

Scientific Herald of Uzhhorod University

Series "Physics"

Journal homepage: <https://physics.uz.ua/en>

Issue 56, 1767–1776

Received: 09.11.2023. Revised: 28.03.2024. Accepted: 22.04.2024



DOI: 10.54919/physics/56.2024.176dy7

Creating a STEAM project with students as an indicator of the effectiveness of training future biologists

Symbat Ibadulla*

Abai Kazakh National Pedagogical University
050010, 13 Dostyk Ave., Almaty, Republic of Kazakhstan

Kalampyr Zhumagulova

Abai Kazakh National Pedagogical University
050010, 13 Dostyk Ave., Almaty, Republic of Kazakhstan

Asia Maimatayeva

Abai Kazakh National Pedagogical University
050010, 13 Dostyk Ave., Almaty, Republic of Kazakhstan

Abstract

Relevance. In the modern world, biology is becoming an increasingly complex and multidimensional science that encompasses numerous subfields. Therefore, future specialists in this field need to possess not only deep knowledge of core disciplines but also a broad outlook, including competencies in technology, mathematics, and the arts.

Purpose. The purpose of this study is to investigate the effectiveness of training focused on the creation of STEAM projects in terms of training future biologists.

Methodology. The methodology of the study included the analysis of 41 projects conducted by 11 teachers of higher educational institutions in Kazakhstan for 5 years. Project classification methods included such aspects as the integration of educational material, problem-solving, search for answers to scientific questions, development of technical devices, cooperation of students, biological content of projects, high involvement and quality of assessment, and creativity. Data collection was conducted through direct observations in classrooms and at events and conducting interviews with teachers.

Results. The results showed that specialised teachers of biological disciplines, as a rule, avoided transdisciplinary projects, while teachers of non-biological disciplines often overlooked biological content in interdisciplinary projects. Biology teachers often avoided teaching methods based on device development, but they emphasised high standards of knowledge and fostered a positive perception of their disciplines through projects that involved discussion and meaningful feedback.

Conclusions. The research findings indicate that combining conventional teaching methods with integrated approaches to delivering the material can be a way to solidify fundamental biological knowledge necessary for further, more advanced education, and prepare students to apply their knowledge and skills in practical situations. The results obtained can be used in pedagogical practice for the effective implementation of project-oriented learning.

Keywords: pedagogy for higher education; interdisciplinary training; integration of educational material; practical training; quality of assessment.

Suggested Citation:

Ibadulla S, Zhumagulova K, Maimatayeva A. Creating a STEAM project with students as an indicator of the effectiveness of training future biologists. *Sci Herald Uzhhorod Univ Ser Phys.* 2024;(56):1767-1776. DOI: 10.54919/physics/56.2024.176dy7

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

Introduction

Science, technology, engineering, math (STEM) is extremely important in modern society. STEM education involves the active integration of knowledge and skills from four areas. To date, various initiatives have been implemented, such as approaches focused on STEM and project-based learning (PBL). PBL is one of the methods of learning Science, technology, engineering, arts and mathematics (STEAM), which also includes art in the list of STEM disciplines. This approach is related to creativity, ethics, aesthetics, innovation, and cross-cultural knowledge. It can be useful not only for direct teaching of a specialised subject, but also for the formation of a broad outlook of students. This method is aimed at students, as they play an active role in it, while teachers only contribute to the learning process.

L. Thibaut et al. [1] identified five main aspects of project-based learning, including material integration, problem-oriented, research, project-based, and collaborative learning. Often projects are presented in the context of the real world, encouraging joint problem-solving. Collaborative learning in STEAM projects is of particular importance for the development of divergent thinking abilities and the creation of different approaches and solution strategies, as noted by A. Hawari and A. Noor [2]. On the other hand, according to K.A. Nguyen et al. [3], coeducation is a concern because it may be difficult for teachers to guide students meaningfully. J.M. Diego-Mantecon et al. [4] report that self-directed students may tend to avoid engaging in their studies.

The studies conducted by D. Potari et al. [5] and C.F. Quigley et al. [6] have demonstrated that STEAM projects in problem-based learning often lack practical context, rendering them meaningless beyond the classroom setting. This is due to the difficulty of their application in real life, which is not so problematic for the natural sciences, compared with engineering or mathematics [5]. To facilitate learning that involves assessment and high levels of knowledge attainment for all students, C.F. Quigley et al. [7] propose involving students in meaningful aspects of the real world that are relevant to them. J.M. Diego-Mantecon et al. [4], J. Zheng et al. [8], and A. Lasa et al. [9] noted that development-oriented projects typically focus on demonstrating the functionality of specific devices rather than creating an environment that facilitates subject learning. According to the study by M.D. Burghardt and M. Hacker [10], development-oriented projects often give preference to engineering aspects rather than justifications from science and mathematics. As per the findings of E.B. Altan and S. Tan [11], this tendency to focus on device creation and neglect other aspects of the project can pose a problem for PBL. The final product should not be the only goal, and all disciplines should be equally applicable during the implementation of the project.

To date, there is no consensus on the roles that teachers and students should play during the implementation of the STEAM project. Bluszcz, Atiya, Quigley et al. [6] suggest that projects should be conducted under the guidance of students, especially at the research stage, since students are more likely to participate in processes such as asking questions, studying, and hypothesising. However, M.A. Samsudin et al. [12] argue that teachers should guide the

learning process as students may naturally have limitations in the questions they can raise. According to N. Valko et al. [13], when software is required for a project, students also need teacher support and cannot be entirely left to their own devices. In addition, some teachers may refuse to co-teach due to students' resistance to change and a low amount of effort on their part [14].

Despite the advantages of the PBL method, its effectiveness is still ambiguous. Although many authors emphasise the positive aspects of this approach, especially to promote collaborative learning and the development of behavioural competencies, its potential to support biology teaching is not fully defined. Some researchers suggest that PBL improves grades in STEM disciplines among students with lower average performance, while others argue that it has minimal natural science content that does not enhance achievement in biology but fosters a positive attitude towards the subject. PBL in biology teaching can help students develop critical thinking and reasoning skills needed for education in the 21st century. It also promotes diversity in lifelong learning by giving students the opportunity to study different disciplines and solve real-world problems. In the context of biology, STEAM projects can help students not only better understand science, but also improve their skills in technology and engineering. Converting biology study programmes to include PBL can lead to more effective and successful education. At the moment, an extremely limited number of studies have been conducted in which the impact of PBL on biology teaching has been evaluated. Thus, the purpose of this study is to investigate 41 precedents of the use of PBL methodology by teachers in higher educational institutions of Kazakhstan and, based on this, to evaluate its effectiveness for teaching biology.

Materials and Methods

Sample characteristics. The study involved 11 teachers from 8 higher educational institutions of Kazakhstan, who were engaged in the implementation of STEAM projects with their students. All of them are teachers of STEM disciplines, 7 out of 11 teach biological disciplines as a primary or secondary subject. The participating teachers, while receiving their higher education, studied the main STEM disciplines, even if they were not specialised in them. All but one of the teachers were over 40 years old and had more than 15 years of non-PBL teaching experience. All the teachers who took part in the study were highly motivated and spent extra-curricular time preparing activities and supporting students. As part of the study, these teachers implemented STEAM projects with their students aged 17 to 23.

Teacher training and project implementation. The study was conducted from September 2018 to February 2023. At the first stage, the teachers received theoretical training on the implementation of PBL and participated in master classes on project reproduction. The seminars were held in the form of three sessions, where the first session (2-3 hours) provided information about the approach to learning and its integration with the educational system, and the other two sessions (2-3 hours each) included the actual implementation of projects. Teachers had the freedom to choose projects for implementation and the way they were conducted. Teachers and students jointly selected a project,

after which students began planning, organising, and distributing tasks. All team members collaborated from the initial proposal to the conclusion, fulfilling requests and design processes, exchanging information, and reaching an agreement. At the end of each project, students had to prepare a report and a video. The report emphasised analytical aspects, and the video demonstrated practical aspects of the construction and application of technical devices. Students also had to present their work online to an audience or at relevant events at the national and international levels.

Data collection and analysis. Data collection for the analysis of the effectiveness of the implementation of 41 projects was conducted over five years. Data was collected through direct observations in classrooms, at events, and at interviews with teachers. The projects were evaluated for belonging to 10 categories, according to L. Thibaut et al. [1]. The affiliation of projects to one of four types (mono-, multi-, inter- and transdisciplinary) was considered, and the area of specialisation of teachers was also taken into account. The project categories together with the description are shown in Table 1.

Table 1. Categories of STEAM projects and their description

Material integration	Implied a high integration of educational material into the project
Problem-solving	Implied solving a real-world problem
Search for an answer	Implied searching for an answer to a scientific question
Development	Implied the creation of a man-made object, system, or device
Group	Implied the joint work of students
Biological	Biology was supposed to be the main discipline
Implied evaluation	At the end of the project, the students' work was evaluated
High engagement	Aimed at the widest possible audience
High requirements	Required deep knowledge of the main subject
Creative	Assumed a creative and extraordinary approach

Source: compiled by the authors.

All the results were compared with the analysis of the project by the students themselves, including information extracted from interviews of teachers conducted before, during, and after the implementation of the project. Teachers were also required to report any notable increase in grades received by students on regular exams in biological disciplines.

Results

Upon analysing 41 conducted STEAM projects, eight projects were classified under the monodisciplinary category. Most of the projects, namely 27 out of 41, were interdisciplinary in nature, and six projects were identified as transdisciplinary (Table 2). Teachers did not conduct a

single project that could be classified as multidisciplinary. It was noted that the monodisciplinary projects were initiated by teachers who initially denied an integrated approach in their pedagogical methodology. The STEAM projects conducted mainly focused on teaching natural sciences, including subjects such as biology, chemistry, and/or physics. For example, some of the monodisciplinary projects were devoted to the composition of food products and animal observation. These projects were led by teachers who did not specialise in the relevant fields and, therefore, did not resort to their usual activities. With regard to the teaching methodology, the focus was on student-based learning and collaborative learning with an emphasis on learning material, as demonstrated in Table 2.

Table 2. Number of projects according to categories

	Material integration	Problem-solving	Search for an answer	Development	Group
Monodisciplinary	8	1	8	0	8
Multidisciplinary	0	0	0	0	0
Interdisciplinary	27	22	23	13	27

Transdisciplinary	6	6	6	6	6
	Biological	Implied evaluation	High engagement	High requirements	Creative
Monodisciplinary	0	0	0	0	0
Multidisciplinary	0	0	0	0	0
Interdisciplinary	22	22	22	15	15
Transdisciplinary	3	3	3	0	0

Source: compiled by the authors.

The projects, which were classified as interdisciplinary, were developed in such a way as to combine educational material from at least two different disciplines. For instance, among the interdisciplinary projects, notable examples were “Water Filter Design” and “Air Quality Assessment.” As shown in Table 2, about 22 out of 27 interdisciplinary projects provided an opportunity for a detailed study of biological disciplines and provided an inclusive learning environment. Moreover, 18 of the 27 projects also contributed to the development of intermediate and high-level cognitive skills in the field of biology, while contributing to a positive attitude towards this discipline.

Despite the fact that the programme encouraged the implementation of transdisciplinary projects, only six such projects were implemented. These projects were aimed at providing real-world experiences that naturally connect different disciplines and consider aspects that are often

simplified in regular classes. For example, some of the transdisciplinary projects included “Vertical Gardens” and “Floating Nest”. Three of the six transdisciplinary projects involved biological disciplines. They had a high quality of assessment and demonstrated a high level of student engagement. However, none of these projects demonstrated an improvement in the cognitive abilities of students at the average and high levels, as well as their initiative in studying biological disciplines, as shown in Table 2. This study presents the approach adopted by teachers for 22 interdisciplinary and three transdisciplinary projects with a focus on biology. Out of the 22 interdisciplinary projects, 12 were implemented by specialised teachers, five by non-specialised teachers, and the remaining five by mixed teams consisting of both specialised and non-specialised teachers, as indicated in Table 3.

Table 3. The number of biological projects, considering the specialisation of teachers

	Material integration			Problem-solving			Search for an answer			Development			Group		
	S	N	C	S	N	C	S	N	C	S	N	C	S	N	C
I	12	5	5	9	5	5	11	3	5	4	4	0	12	5	5
T	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2
	Biological			Implied evaluation			High engagement			High requirements			Creative		
	S	N	C	S	N	C	S	N	C	S	N	C	S	N	C
I	12	5	5	12	5	5	12	5	5	9	1	5	9	1	5
T	0	1	2	0	1	2	0	1	2	0	0	0	0	0	0

Note: I – interdisciplinary projects; T – transdisciplinary projects; S – specialised teacher; N – non-specialised teacher; C – collaboration between specialised and non-specialised teachers.

Source: compiled by the authors.

The training of specialised teachers primarily involved a problem-based approach in nine cases, inquiry-based learning in 11 cases, and collaborative learning in 12 cases. On the other hand, teachers for whom the biological

discipline was not the main subject mainly focused on problem-oriented learning (in five cases), development-oriented learning (in four cases), and collaborative learning (in five cases). The mixed collaboration covered all the

areas studied, with the exception of development-oriented training. An analysis of 25 projects showed that 14 projects were devoted to fundamental biological disciplines such as botany, zoology, and anatomy, and 11 projects were devoted to more modern branches such as genetics, immunology, microbiology, and cytology. For comparison, biotechnologies were present in seven projects, and ecology was represented in only one project. Chemistry was often featured in the projects of both specialised and non-specialised teachers due to its high involvement in biological science and its utility in project development (for example, "Creation of nanoparticles" and "Protein ice cream"). On the other hand, bioinformatics was most commonly found in projects that involved collaboration with mathematics and computer science teachers for data modelling and explaining real-life phenomena (for example, the modelling of animal population changes).

In all biological STEAM projects, teachers gave priority to creating opportunities for effective assessment and ensuring the high involvement of the maximum number of groups of students. Regardless of their specialisation, teachers sought to create an inclusive and interactive learning environment by providing feedback and support to students. The format of stimulating students' interest in the project by other students was used to encourage students to share their thought processes, providing high-quality feedback that facilitated the adjustment of learning. Moreover, during the development of the project and the presentation at the events, all students were given the opportunity to familiarise themselves with educational materials on biology and practical classes, so that each student could benefit from the provided learning experience.

Although all the projects provided ample opportunities for learning, the teachers' approach to presenting the material was different. Some of the specialised teachers set tasks that did not require deep knowledge, such as the definition and memorisation of biological terms and facts, as was seen in early experiments with quizzes aimed at determining the level of biological knowledge. On the contrary, other specialised teachers created an environment that required a high level of knowledge that met the standards of the curriculum. Nine projects had requirements ranging from average to high, as they involved the application of concepts and/or procedures that were of particular significance within the project. Meanwhile, five projects promoted a high level of knowledge by requiring students to analyse, synthesise, and justify experimental findings for interpreting project results. For example, the Endangered Species project included a mathematical analysis of data on finds of various animal and plant species from open databases to establish the reasons for the decline in their populations and to predict their further size. In projects focused on the design-oriented learning approach, such as the "Terrarium" or "Floating Nest" projects, which involved an engineering aspect, the direct application of biological knowledge was relatively less emphasised.

In projects conducted by non-specialised teachers, the biology content was typically foundational and naturally emerged from the tasks at hand. These projects implied a low level of knowledge and skills, such as identifying the

species of animals and plants needed for the project or performing simple arithmetic calculations, such as the cost of materials. Teachers of chemical disciplines, who instructed projects based on students' requests, also included basic biological statements, including basic ideas about the functioning of ecosystems or human physiology, which corresponded to the educational standards of students. Only one project under the guidance of a non-specialised teacher involved a high level of biology knowledge. On the contrary, specialised teachers, as a rule, preferred development-oriented training in which biology would be used. This became obvious when one of the teachers was asked to implement a project related to the creation of an underwater robot for observing fish. The teacher directly collected the details to improve the design of the robot and then focused on explaining the concept of collecting statistical data. He focused on the importance of the design and electronic filling of the robot to perform the task. The teacher not only stimulated the search for an engineering solution to the problem but also focused on understanding its meaning. He invited the students to develop their own versions of the design, which contributed to the development of the discussion.

Three projects that encompassed multiple disciplines, included the integration of biological content, qualitative assessment, and high engagement, did not stimulate an increase in the level of knowledge of the material nor foster a positive attitude towards biology. These projects were based on realistic and practical scenarios, organically linking different areas of learning. They were optimised using simplified concepts that are usually taught to non-specialised students. Such projects included "Drop of Life" and "Floating Nest". These experimental projects were extremely complex and required a lot of time both in and out of school, where teachers used knowledge from their respective areas of specialisation. For example, in the case of the "Floating Nest" project aimed at conserving the Great crested grebe, a waterfowl species on the verge of extinction due to the lack of natural breeding surfaces, participants procured materials for nest construction, conducted experiments to test the viability of prototypes, and obtained government permits for placing platforms in the lake. Although this project combined knowledge and skills from four STEM disciplines, the biological requirements were rudimentary and limited to basic knowledge of zoology and ecology.

Based on the interviews conducted, it was found that teachers in the relevant fields, as a rule, avoided these projects because of their time-consuming nature and the required amount of attention to detail. Teacher No. 10, a 52-year-old male zoologist, stressed that "these real-life experiments are breath-taking, but they require considerable time and extensive cooperation to solve rather sporadic biological concepts." These lessons were usually conducted by teachers focused on other natural or engineering sciences, who tend to simplify complex concepts to the detriment of developments. These teachers mostly came from private educational institutions, where they felt better than their counterparts from public schools and universities. All teachers agreed that successful interdisciplinary implementation would require a change in the schedule of subjects and close cooperation between teachers. Throughout the programme, there was a

noticeable increase in cooperation between teachers as a result of constant interaction during events. Interdisciplinary conditions were created for five examples of cooperation between specialised and non-specialised teachers, which required an average and high level of knowledge. Meanwhile, two examples of cooperation between non-specialised teachers led to the creation of transdisciplinary projects that had low or medium requirements for the competence of students.

It was demonstrated that teachers participating in projects recognise the benefits of using the PBL approach and stimulating student interest through peer-to-peer teaching in STEM disciplines. Although regular assessment scores have not improved considerably, teachers have noticed that students retain the knowledge gained during these projects for a longer period of time. This may be due to the more exciting and group nature of these projects, which allowed students to apply their knowledge of biology in the context of the real world and work together with their colleagues to find solutions to current problems. Moreover, the experience gained was useful not only for students but also for teachers, allowing them to improve their skills and gain knowledge from colleagues. Notably, the inclusion of educational materials in biology and compliance with educational standards is crucial for the success of the implementation of STEAM projects for the training of future biologists. Therefore, it was necessary to ensure that these projects are developed and implemented with special attention to the subject and learning outcomes.

Although efforts were made to create biological projects that would ensure high engagement for all groups of students, it was noticed that not all students benefited from them. Some of them had other priorities, for example, they sought to get high scores on state exams or simply showed no interest in studying at the university. In addition, different categories of students took part in projects in different ways. This was manifested in the fact that some of them preferred to focus exclusively on practical tasks, not participating in analytical processes or not sharing the results. This led some teachers to doubt the effectiveness of collaborative learning, despite the fact that they recognised its potential to create a stimulating biological environment. In addition, it was difficult for teachers to objectively assess students, especially in group projects. They recognised that collective assessments can be unfair and unrealistic since each student's assessment should correspond to their individual achievements. Teacher No. 7, a 64-year-old male microbiologist, summarised it by saying: "It is difficult to assess students as a group because grades must meet the standards achieved by each student."

The results demonstrated that interdisciplinary projects had a significant impact on students' perception of the applicability of biology in various contexts. According to the teachers who participated in the study, at least eight projects allowed students to understand the importance of biological concepts and methods in solving real-world problems. These projects provided students with the opportunity to apply biological knowledge in practice, which helped them to assess the relevance of the subject. For example, in the project "Measuring Soil Indicators", students had to use their knowledge to accurately calibrate

instruments. In another project, "Principles of Muscle Training", students used knowledge of human anatomy and physiology to build an effective training scheme. This experience led students to appreciate even non-specialised disciplines and become more confident in those subjects, which was noted by all participating teachers. It is vital to provide context for the study of biological concepts, as this helps students to see the relevance and applicability of the subject. When a subject is taught out of context, students may not understand the reasons for studying it, as teacher No. 4 pointed out. Therefore, the inclusion of interdisciplinary projects that allow students to apply biological knowledge in real conditions can help them better understand the programme and deepen their knowledge in various highly specialised subjects.

Discussion

One of the main problems with the implementation of PBL is the lack of structure and recommendations for students. Since this approach involves more independent learning, it may be difficult for some students to take responsibility for their studies and carefully follow the curriculum. Teachers may need additional support to help students navigate the project and stay motivated. In addition, PBL can be time-consuming and requires careful planning and coordination between teachers and students. This can be a problem for teachers who may already have a full workload, which reduces their motivation to participate in such initiatives. It is also particularly tough to select an effective assessment system for the implementation of projects since with this type of activity it can be difficult to measure and compare the results of students' studies and their success for different groups and projects.

According to the results of the study, which involved both specialised and non-specialised teachers, a total of 41 projects were implemented over a period of five years. Out of those, 25 projects included a significant amount of material from biological disciplines, and the educators ensured equal access to the immersive biological environment. It was found that among these 25 projects, 15 assumed an average or high level of knowledge in biology and contributed to the formation of a positive attitude toward this discipline. The study showed that, given enough time, teachers can move from the implementation of monodisciplinary projects to interdisciplinary and even transdisciplinary ones. Some educators started with monodisciplinary projects that did not integrate various STEM disciplines. However, over time, they transitioned to integrated teaching through continuous interaction with students and collaboration among themselves.

The results obtained are consistent with the results of D. Potari et al. [5], who found that the transition to integrated learning is associated with a high desire to improve and a sense of belonging to a successful professional community. The research also revealed that educators required multiple attempts and quality feedback to transition to a more complex approach, as suggested in the study by M.K. Al Salami et al. [15]. Initially, some teachers were engaged in organising interdisciplinary projects that required shallow and average knowledge of biology, but later they moved on to projects with higher requirements for students, thereby encouraging the in-depth study of the subject. Realistic transdisciplinary

projects were also conducted, which naturally linked disciplines and considered a number of contextual variables that still had low requirements for students' knowledge in biology. The results obtained are consistent with the data provided by K.Y. Lin et al. [16], who reported that many provisions of STEM disciplines are not applicable outside the university or are not always applicable in everyday situations.

The study showed that both biology subject teachers and examples of interdisciplinary collaboration among educators contributed to raising the knowledge requirements in biology from moderate to high levels in 14 interdisciplinary projects. This was achieved through the use of various pedagogical techniques, often focused on problem-solving, research, and collaborative learning. Specialised teachers, as a rule, simplified the design processes and encouraged the practical application of biological knowledge, with the meaningful use of biological concepts and techniques, which is consistent with the conclusions of J.M. Diego-Mantecón et al. [4]. On the other hand, non-specialised educators mostly approved tasks that required moderate and lower levels of knowledge in interdisciplinary projects focused on problem-solving, design, and collaborative learning. The biological content of these projects mainly included primitive knowledge of fundamental biological disciplines and the application of basic zoological and botanical procedures related to the implementation of the project. Such results are consistent with the difficulties of considering biological content in development-oriented projects, as reported by M.D. Burghardt and M. Hacker [10], and also A. Lasa et al. [9]. Interdisciplinary training of non-specialised teachers did not contribute to increasing the use of biology and increasing the requirements of their projects for students' knowledge. These results indicate that interdisciplinary projects facilitate the use of school biology, while transdisciplinary ones cover real-life situations where biology occurs less explicitly. This result is consistent with the statement of Y.B. Bhakti et al. [17] that efforts are needed for the emergence of a particular STEAM discipline in projects, and that this does not happen naturally.

Despite the implementation of effective project assessment and the promotion of in-depth learning through interdisciplinary projects, the participating educators in this study did not observe significant improvement in students' biology grades during regular exams. However, similar studies conducted by S. Han et al. [18-19] demonstrated considerable improvements in the achievements of students who participated in STEAM projects. Whereas J.M. Diego-Mantecón et al. [4] did not find any changes in grades for specialised disciplines in engineering-focused projects. Teachers in this study noted that students were able to retain the knowledge and skills acquired during PBL training for a longer period of time. Working on projects for several months and preparing presentations for different audiences, students better understood the applicability of biology in other fields and contexts. Despite the creation of an equal biological environment for all students, teachers noticed that not all students were equally involved in the learning process, indicating that learning requires effort and commitment from students. Some teachers who participated in the study

reported that students' resistance to cooperation could lead to teachers rejecting innovative teaching methods. The assessment of collaborative learning in STEAM projects varied among educators, with some reporting that it was more beneficial for certain students compared to others. The teachers agreed that the assessment of individual students in groups can be a difficult task, and suggested that with this approach, there is no fair way of grading. L. Thibaut et al. [1] stated that it is currently unclear how STEAM projects should be assessed, while S. Mystakidis et al. [20] suggested that assessment should consider not only students' solutions but also other aspects such as interaction that promotes knowledge integration.

The use of PBL in the training of future biologists can indeed provide more exciting and interdisciplinary learning for students. By integrating various disciplines, students can see the relevance of biology in the context of real life, which makes learning more meaningful and applicable. In addition, the implementation of projects can contribute to the development of critical thinking, problem-solving, collaboration, and communication skills, which are important for the holistic development of students. PBL can also provide opportunities for self-assessment and assessment of student success. Students can reflect on their learning process, identify their strengths and weaknesses, and set goals for improvement. Teachers can also use various pedagogical tools to evaluate the effectiveness of PBL implementation and identify areas for improvement. In general, such an approach can be an effective pedagogical method for training future biologists, since it can improve the learning experience of students and contribute to the development of important skills and competencies in them.

Conclusions

This study highlights the potential of project-based approach, which involves creating STEAM projects with students to prepare future biologists and promote interdisciplinary learning, problem-solving, and collaboration among students. However, the implementation of this approach requires considerable efforts from teachers, and the pace of positive changes may be insignificant. The results obtained did not demonstrate a notable improvement in students' scores on exams. In addition, assessing students' performance in STEAM projects remains a challenging task that requires further research to determine effective assessment methods for this approach. Nevertheless, the study suggests that a project-based approach can enhance students' positive attitudes towards biology and promote the integration of biological subjects with other disciplines.

Despite the fact that it is very important to provide students with a solid foundation in fundamental biological subjects, it is also crucial to prepare them to apply their biological knowledge and skills in real tasks and situations, this issue is a key aspect that educators and policymakers should consider when developing educational approaches that include STEAM-oriented learning. It was shown that it can be useful for teachers to use a combination of interdisciplinary and transdisciplinary projects that balance the development of biological skills with the application of biological concepts and techniques in applied fields. Furthermore, it is important to recognise that while

interdisciplinary and transdisciplinary projects can provide students with a rewarding learning experience, they can also be time-consuming and challenging to implement effectively. Thus, teachers and educational institutions should provide adequate resources and mutual support for the effective development and implementation of STEAM projects. Furthermore, ongoing research and evaluation are needed to determine the effectiveness of PBL approaches in promoting student learning and achievements in biology and other STEM disciplines. This study provides the necessary information to develop evidence-based teaching methods that contribute to student success in biology and STEM education in general.

It is necessary to find a balance between providing students with a solid foundation in fundamental biology and preparing them for real-life situations related to professional activities in the field of biology. The results of this study indicate the need to combine conventional learning with integrated approaches to material selection, such as interdisciplinary and transdisciplinary projects, to

achieve both goals. With the correct application of this approach, students have the opportunity to study biological patterns and techniques necessary to solve real problems, and can also apply them in the field or laboratory conditions. The introduction of a STEAM subject taught by at least two teachers into the school curriculum can be a good starting point for implementing an integrated approach. However, radical changes in education should not be introduced without a proper assessment of their effectiveness. In further research, it is necessary to assess exactly how the approaches of conventional teaching and integrated presentation of material interact, and how they impact educational outcomes.

Acknowledgements

None.

Conflict of Interest

None.

References

- [1] Thibaut L, Ceuppens S, De Loof H, De Meester J, Goovaerts L, Struyf A, Boeve-de Pauw J, Dehaene W, Deprez J, De Cock M, Hellinckx L, Knipprath H, Langie G, Struyven K, Van de Velde D, Van Petegem P, Depaep F. Integrated STEM education: a systematic review of instructional practices in secondary education. *Eur J STEM Educ.* 2018;3(1): article number 2.
- [2] Hawari ADM, Noor AIM. Project based learning pedagogical design in STEAM art education. *Asian J Univ Educ.* 2020;16(3):102-111.
- [3] Nguyen KA, Borrego M, Finelli CJ, DeMonbrun M, Crockett C, Tharayil S, Shekhar P, Waters C, Rosenberg R. Instructor strategies to aid implementation of active learning: a systematic literature review. *Int J STEM Educ.* 2021;8(9):2-18.
- [4] Diego-Mantecón JM, Prodromou T, Lavicza Z, Blanco TF, Ortiz-Laso Z. Implementing STEM projects through the EDP to learn mathematics: the importance of teachers' specialization. *ZDM Math Educ.* 2022;53:1137-1148.
- [5] Potari D, Psycharis G, Spiliotopoulou V, Triantafyllou C, Zachariades T, Zoupa A. Mathematics and science teachers' collaboration: Searching for common grounds. In: *Proceedings of the 40th Conference of the International Group for the Psychology of Mathematics Education (PME 40)* (pp. 91-98). Szeged: PME; 2016.
- [6] Quigley CF, Herro D, King E, Plank H. STEAM designed and enacted: understanding the process of design and implementation of STEAM curriculum in an elementary school. *J Sci Educ Technol.* 2020;29:499-518.
- [7] Quigley CF, Herro D, Shekell C, Cian H, Jacques L. Connected learning in STEAM classrooms: Opportunities for engaging youth in science and math classrooms. *Int J Sci Math Educ.* 2020;18:1441-1463.
- [8] Zheng J, Xing W, Zhu G, Chen G, Zhao H, Xie C. Profiling self-regulation behaviors in STEM learning of engineering design. *Comp Educ.* 2020;143:103669.
- [9] Lasa A, Abaurrea J, Iribas H. Mathematical content on STEM activities. *J Math Educ.* 2020;11(3):333-346.
- [10] Burghardt MD, Hacker M. Informed design: A contemporary approach to design pedagogy as the core process in technology. *Technol Teach.* 2004;64(1):6-8.
- [11] Altan EB, Tan S. Concepts of creativity in design based learning in STEM education. *Int J Technol Des Educ.* 2021;31:503-529.
- [12] Samsudin MA, Jamali SM, Zain ARM, Ebrahim NA. The effect of STEM project based learning on self-efficacy among high-school physics students. *J Turk Sci Educ.* 2020;16(1):94-108.
- [13] Valko N, Kushnir N, Osadchyi V. Cloud technologies for STEM education. *CTE Worksh Proc.* 2020;2643:416-434.
- [14] Chaaban Y, Qadhi S, Du X. Student teachers' perceptions of factors influencing learner agency working in teams in a STEAM-based course. *Euras J Math Sci Technol Educ.* 2021;17(7):em1980.
- [15] Al Salami MK, Makela CJ, de Miranda MA. Assessing changes in teachers' attitudes toward interdisciplinary STEM teaching. *Int J Technol Des Educ.* 2017;27:63-88.
- [16] Lin KY, Wu YT, Hsu YT, Williams PJ. Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking. *Int J STEM Educ.* 2021;8:1.
- [17] Bhakti YB, Astuti IAD, Okyranida IY, Asih DAS, Marhento G, Leonard L, Yusro AC. Integrated STEM project based learning implementation to improve student science process skills. *J Phys Conf Ser.* 2020;1464:012016.
- [18] Han S, Capraro R, Capraro MM. How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement. *Int J Sci Math Educ.* 2015;13:1089-1113.

- [19] Han S, Rosli R, Capraro MM, Capraro R. The effect of science, technology, engineering and mathematics (STEM) project based learning (PBL) on students' achievement in four mathematics topics. *J Turk Sci Educ.* 2016;13(S):3-29.
- [20] Mystakidis S, Christopoulos A, Pellas N. A systematic mapping review of augmented reality applications to support STEM learning in higher education. *Educ Inform Technol.* 2022;27:1883-1927.

Створення зі студентами STEAM-проекту як показник ефективності підготовки майбутніх біологів

Симбат Ібадулла

Казахський національний педагогічний університет імені Абая
050010, пр. Достик, 13, м. Алмати, Республіка Казахстан

Калампір Жумагулова

Казахський національний педагогічний університет імені Абая
050010, пр. Достик, 13, м. Алмати, Республіка Казахстан

Асія Майматаєва

Казахський національний педагогічний університет імені Абая
050010, пр. Достик, 13, м. Алмати, Республіка Казахстан

Анотація

Актуальність. У сучасному світі біологія стає все більш складною та багатовимірною наукою, яка охоплює численні підгалузі. Тому майбутнім фахівцям у цій галузі необхідно володіти не лише глибокими знаннями профільних дисциплін, а й широким кругозором, включаючи компетенції в технологіях, математиці та мистецтві.

Мета. Мета даного дослідження – дослідити ефективність навчання, орієнтованого на створення STEAM-проектів, з точки зору підготовки майбутніх біологів.

Методологія. Методологія дослідження включала аналіз 41 проекту, виконаного 11 викладачами вищих навчальних закладів Казахстану протягом 5 років. Методи класифікації проектів включали такі аспекти, як інтеграція навчального матеріалу, вирішення проблем, пошук відповідей на наукові питання, розробка технічних пристроїв, співпраця студентів, біологічний зміст проектів, висока залученість і якість оцінювання, креативність. Збір даних проводився шляхом прямих спостережень у класах та на заходах, а також за допомогою проведення інтерв'ю з учителями.

Результати. Результати показали, що викладачі біологічних дисциплін, як правило, уникали трансдисциплінарних проектів, тоді як викладачі небіологічних дисциплін часто пропускали біологічний зміст у міждисциплінарних проектах. Вчителі біології часто уникали методів навчання, заснованих на розробці пристроїв, але вони наголошували на високих стандартах знань і сприяли позитивному сприйняттю своїх дисциплін за допомогою проектів, які передбачали обговорення та змістовний зворотний зв'язок.

Висновки. Результати дослідження вказують на те, що поєднання звичайних методів навчання з інтегрованими підходами до викладання матеріалу може стати способом закріплення фундаментальних біологічних знань, необхідних для подальшої, більш поглибленої освіти, і підготовки студентів до застосування своїх знань і навичок у практичних ситуаціях. Отримані результати можуть бути використані в педагогічній практиці для ефективної реалізації проектно-орієнтованого навчання.

Ключові слова: педагогіка вищої освіти; міждисциплінарне навчання; інтеграція навчального матеріалу; практичний тренінг; якість оцінки.