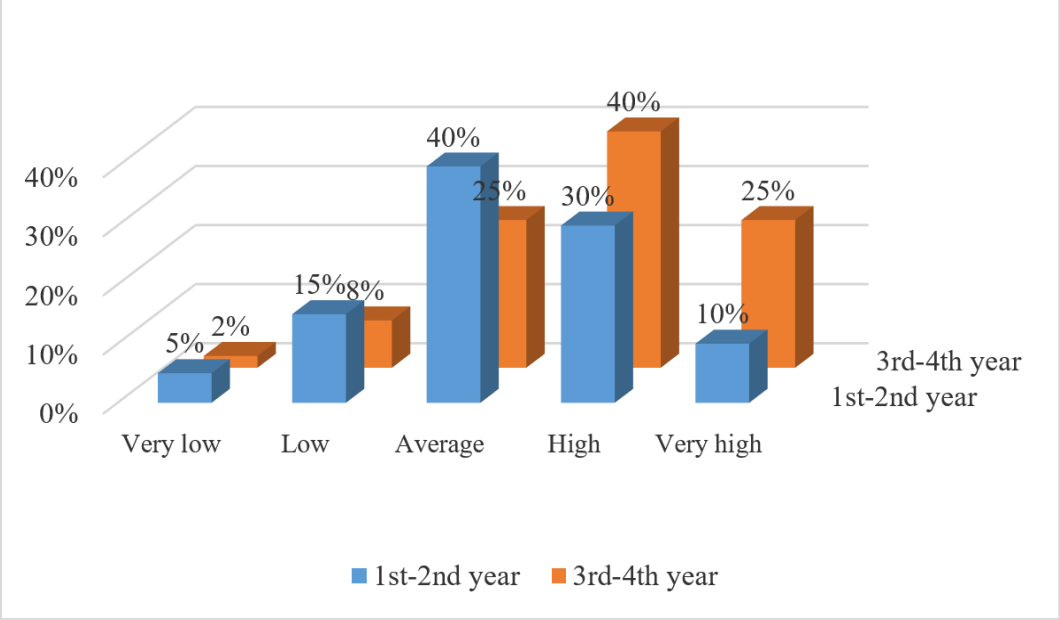

Figure 1: Self-assessment of knowledge in ecology and biology.

Most students from both groups highlight an insufficient focus on ecological education within their curricula. This is especially true for the practical and applied aspects of ecology, which students consider critically important for their future professional activities as shown in Table 2 and Figure 2. There is a noted need for deeper integration of ecological subjects into the general educational process, including the development and implementation of interdisciplinary projects and research [3].

Table 2: Perception of ecological education integration into the curriculum.

Group	Yes	Probably yes	Probably no	No	Undecided
1st-2nd year	10%	30%	40%	15%	5%
3rd-4th year	25%	35%	30%	5%	5%

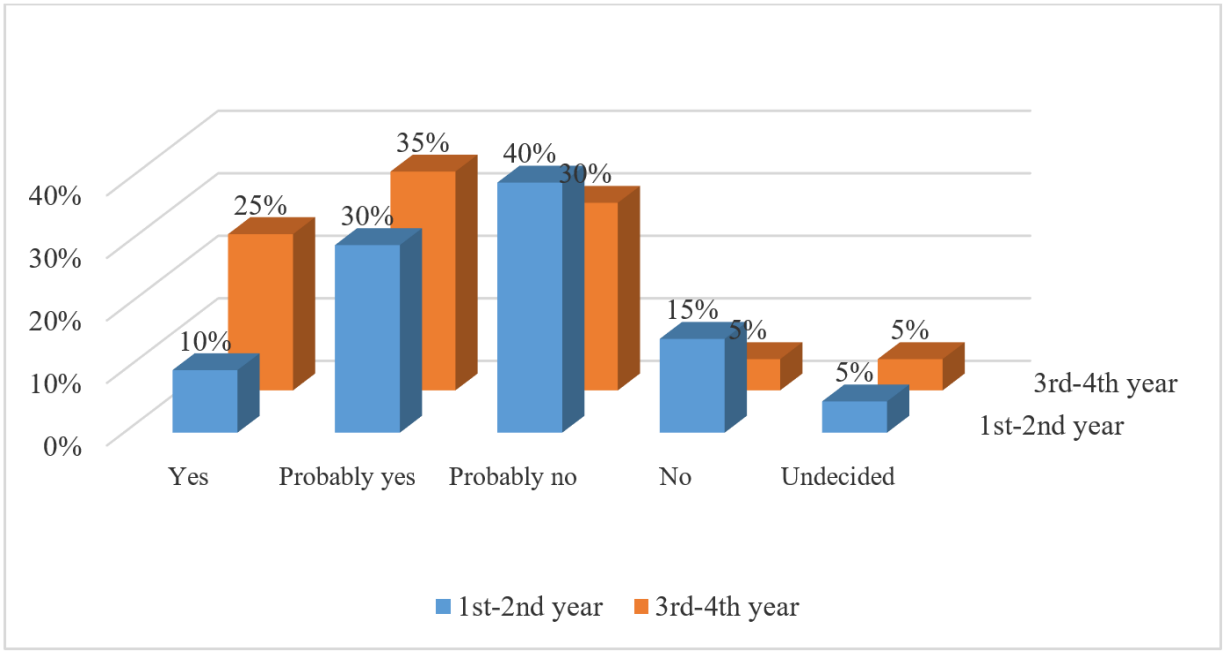

Figure 2: Perception of ecological education integration.

The above results clearly indicate a substantial need to improve the integration of ecological education into the curriculum (Table 2), particularly in the early stages of training, as a large proportion of 1st-2nd-year students and a significant share of 3rd-4th-year students express concerns about the insufficient focus on ecological education. This underscores the necessity to revise curricula to enable a more comprehensive integration of ecological disciplines.

An analysis of student preferences regarding teaching methods revealed a strong interest in active and interactive learning forms as demonstrated in Table 3. Practical sessions, project work and field research were identified as the most effective and motivating methods. These forms of education not only facilitate a deeper understanding of ecological knowledge but also develop critical thinking skills and the ability to apply theoretical knowledge in practice [13].

It is noteworthy that interest in active and interactive learning methods, such as practical sessions and seminars, is higher among senior-year students. This may suggest an increased motivation for in-depth study of ecology as students gain more experience in their educational journey.

Table 3: Teaching methods evaluation.

Method	1st-2nd year (preference)	3rd-4th year (preference)
Lectures	20%	15%
Seminars	25%	30%
Practical sessions	35%	40%
Project work	15%	10%
Field research	5%	5%
On-line courses	0%	0%

Participation in ecological activities is an important aspect of developing ecological-pedagogical competency (Table 4 and Figure 3). The data show an increase in student engagement in this area as they advance to senior years, which may be related to their growing competencies and understanding of the importance of practical application of knowledge in real-world ecological activities.

Table 4: Participation in ecological activities.

Group	Yes	No	Plan to in the future
1st-2nd year	20%	60%	20%
3rd-4th year	45%	40%	15%

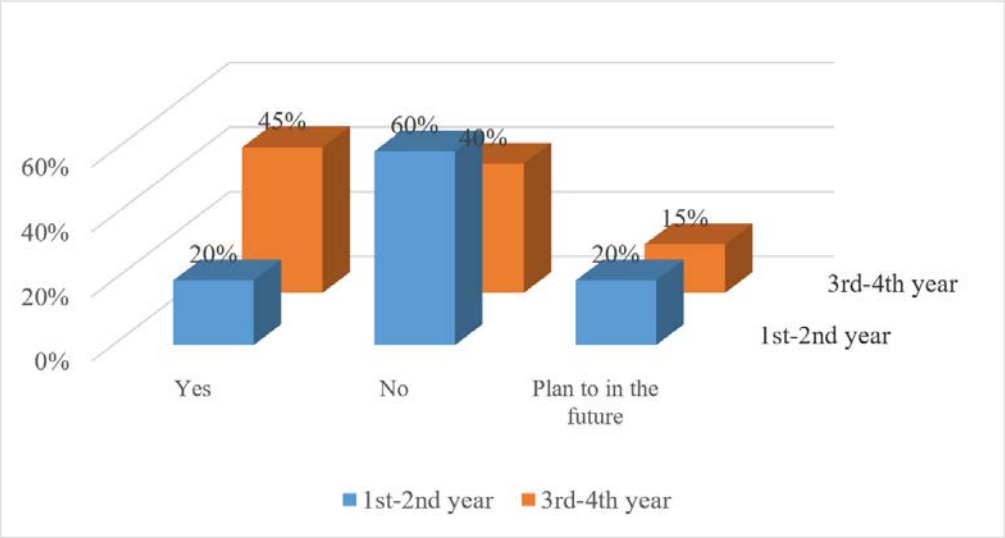

Figure 3: Participation in ecological activities.

The study results underscore the importance of focusing on practice-oriented education and the need for deeper integration of ecological knowledge and skills in biology teacher training, starting from the initial stages of education and continuing throughout the entire learning process.

Suggestions for Improving Training

The analysis of the survey data revealed that students from both groups actively support the idea of modernising the curriculum to enhance the effectiveness of ecological-pedagogical training. Among the suggestions from junior-year students, there was a strong emphasis on increasing the practical components of the education process. Students proposed increasing the number of field sessions and excursions, which would not only allow for a more visual study of ecological processes and phenomena but also help students develop observation and analytical skills in a natural

environment (Table 5). In the context of these proposals, emphasising the integration of theoretical knowledge with practical skills is essential, since this forms a comprehensive vision of environmental educational activities for future biology teachers.

Table 5: Increasing the frequency of practical sessions.

Criterion	Description	Expected results	Examples of techniques	Quantitative indicators
Goal	Improving students' hands-on learning experience	Enhancement of the ability to apply theoretical knowledge in practical contexts	Fieldwork, laboratory research	A 30% expansion in the number of field sessions
Expected effect	Comprehensive understanding of ecological processes	Development of observation and analytical skills	Performing experiments and conducting observations in the natural environment	A 25% increase in the successful completion rate of ecological projects

The objective of expanding practical sessions is to provide students with hands-on experience and a deeper understanding of ecological processes. Activities such as fieldwork and laboratory research play a critical role in bridging theoretical knowledge with real-world applications. This is particularly significant in ecology, where the ability to observe and analyse real conditions is essential.

The projected 30% increase in field sessions is expected to enhance comprehension of course material and boost student motivation. Engaging in experiments and observations in natural settings not only strengthens practical skills but also promotes analytical thinking and the development of independent scientific inquiry.

Senior-year students, in turn, highlighted the need to incorporate specialised courses in the curriculum that focus on teaching methods for ecology and biology, as well as the development and implementation of ecological educational projects (Table 6). Special attention was given to cultivating critical thinking and independent research skills, which, according to students, would promote high ecological literacy levels among school students. These suggestions reflect students' understanding of the importance of active learning methods and the need to prepare biology teachers as both researchers and educational organisers who can inspire interest and foster a responsible attitude toward the environment among students.

Table 6: Inclusion of specialised courses.

Criterion	Description	Expected results	Examples of techniques	Quantitative indicators
Goal	Introduction of courses focused on methods for teaching ecology	Training of specialists who are able to effectively teach and involve students in environmental education	Development and implementation of educational projects	Incorporation of a minimum of two new specialised courses into the curriculum.
Expected effect	Enhancement of the standards of ecological education	Formation of students' competencies necessary for the implementation of modern environmental educational programmes	Workshops from practicing ecologists	Improving the level of environmental literacy of students by 20%

It is noteworthy that both groups of students suggested expanding the use of information and communication technologies (ICT) in the learning process (Table 7).

Table 7: Broadening the integration of ICT in education.

Criterion	Description	Expected results	Examples of techniques	Quantitative indicators
Goal	Integration of modern educational technologies	Ensuring accessibility and interactivity of learning, development of digital competencies	Virtual laboratories, on-line courses	Introduction of five new on-line modules within the curriculum
Expected effect	Improved quality and accessibility of education	Stimulating self-study and research, increasing motivation to learn	Use of educational platforms and apps	Anticipated 40% growth in student involvement in on-line projects

The inclusion of modern educational platforms, on-line courses and virtual laboratories into the curriculum can significantly enrich the methodological toolkit of future teachers, enhancing the interactivity and accessibility of ecological education [14]. This underscores students' desire for innovation in educational practice and their willingness to use the latest technologies to achieve better results in their professional careers.

The expanded use of information and communication technology in education aims to enhance accessibility and interactivity in the learning process. The curriculum will include five new on-line modules featuring virtual laboratories and on-line courses to complement traditional teaching methods (Table 7). This initiative is projected to increase student involvement in on-line projects by 40%, fostering greater motivation to study ecology while strengthening digital competencies. By leveraging ICT, students gain deeper insights into ecological topics through access to diverse resources and learning materials, while promoting collaboration and knowledge-sharing between students and instructors. All these skills are also of great importance in teacher preparation, as the ultimate goal of the educational process is to develop a qualified specialist in their field - in the present case, a qualified teacher [14][15].

The proposed improvements to biology teacher training focus on fostering a more adaptable, practice-oriented and technologically advanced educational environment. Their implementation necessitates a holistic approach, encompassing curriculum revisions, the creation of new instructional resources and the incorporation of contemporary educational technologies.

The study results indicate that students possess a deep understanding of the need for a comprehensive approach to ecological-pedagogical training, which includes deepening theoretical knowledge, developing practical skills and mastering modern educational technologies. Such training will enable future biology teachers to not only effectively teach ecological subjects but also to instil a responsible attitude toward the environment in the younger generation.

DISCUSSION

The findings of this study offer an understanding of the dynamics involved in developing ecological-pedagogical competency among biology students at different educational stages, while also highlighting key challenges and requirements within the framework of ecological education. The analysis of students' self-assessment of their ecology and biology knowledge (Table 1) indicates a notable positive progression from the junior to senior years of study.

In the 1st-2nd years, *average* and *below average* ratings dominate, accounting for 55%, but this proportion declines to 33% by the 3rd-4th years. Concurrently, the proportion of *high* and *very high* ratings rises from 40% to 65%, indicating the effective accumulation of specialised knowledge throughout the programme. However, the relatively low self-assessments among junior-year students underscore the need for a stronger focus on foundational ecological knowledge at the initial stages of their education.

The assessment of ecological education integration into the curriculum (Table 2) also shows positive progression. The proportion of positive ratings among 3rd-4th year students (60%) is almost twice that of 1st-2nd year students (40%), while the proportion of negative opinions decreases from 55% to 35%. This trend may reflect the gradual increase in attention to ecological education components as students advance through their studies. Nevertheless, a significant portion of both junior and senior students still noted the insufficient integration of ecological topics in the curriculum.

The analysis of teaching method preferences (Table 3) reveals a consistent interest among students in active and interactive learning forms. Practical sessions, project work and field research are the most preferred methods among both junior- and senior-year students, confirming the effectiveness of these methods for material comprehension and professional competency development. In contrast, passive methods (lectures, on-line courses) exhibit extremely low popularity.

Data on student participation in ecological activities (Table 4) indicate a substantial increase in engagement from junior to senior students. While only 20% of 1st-2nd-year students participate in such activities, this figure reaches 45% in the 3rd-4th years, which may be attributed to both the accumulation of knowledge and competencies and the growing recognition of the importance of practical application. However, 60% of junior-year and 40% of senior-year students remained uninvolved in ecological activities, highlighting potential for further engagement.

In terms of suggestions for improving ecological-pedagogical training, students from both groups showed similar priorities, with some differences. Both groups emphasised strengthening the practical orientation of the training through active and interactive methods. Junior-year students particularly stressed the need to expand field sessions and excursions (Table 5), while senior-year students focused on integrating specialised courses on ecological teaching methods (Table 6).

Another shared area of suggestion is the increased integration of information and communication technologies in the learning process (Table 7). Both groups see great potential in on-line courses and digital technologies for enhancing the quality and accessibility of ecological education. However, junior-year students tend to focus more on the technological aspects, while senior-year students emphasise methodological and content-related improvements.

A consistent increase is observed both in students' self-assessed knowledge and in practical involvement in ecological activities. Competency development occurs alongside improvements in ecology teaching quality; however, students from both groups still noted an insufficient focus on this aspect within the curriculum, suggesting room for optimisation. The nature of suggested improvements evolves from a predominance of practical knowledge requests among junior-year students to an emphasis on specialised competencies and innovative teaching methods among senior-year students. Yet, the key idea of a comprehensive approach with a focus on active and interactive learning methods is evident in the recommendations of students from all years. These findings offer valuable insights into potential ways of enhancing the effectiveness of ecological training for future biology professionals.

Specific recommendations for improving ecological-pedagogical training of biology students are as follows:

1. To implement a mandatory introductory course on fundamental and applied aspects of ecology as a methodological foundation for further study in this field. The course units should include both theoretical and practical components. Interactive educational technologies are recommended, utilising a problem-case-based approach.
2. To ensure a gradual increase in the proportion of environmental-oriented academic disciplines as students progress academically within the framework of the basic educational programme. For this purpose, the implementation of specialised courses reflecting the current state and promising areas of development of environmental science is proposed. The courses should be interconnected in the context of the formation of a holistic worldview.
3. To ensure a significant expansion of the practical components of eco-oriented education through the integration of various formats of active pedagogical activity. It is recommended to increase the proportion of practical, seminars, field workshops and laboratory work with an environmental focus. It is advisable to use interactive collective projects that simulate the solution of real environmentally significant cases.
4. To provide incentives and support for the involvement of students in various formats of environmentally oriented activities at the initial stage of training. It is recommended to institutionalise and formalise mechanisms to encourage students to participate in voluntary eco-initiatives, scientific and applied projects, public campaigns and other relevant events.
5. To comprehensively implement digital and information and communication technologies in the structure of environmental education. It is recommended to expand the use of virtual and e-learning formats, including modelling of environmental processes. An integrated digital environment for interdisciplinary environmental research should be developed.
6. To develop and implement elective special courses reflecting the latest achievements and trends in the field of environmental technologies. These disciplines may cover *green* technologies, renewable energy sources and eco-engineering methods. It is possible to carry out joint projects with leading companies in the industry under the auspices of experts.
7. To ensure the expansion of opportunities for students to conduct research activities in the subject area of ecology and sustainable development. It is recommended to stimulate the involvement of students in collective and personal research projects of this orientation, conducted on the basis of an educational organisation. A grant system should be organised for financial support.

Thus, the proposed measures are aimed at optimising the environment-oriented training system by deepening integration between the academic and practice-oriented components, as well as the traditional and digital educational environment. This comprehensive approach is designed to ensure the effective formation of environmental and pedagogical competency.

CONCLUSIONS

This study, based on a combination of qualitative and quantitative analysis methods, allows the authors to formulate the following key conclusions:

1. A positive trend was observed in the accumulation of specialised knowledge and self-assessment of competencies among biology students as they progress academically. The proportion of *high* and *very high* ratings increased from 40% in the 1st-2nd years to 65% in the 3rd-4th years. However, relatively low self-assessments in the early stages (with 55% rating their knowledge as *average* or *below average*) highlight the need to strengthen the foundational level of ecological literacy.
2. A gradual optimisation of the integration of ecological components into the overall curriculum was identified, with positive ratings increasing from 40% in junior years to 60% in senior years. Nevertheless, a significant number of students (30% in senior years and 55% in junior years) reported insufficient inclusion of this component in educational programmes. This underscores the need to expand the presence of ecological subjects, particularly at the beginning of the programme.
3. Students demonstrated a strong preference for active and interactive educational technologies (such as practical sessions, projects and research), with these methods receiving 55% of preferences. Meanwhile, the motivational effectiveness of traditional lecture-based methods remained low (15-20%).
4. An increase in student engagement in practical, ecology-oriented activities was recorded, from 20% in junior years to 45% in senior years. However, 60% of junior and 40% of senior students were still not involved in such activities.
5. A consistent trend in recommendations for process optimisation was observed across student groups, with different emphases: from practice-oriented learning in junior years to a methodological focus in senior years.

Thus, the results of this study indicate the need to optimise the process of developing ecological-pedagogical competency in future biology specialists through a comprehensive approach that integrates both theoretical and practical aspects of training.

Key recommended measures include:

1. Developing and introducing a mandatory introductory course on the fundamentals of ecology with practical elements.
2. Gradual increase in the proportion of specialised ecology courses as students advance through the programme.
3. Significant expansion of practical learning formats, including laboratory and fieldwork, case studies and project activities.
4. Encouraging student involvement in real-world ecological initiatives and research activities.
5. Actively integrating digital technologies and on-line resources to expand opportunities for self-learning.

This comprehensive approach, integrating both academic and practical elements of the educational process through traditional and innovative methods, will optimally develop the required level of ecological-pedagogical competency in future biology teachers. This is critically necessary to enhance the quality of school ecological education and ultimately foster a responsible attitude toward the environment in society amidst the growing global challenges of the modern world.

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