Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Integrating sustainable development goals into biology teacher education: Model development and readiness assessment

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ABSTRACT

This article examines methodological approaches to training future biology teachers aimed at integrating sustainable development goals (SDGs) into the educational process. The main objective of the study is to develop a structural-content model of the methodology for implementing the SDGs in the learning process, as well as to assess the readiness of biology teachers to integrate the principles of sustainable development into their teaching practice. The study analyzed modern methods of training teachers, identified key components and stages of their preparation for the implementation of the SDGs. Special attention is paid to the formation of the necessary competencies and skills in future biology teachers that contribute to the effective implementation of the principles of sustainable development in educational activities. The results of the study will improve the quality of pedagogical training and promote the achievement of the goals of sustainable development through the educational process.

Keywords: Biology teachers, Education for sustainable development, Pedagogical education, SDGs, Structural-content model, Sustainable development.
Article type: Perspective.

INTRODUCTION

In the 21st century, one of the key challenges for society is to create a sustainable development model. Education plays a significant role in achieving this goal, as it is the key to the formation of a sustainable society. The term "sustainable development" (SD) was introduced as early as 1713 by Karlowitz and then reinterpreted by Brundtland in 1987. Since then, the concept of SD has become one of the central points on the agenda of international conferences and documents, such as the United Nations Agenda 21 (Brown & Harris 2018; Smith & Johnson 2020). In the context of this research on the SD model in Kazakhstan, the main emphasis is on the role of education in achieving sustainable development. Education for Sustainable Development (ESD) is becoming a central part of both national and international educational policies. It is becoming important for teachers to raise awareness of the principles of SD and ESD, which contributes to the integration of these concepts into educational practice. Thus, the study on the SD model in Kazakhstan aims to analyze the role of education in achieving sustainable development, as well as to find new approaches to integrating the principles of SD into educational practice, taking into account the specifics of Kazakhstani society and its environment (Miller *et al.* 2014). This article is devoted to the development of methodological approaches to the training of future biology teachers for the integration of sustainable development goals (SDGs) into the educational process. Due to the growing importance of sustainable development, one of the main tasks of the education system is the training of teachers who are able to implement effectively the principles of sustainable development in educational activities. In this context, the development of the structural-content model of the SDGs' implementation methodology in the process of training biology teachers is an important step towards the formation of a sustainable society.
The objectives of this study are:

Caspian Journal of Environmental Sciences, Vol. 24 No. 4 pp.1247-1256 Received: May 14, 2026 Revised: Aug. 09, 2026 Accepted: Sep. 25, 2026
DOI: 10.22124/cjes.2026.10072
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Publisher: University of Guilan

Development of the structural-content model of the methodology for training future biology teachers to integrate the SDGs into the educational process.
Assessment of the readiness of biology teachers to implement the principles of sustainable development in educational activities.
We believe that the results of this study will improve the quality of teacher training and contribute to the achievement of sustainable development goals through the educational process, taking into account the specifics of Kazakhstani society and its environment. Our research has identified a variety of approaches to integrating sustainability into education, particularly in the field of biology education. These models include aspects of social responsibility at the local, regional and global levels, interdisciplinary approaches and changes in teaching methods. Our research highlights the multidimensional nature of educational approaches, combining social, economic and environmental aspects, as well as the development of skills and competencies necessary for active participation in the modern world (Karabalayeva *et al.* 2026). One of the key aspects of our research is to analyze the impact of teachers' activities on sustainable practices in their local communities. We also examine the development of negotiation, problem-solving and decision-making skills through discussions of environmental, social and economic issues related to local and global responsibility. Our findings highlight the importance of active and interactive teaching methods that enable teachers to discuss their values, analyze and evaluate information and make informed decisions. We view biology education as a means to engage students in social change activities rather than simply as a process of knowledge transfer. Our analysis also reveals an underestimation of the importance of students' active participation in environmental initiatives, highlighting the need for changes in pedagogical practice to encourage active student participation (Karabalayeva *et al.* 2024).
Understanding sustainable development and education for sustainable development is a fundamental aspect of preparing future teachers. Differences in approaches to integrating sustainable development into educational systems in diverse countries were identified, and explore how these approaches can be adapted and applied in the context of Kazakhstani education. In the context of global environmental, economic and social challenges, sustainable development has become one of the key tasks of our time. Education plays a central role in achieving sustainable development, as it forms the worldview, knowledge and skills of future generations. In this regard, special attention is paid to the training of teachers who are able to integrate sustainable development goals (SDGs) into the educational process. Biological education, as part of the natural sciences, has significant potential for the implementation of sustainable development principles through an interdisciplinary approach and active learning methods (Sterling 2010). Since the purpose of our study is to develop the structural-content model of the methodology for training future biology teachers to integrate sustainable development goals into the educational process, as well as to assess their readiness to implement sustainable development principles into their teaching practice, the structural-content model of the methodology for training future biology teachers presented in Fig. 1 was developed.
The structural-content model of the methodology for implementing sustainable development goals in the training of future biology teachers (Fig. 1) is a comprehensive and systematic approach to developing students' professional readiness to integrate sustainable development principles into their teaching activities.
The model includes five main blocks:
Theoretical basis: an introduction to the concept of sustainable development and sustainable development goals, as well as a study of the role of biology education in this context.
Formation of competencies of future teachers: providing students with the necessary knowledge, skills and values for successful integration of sustainable development principles into their teaching practice.
Methodological approaches: development and testing of interactive teaching methods, interdisciplinary approaches and practical classes that promote understanding and application of sustainable development principles.
Assessment and monitoring: a system for assessing students' knowledge, skills and learning outcomes, as well as monitoring and analysis of the effectiveness of the methods and approaches used.
Professional development: providing students with opportunities to update constantly their knowledge and skills in the field of sustainable development, including participation in advanced training courses and professional communities.
Therefore, the theoretical basis allows students to understand the core of the concept of sustainable development and their role in this process. The formation of competencies of future teachers provides the necessary knowledge,

skills and values for the successful integration of sustainable development principles. Methodological approaches help to develop and test effective teaching methods that promote understanding and application of these principles. Assessment and monitoring allow evaluating the learning outcomes and adapting methods and approaches to improve the learning process. Professional development of students ensures the constant updating of their knowledge and skills in this area.

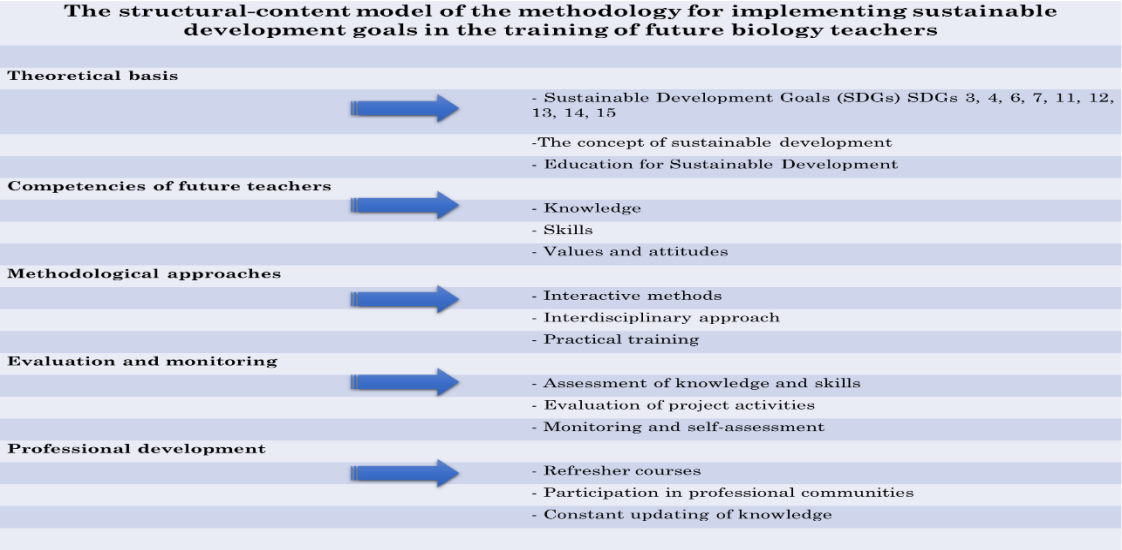


Fig. 1. The structural-content model of the methodology for implementing sustainable development goals in the training of future biology teachers.

Generally, this model promotes the development of qualified and responsible biology teachers who are ready to implement effectively the principles of sustainable development in the educational process and form active and competent citizens who are capable of making positive changes in society and the environment.

The developed the structural-content model of the methodology for training future biology teachers to integrate sustainable development goals into the educational process demonstrates a comprehensive and interdisciplinary approach that takes into account modern requirements and challenges. The model is aimed at developing the necessary knowledge, skills and values in future teachers that will allow them to effectively implement the principles of sustainable development in their professional activities.

The implementation of this model contributes to the development of teaching practices focused on sustainable development and the formation of an active civic position in future biology teachers. This, in turn, will lead to a deeper understanding and implementation of sustainable development principles in the educational process, which is a key factor in achieving global sustainable development goals.

MATERIALS AND METHODS

The methodology of the model is based on a combination of an analytical approach, project work, experimental learning and a system for assessing results. Analysis of existing practices in education, development of innovative methods, their testing and further improvement are key stages of the study (Tilbury & Wortman 2004; Lotz-Sisitka *et al.* 2015; UNESCO 2017).

The research methodology includes the following stages:

Analytical stage: analysis of literary sources, regulatory documents and modern methods of training teachers.

Project stage: development of the structural-content model of the methodology for training biology teachers.

Experimental stage: testing the developed model in educational institutions.

Evaluation stage: collecting and analyzing data on teachers' readiness to implement sustainable development principles, adjusting the model based on the results obtained (UNCED 1992; Orr 2004; United Nations 2015; Orazkul *et al.* 2022).

RESULTS

In today's world, facing the challenges of climate change, environmental crises and social problems, sustainable development is becoming an increasingly important priority. Education plays a key role in preparing a new generation of citizens who are able to respond effectively to these challenges and build a sustainable future for

all. In this context, preparing future biology teachers to integrate sustainable development principles into their teaching practice is becoming an important task.

This model assumes a comprehensive approach to developing students' professional readiness to integrate sustainable development principles into the educational process.

Thus, the implementation of this model should lead to:

Improving the training of future biology teachers in the field of sustainable development. Students will gain a deeper understanding of the concept of sustainable development, its goals and principles. They will be equipped with the necessary knowledge about the biological aspects of sustainability and how to apply them in the educational environment.

Effective integration of sustainable development principles into the educational process. Students will be trained in methods and approaches that will enable them to implement successfully sustainable development principles into their teaching practice. This includes developing teaching materials, conducting lessons with an emphasis on sustainable development, organizing excursions and practical classes.

Developing civic responsibility and active participation of students in environmental and social initiatives. Students will be encouraged to participate in various environmental and social projects and initiatives as part of their learning process. This will help them develop a sense of responsibility for the future of the planet and actively engage with society.

Improving the quality of education and training of teachers for modern society. The implementation of the model is focused on providing students with the necessary competencies for successful work in the modern educational context. This includes not only the ability to teach effectively biology, but also the ability to integrate the principles of sustainable development, which will make future teachers more in demand and effective in their professional activities.

The implementation of the developed model should lead to many positive results. Increasing the level of training of future biology teachers in the field of sustainable development, effectively integrating the principles of sustainable development into the educational process, developing civic responsibility and active participation of students in environmental and social initiatives, as well as improving the quality of education and training of teachers for modern society - all this is an important step towards creating a sustainable future for all.

Testing

To test the model of the methodology for implementing the goals of sustainable development in the training of future biology teachers, a study was conducted among the teachers of the author's university. The purpose of the testing was to assess the reaction of teachers to the proposed model, their readiness to implement and apply the proposed methods and approaches.

The study included a survey of teachers in which they assessed the following aspects of the model:

Theoretical basis. Assessing the importance of introducing sustainable development into the educational process and the role of biological education in this context.

Developing the competencies of future teachers. Assessing the importance of preparing students to integrate sustainable development principles into their teaching activities.

Methodological approaches. Evaluation of the effectiveness of the proposed teaching methods and their suitability for use in the educational process.

Evaluation and monitoring. Evaluation of the need to introduce a system for assessing students' knowledge, skills and learning outcomes on sustainable development issues.

Professional development. Assessment of the need for advanced training courses and professional seminars on sustainable development for teachers (World Commission on Environment and Development 1987; Leal Filho 2019; Scott & Gough 2003; Tilbury 2011; Wals & Corcoran 2012; Maratkyzy *et al.* 2025).

A total of 168 teachers from the Kyzylorda region participated in the survey for this research.

RESULTS

This diagram presents the percentage distribution of teachers' responses to the question about the importance of integrating sustainable development principles into the educational process (Fig. 2). Based on the data obtained: 40% of teachers highly value the importance of integrating sustainability principles, rating it as "very important." 30% consider sustainability integration "important." 20% of teachers expressed a medium rating of importance. 10% consider sustainability integration "not very important." 0% of teachers indicated that sustainability integration is "not important at all." This chart illustrates teachers' opinions on the importance of biology

education's contribution to solving environmental and sustainable development problems. The survey results show that 52% of teachers believe that biology education will make a strong contribution to solving environmental and sustainable development problems.

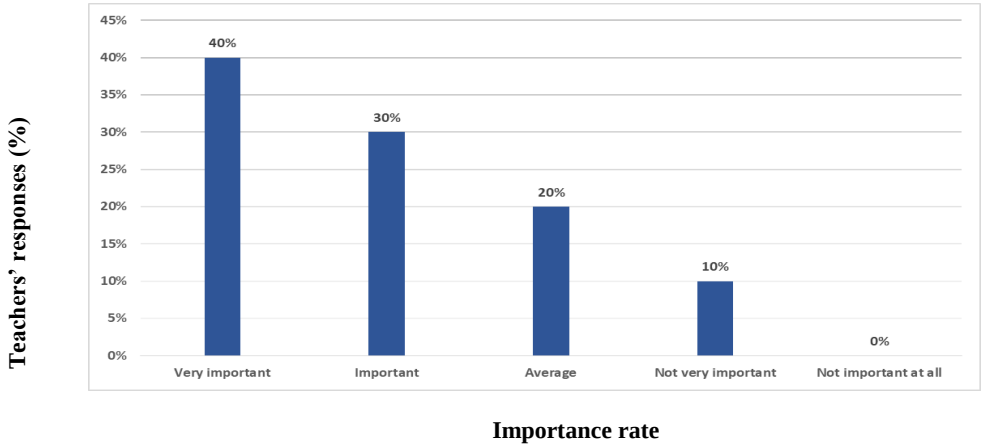


Fig. 2. Percentage distribution of teachers' responses on the importance of integrating sustainable development principles into the educational process.

This indicates a broad recognition of the role of biology education in preparing for solving current environmental problems. Thirty percent (30%) of teachers believe that biology education will make a contribution. This indicates that a significant portion of respondents recognize the importance of biology education, but do not perceive its contribution as extremely significant. Thirteen percent (13%) assess this contribution as neutral. These teachers may have limited experience or knowledge of the level of contribution of biology education to solving environmental problems. Five percent (5%) believe that biology education will make a small contribution. These teachers probably believe that biology education plays an insignificant role in solving these problems. This chart presents teachers' opinions on the effectiveness of teaching methods aimed at integrating sustainable development principles into the educational process. 168 teachers participated in the survey, and their answers were distributed as follows:

Very effective: Thirty-five percent (35%) of teachers (59 people) believe that the proposed teaching methods are very effective in integrating sustainability principles. This indicates a high level of satisfaction and perception of these methods as a powerful tool for changing the educational process towards sustainability.

Neutral: Ninteen percent (19%) of teachers (32 people) stated a neutral opinion about the methods. Perhaps they do not yet see significant changes or are not sufficiently familiar with these methods.

Not very effective: Fifteen percent (15%) of teachers (25 people) consider the methods not very effective. This may indicate the need for further improvement and adaptation of the methods to the specific conditions and needs of teachers.

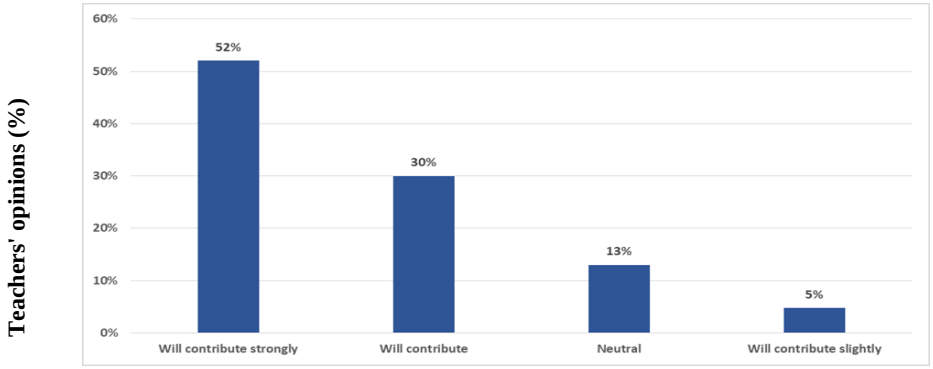


Fig. 3. Teachers' opinions on the contribution of biology education to solving environmental problems and sustainable development issues.

Not effective at all: Two percent (2%) of teachers (3 people) consider the methods completely ineffective. This small number indicates possible complications in perceiving and applying the methods for a certain group of teachers.

Fig. 5 presents the opinions of teachers on the effectiveness of the methods of assessing knowledge and skills related to sustainable development. The survey involved 168 teachers, and their answers were distributed as follows: 52.38% of teachers (88 people) consider the assessment methods to be very effective. This significant majority indicates a high level of satisfaction and perception of these methods as a reliable tool for assessing knowledge and skills in sustainable development. 25.33% of teachers (43 people) rate the methods as effective. This is also a significant proportion, indicating recognition of their positive influence, although not as high as that of the first group. 14.29% of teachers (24 people) stated a neutral opinion about the assessment methods. Perhaps they do not yet see significant changes or are not sufficiently familiar with these methods. 5% of teachers (8 people) consider the methods not very effective. This may indicate the necessity for further improvement and adaptation of assessment methods to the specific conditions and needs of teachers and students. 3% of teachers (5 people) consider the methods completely ineffective. This small number indicates possible difficulties in the perception and application of assessment methods among a certain group of teachers.

This Fig. 6 shows the frequency with which teachers integrate sustainability issues into their teaching materials and curricula. 168 teachers responded to the survey and their responses were as follows:

47% of teachers (79 people) integrate sustainability issues into their teaching materials and curricula very often. Fig. 5 shows a significant number of teachers who systematically include sustainability principles in the educational process, which underlines their commitment to this topic. 27% of teachers (45 people) integrate such issues regularly. This is also a significant share, indicating that these teachers include sustainable development in their programs systematically, although not as often as the first group. 12% of teachers (20 people) do this sometimes. This may mean that they only include sustainability issues in certain topics or when required by the curriculum. 9% of teachers (15 people) rarely integrate sustainability issues.

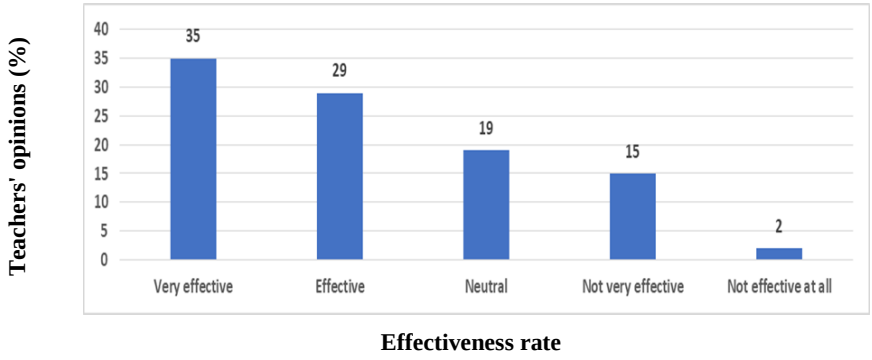


Fig. 4. Teachers' opinions on the effectiveness of teaching methods for integrating sustainable development into the educational process.

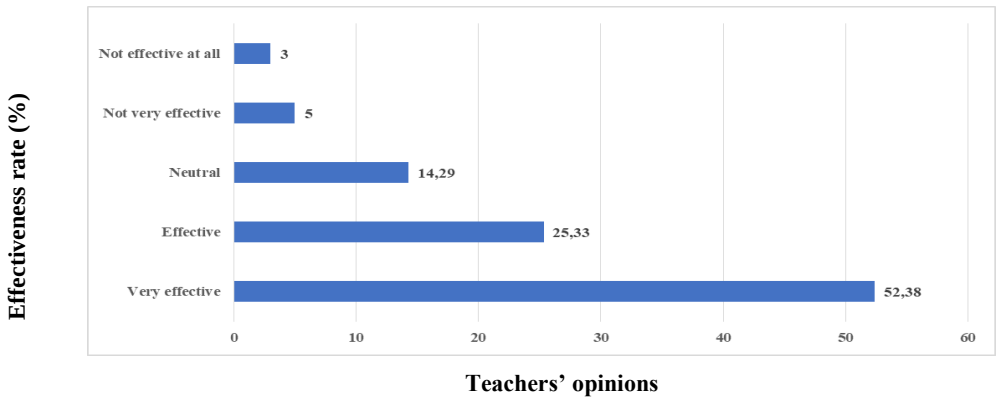


Fig. 5. Teachers' opinions on the effectiveness of methods for assessing knowledge and skills in sustainable development.

This may indicate limited understanding, the lack of time or resources to integrate sustainability into the curriculum. 5% of teachers (9 people) never integrate sustainability issues into their teaching materials. This shows that for this group of teachers, sustainable development is not a priority in the educational process, possibly due to a lack of awareness, interest or support.

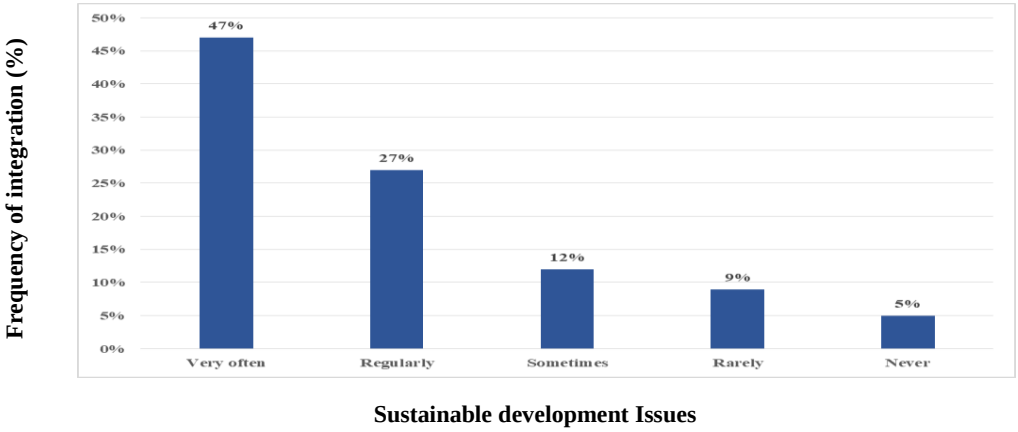


Fig. 6. Frequency of integration of sustainable development issues into teaching materials and curricula.

Fig. 7 shows the level of interest of the teachers in sustainable development training. The survey results show that 53% of the teachers would very much like to receive training in sustainable development. This indicates a high level of interest in the topic and willingness to participate in training in this area. 31% of the teachers would like to receive training in sustainable development. This also indicates a significant interest in the topic, although it is slightly less than the group that expressed a very strong desire to receive such training. 12% of the teachers stated a neutral position on this issue. They may not have a clear opinion on the importance of sustainable development training. 4% of the teachers said that they would not be very interested in receiving such training. This may be due to their preferences in professional development or a lack of understanding of the importance of sustainable development.

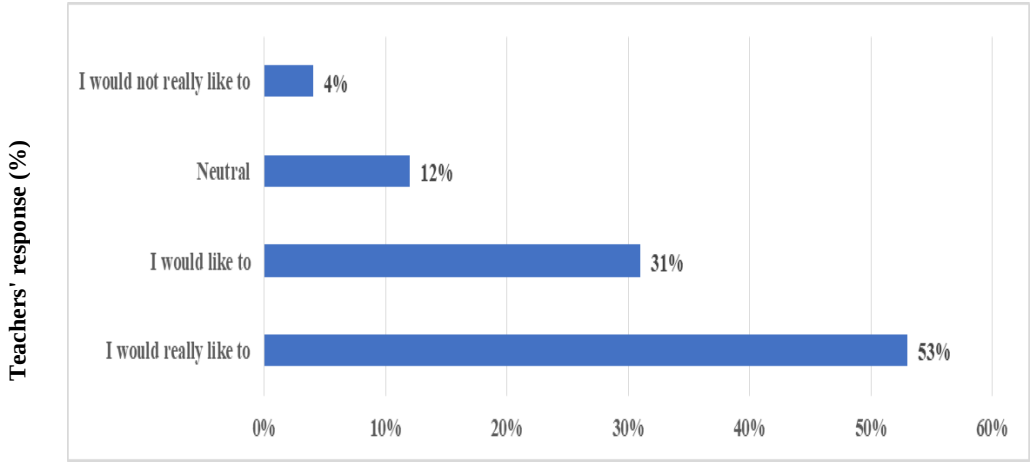


Fig. 7. Teachers' interest in sustainable development training.

Fig. 8 shows the teachers' readiness to apply the principles of sustainable development in their teaching. The survey results show the following: 36% of the teachers stated that they are very ready to apply the principles of sustainable development in their teaching. This indicates a high level of readiness of this group of teachers to implement sustainable development in their practice. 47% of the teachers are ready to apply the principles of sustainable development. This is also a high percentage, which indicates a wide interest and readiness of the

teachers to implement sustainable development in their work. 13% of the teachers assessed their readiness as average. This may indicate that they have some doubts or uncertainty about the application of the principles of sustainable development. 4% of the teachers stated that they are not very ready to apply the principles of sustainable development. This is a small group, which indicates that most teachers have a positive attitude towards this idea.

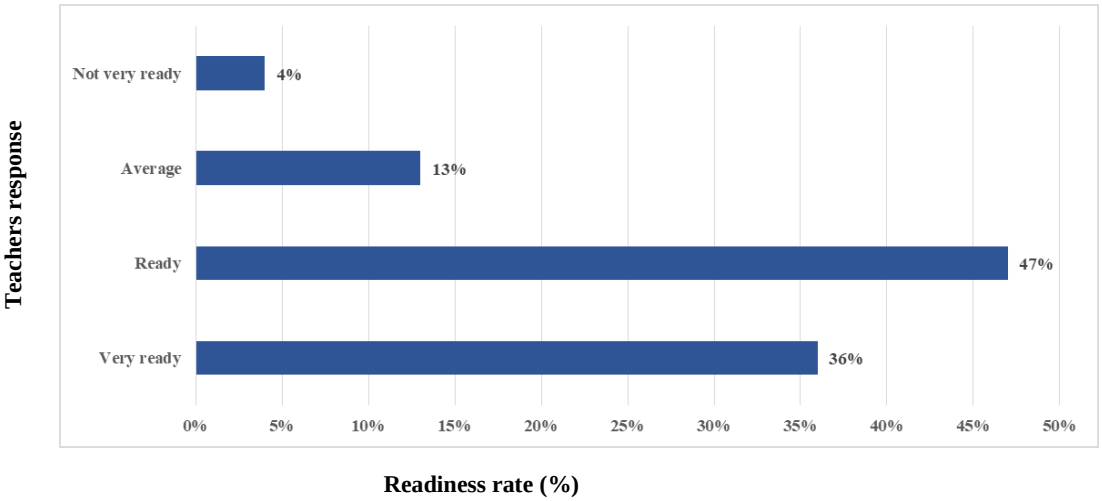


Fig. 8. Readiness of teachers to apply the principles of sustainable development in teaching activities.

DISCUSSION

This study reflects the diverse views of teachers on the importance of integrating sustainability principles into education, highlighting the importance of discussing and developing this topic within the university community. This study highlights the importance of strengthening biology curricula and providing students with the knowledge and skills to address environmental issues, a key aspect of sustainable development. The majority of teachers (64%) consider teaching methods for integrating sustainability principles into the learning process effective or very effective. However, there is a significant proportion of teachers (36%) who are either neutral or do not see a significant effect from these methods. This highlights the need for further improvement of the methods, as well as additional training activities and provision of resources to increase their effectiveness and acceptance among teachers. The majority of teachers (77.71%) consider the methods of assessing knowledge and skills on sustainable development to be effective or very effective. However, there is a share of teachers (22.29%) who are either neutral or do not see a significant effect from these methods. This highlights the need for further improvement of assessment methods, as well as additional training activities and provision of resources in order to improve their effectiveness and acceptance among teachers. Almost half of teachers (47%) integrate sustainability issues into their teaching materials and curricula very often, which highlights their high level of engagement and awareness of the importance of sustainability in the educational process. However, a significant proportion of teachers (53%) do so irregularly or not at all, which highlights the need for additional efforts to support and train teachers to integrate more effectively sustainability principles into the educational process. Thus, the survey results show that the majority of teachers (84%) expressed interest in training in sustainability development, 53% among which would very much like to receive such training and 31% expressed a desire to receive it. This indicates a broad recognition of the importance of sustainability in education and the willingness of teachers to integrate it into the teaching process. A small proportion of teachers (16%) expressed a neutral or negative attitude towards training on this topic. This may require additional work to inform and motivate this group of teachers to participate in training in sustainability development. Therefore, the survey results show that the majority of teachers (83%) expressed readiness or high readiness to apply sustainability principles in their teaching. This indicates a broad recognition of the importance of sustainable development in education and the readiness of teachers to implement it in their work. A small proportion of teachers (17%) assessed their readiness as moderate or not very high, which may require additional support and training.

CONCLUSION

Thus, the results of the survey of teachers on various aspects of sustainable development allow us to draw several key conclusions:

Most teachers recognize the importance of integrating the principles of sustainable development into the educational process. They also highly value the contribution of biological education to solving environmental problems and problems of sustainable development.

Most teachers consider teaching methods for integrating sustainable development into the educational process to be effective or very effective. However, the effectiveness of methods for assessing knowledge and skills on sustainable development requires further attention and development.

Most teachers expressed interest and willingness to be trained in sustainable development. This indicates a broad recognition of the importance of this topic and the willingness of teachers to master it.

The survey results confirm the relevance and importance of integrating sustainable development principles into the educational process. Teachers perceive this initiative positively and show interest and readiness to implement it. However, for the effective implementation of sustainable development in education, it is necessary to continue working on improving teaching methods, assessing knowledge and skills, and maintaining the interest and readiness of teachers to learn and apply sustainable development principles in their teaching activities.

The results of the testing showed a high interest of teachers in the proposed model and their readiness to implement it. Most teachers highly appreciated the importance of integrating the principles of sustainable development into the educational process and expressed their readiness to support this initiative. They also expressed interest in conducting additional training events on this topic.

Thus, the results of the testing indicate the prospects of the proposed model and the readiness of the university teachers to implement it and further improve it.

ACKNOWLEDGMENTS

This article was prepared as part of the AP25796815 project "Creation of interactive eco-platforms and digital educational resources for the development of environmental literacy among school students in Kazakhstan", funded by the Ministry of Science and Higher Education of the Republic of Kazakhstan.

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Bibliographic information of this paper for citing:

Zhumadilov, B, Karabalayeva, A, Auezova, N, Abilova, S 2026, Integrating sustainable development goals into biology teacher education: Model development and readiness assessment, Caspian Journal of Environmental Sciences, 24: 1247-1256.

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