Revista Românească pentru Educație Multidimensională
ISSN: 2066-7329 | e-ISSN: 2067-9270
Covered in: Web of Science (WOS); EBSCO; ERIH+; Google Scholar; Index Copernicus; Ideas RePeC; Econpapers; Socionet; CEEOL; Ulrich ProQuest; Cabell, Journalseek; Scipio; Philpapers; SHERPA/RoMEO repositories; KVK; WorldCat; CrossRef; CrossCheck

2022, Volume 14, Issue 2, pages: 19-49 | https://doi.org/10.18662/rrem/14.2/565
Submitted: May 13th, 2021 | *Accepted for publication:* February 9th, 2022

Education for Sustainable Development in Training of Future Biology Teachers for Research Activity: An Applied Aspect

Maryna SIDOROVICH[1],
Olga TSURUL[2],
Ruslana ROMANIUK[3],
Yulia SOLONA[4],
Oksana KUNDELCHUK[5],
Inna KORENEVA[6],
Oleg BLAZHKO[7]

[1] Doctor of Pedagogical Sciences, Kherson State University, Kherson, Ukraine, marinasidorovich1@gmail.com

[2] PhD in Pedagogical Sciences, National Pedagogical Dragomanov University, Kyiv, Ukraine, olgatsurul@ukr.net

[3] Doctor of Pedagogical Sciences, PhD in Biological Sciences, Zhytomyr Ivan Franko State University, Zhytomyr, Ukraine, melnychenko.ruslana@gmail.com

[4] PhD in Pedagogical Sciences, Kherson State University, Kherson, Ukraine, yusolona@ukr.net

[5] PhD in Biological Sciences, Kherson State University, Kherson, Ukraine, okundelchuk@gmail.com

[6] Doctor of Pedagogical Sciences, Hlukhiv National Pedagogical University of Oleksandr Dovzhenko, Hlukhiv, Ukraine, i.koreneva74@gmail.com

[7] Doctor of Pedagogical Sciences, Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Vinnytsia, Ukraine, blazhk.oleg@ukr.net

Abstract: The article presents the experience of creating an innovative format of extracurricular training of applicants as a means of implementation of education for sustainable development – the experimental group "Cytoecologist". The functioning of this format is based on the implementation of selected principles of STEM-education and open education of applicants. To implement these principles in the training of specialists, the group leader uses a number of formats of students' activity that are not inherent in traditional education. Among them are dynamic temporary microgroups for experimental search; format "information activities", Internet surfing, WIKI format, educational coworking or collaboration in space. The pedagogical experiment consisted of two parts. The first part is to find out the state of implementation of research skills by biology teachers in practice, which included determination of the level of their self-realization and interest in the organization of research activities of students. The second part is to find out the effectiveness of the presented experience of creation of a scientific student group "Cytoecologist", within which the implementation of education for sustainable development by means of research activities of future biology teachers is carried out. A survey of graduates of the group shows that the basic principles of the group provide the formation of a stereotype of a specialist-researcher, and the vast majority of respondents (95%) use research skills in their professional activities, one of the directions of which is education for sustainable development. The experience of creating a research group of students presented in the article is the result of many years of scientific research of authors (teachers-practitioners of leading universities of Ukraine). This acquisition is original and is being published for the first time, and the obtained positive results give grounds to recommend it for implementation in the practice of training biology teachers in Western Europe.

Keywords: *education for sustainable development; training of future biology teachers; research activity; STEM education; dynamic group.*

How to cite: Sidorovich, M., Tsurul, O., Romaniuk, R., Solona, Y., Kundelchuk, O., Koreneva, I., & Blazhko, O. (2022). Education for Sustainable Development in Training of Future Biology Teachers for Research Activity: An Applied Aspect. *Revista Românească pentru Educație Multidimensională, 14*(2), 19-49.
https://doi.org/10.18662/rrem/14.2/565

Introduction

The international concept of Sustainable development strategy (World Commission on Environment and Development, 1987) is based on several principles. One of the leading is the principle of education for sustainable development. Numerous studies have been devoted to the problem of its implementation (Abdurakhmanov et al., 2017; Bascope et al., 2019; Du et al., 2013; Glavic, 2020; Grund & Brock, 2020; Hofman-Bergholm, 2018; Jain et al., 2013; Jurs et al., 2017; Kabanov et al., 2020; Khan et al., 2020; Molderez & Fonseca, 2018; O'Flaherty & Liddy, 2018; Sinakou et al., 2019; Thomas, 2009; Weng et al., 2020).

Among them, in our opinion, the most relevant are the works in which this problem is developed in the context of future biology teachers training. Such specialists are able to lay professionally a solid groundwork of the necessary knowledge of the younger generation to solve the problem of sustainable development of our planet. The most effectively biology teachers are able to do this during the organization of research activities of students. It provides them with an immersion in the strategy of sustainable development in the search process activity. The organization of such activities within the search work of applicants is one of the ways to solve the outlined problem. Therefore, the purpose of the study is to present the experience of creating an innovative format of extracurricular training of future biology teachers (research group "Cytoecologist") as a means of implementation of education for sustainable development.

Literature Review

Scientific and methodological literature contains works on certain elements of future biology teachers training through education means for sustainable development. Among them the main ones are: introduction of residential field course (Jegstad et al., 2018), separation of elements of biological knowledge for education for sustainable development (Hartadiyati et al., 2019), understanding of sustainability and education for sustainable development (Bezeljak et al., 2020), the organization of mobile learning (Sebastian-Lopez & de Miguel Gonzalez, 2020), the inclusion of education elements for sustainable development in the content of future teachers training (Chisingui & Costa, 2020). An example of thorough work on the problem of introduction in the of future biology teachers training of education for sustainable development is the study of Koreneva (2018). Scientists pay significant attention to the implementation of such education by means of research activities of specialists (Bangera & Brownell, 2014;

Brownell & Kloser, 2015; Cebrián & Mercè, 2015; Cheruvelil et al., 2020; Cipkova & Karolcik, 2018; Evans et al., 2017; Feitosa & Dias, 2019; Gramatik, 2020; Hayat et al., 2018; Heim & Holt, 2019; Maryuningsih et al., 2018; Sari et al., 2018; Spell et al., 2014; Tomio et al., 2010). At the same time, the specified aspect of the problem is insufficiently outlined concerning the training of future biology teachers. There are single studies in this area, which consider only the issue of widespread implementation of active learning methods and the formation of critical thinking of applicants for the introduction of education for sustainable development (Koreneva, 2018). Thus, the introduction of education for sustainable development in the process of training of future biology teachers by means of research activities organization is an underdeveloped issue at the international level. From such positions the presented work is an original contribution of the authors.

Training of the future biology teachers for research activities has several aspects. Leading among them, as evidenced by the previous research (Sidorovich, 2018), is the teacher's building of an individual research trajectory, the leading means of which is self-education, and the teacher's organization of various research activities in class and after school. In our opinion, an interesting direction of the research is the creation of original didactic support for teaching biology and ecology in schools not only on the basis of processing and synthesizing of the information from various information sources, but also on the results of environmental research student projects within JAS (Junior Academy of Sciences of Ukraine) and other science research activities. The latest direction, unlike the other ones of the teacher's research activity, is insufficiently presented in scientific and methodological works. In particular, there is almost no thorough outline of the approaches to future biology teachers training for research activities by means of, firstly, education for sustainable development, and secondly, STEM education. We believe that the preparation of future biology teachers for research activities can be significantly improved by providing education for sustainable development in the scientific STEM laboratory of environmental orientation of the university. The experience of creation of such a laboratory presented in the article is the result of many years of scientific research of authors (teachers-practitioners of leading universities of Ukraine). This acquisition is original and is published for the first time, and the positive obtained results give grounds to recommend it for implementation in the practice of biology teachers' training in Western Europe.

Materials & Methods

Theoretical and empirical methods were used in the study to achieve the goal. Among them are analysis, synthesis, comparison of the results of the literature sources analysis on the research problem, modeling of formats of training for research activity on the principles of STEM education. Empirical research methods include diagnostic, in particular, pedagogical observation of the effectiveness of practical implementation of selected and developed formats of STEM education in the functioning of the student research group.

The pedagogical experiment consisted of two parts. The first part – to update the topic and subject of the study: to clarify the state of implementation of research skills by biology teachers in practice, which included determining the level of their self-realization and interest in organization of students' research activities. The second part is to find out the effectiveness of the presented experience of creating a scientific student group "Cytoecologist", within which the implementation of education for sustainable development by means of research activities of future biology teachers is carried out. Both parts of the pedagogical experiment were carried out by means of a survey using Google Form. In the first part, 178 biology teachers from different regions of Ukraine took part in the survey. Their teaching experience ranged from 1 to 40 years, 97% – women. They were offered to perform the method "Teacher's ability to self-development" (Semichenko, 2020), which is given below.

Instructions: answer the following questions by grading:

5 – if this statement completely matches reality;
4 – more yes than no;
3 – both: yes and no;
2 – rather does not match;
1 – does not match.

Statements:

1 I seek to study myself.
2 I leave time for development, no matter how busy I am with work and household chores.
3 Obstacles that arise stimulate my activity.
4 I look for feedback because it helps me to know and evaluate myself.
5 I reflect on my activities, devoting special time for this.
6 I analyze my feelings and experiences.
7 I read a lot.
8 I discuss widely the issues that interest me.
9 I believe in my own abilities.

10 I want to be more open.
11 I am aware of the influence that people around me have on me.
12 I manage my professional development and get positive results.
13 I enjoy learning something new.
14 Growing responsibilities do not frighten me.
15 I would be positive about my career development.

Rating scale: 60-75 points - high level of self-development, 45-60 points - sufficient level of self-development, 15-45 points - the level of self-development is not sufficient.

Respondents were also offered to answer a questionnaire consisting of:

A) Is your research skills improvement a part of self-education?

B) Do you conduct experimental research with students?

C) If so, within which organizational forms of training do you conduct them? *(in class, school clubs, extracurriculars, as creative homework, within the JAS, another answer)*

D) Assess their own level of professional competence in the organization of research activities *(high, sufficient, medium, initial);*

E) Indicate the skills that need to be formed in the future biology teacher in the organization of experimental research activities in general secondary education? *(to organize all stages of scientific research, to focus on information sources, to master of new experimental techniques, to organize corresponding activity of pupils on passing of scientific research stages, other variant of the answer)*

The second part of the pedagogical experiment was carried out by interviewing graduates of the group "Cytoecologist". There have been 20 such graduates in the last five years, who work by speciality. They were offered a questionnaire consisting of the following questions:

Evaluate on a 5-point scale the effectiveness of your own participation in the work of the group "Cytoecologist" for your professional activity.

1. Do you use research skills in your professional activities?
3. If so, what skills do you use in your professional activity?
4. Do the research skills acquired in the "Cytoecologist" group help you to implement education for sustainable development and to carry out ecological education of students? How exactly?
5. What formats of the group "Cytoecologist", in your opinion, should be introduced to increase the effectiveness of the formation of future teacher' research skills?

Results and Discussion

To clarify the practical development state of the above two aspects of the problem of preparation for research activities (individual trajectory by means of self-education and organization of research activities of students), the processing of the results of the teachers' survey was conducted on the following positions:

- teacher's ability to self-development;
- the level of self-education of biology teachers in different regions of Ukraine in accordance with their teaching experience;
- research activity of teachers as a component of the self-education system;
- the state of implementation of experimental research in the educational process in biology;
- variety of organizational forms of such implementation;
- level of professional competence in the organization of research activities (teacher's own assessment);
- recommendations of teachers-practitioners on future biology teachers training for research activities in universities.

Qualitative analysis of the survey results showed that the vast majority of biology teachers in different regions of Ukraine have a high level of ability to self-development (69.14% of respondents) *(**Fig.** 1)*. A sufficient level of this ability is diagnosed in 27.8%, while only 3 % of respondents have a low level. Accordingly, the dominant qualitative indicator of the formation of the ability of a biology teacher to self-development is its high level.

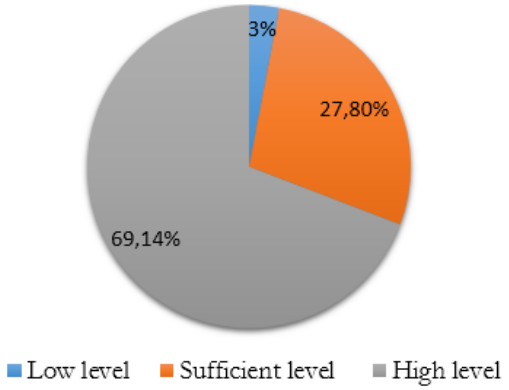

Fig. 1. Levels of formation of ability to self-development of biology teachers from different regions of Ukraine
Source: Authors' own work

The results of the analysis on the position "self-education level of biology teachers in different regions of Ukraine according to their teaching

experience" are contained in Table 1. As shown by the distribution of the sample, recent graduates are the least represented. We see this as indirect evidence of a lack of motivation and, consequently, a low level of desire for self-education, in particular, its component of "the formation of skills for research in the professional sphere." The analysis of the same sample of biology teachers regarding the levels of formation of their ability to self-education showed the existence of differences in different groups of respondents. According to the data in this table, the sample is dominated by a category of specialists whose teaching experience is in the range from 11 to 25 years. It contains the largest share of respondents with a high level of ability to self-development compared to other categories. There are no respondents with a low level of this ability in this group. Respondents of the first two groups have a much lower percentage of high-level representation, especially the youngest professionals. This is not entirely clear, based on the degree of active participation of representatives of this group in the survey.

Table 1. Division of biology teachers from different regions of Ukraine by levels of ability to self-development
Source: Authors' own work

Work experience (group)	Proportion of respondents, %	Levels of formation of the teacher's ability to self-development, %		
		Low	Sufficient	High
group 1 (0 – 4 years)	8,7	0	43	57
group 2 (5 – 10 years)	23,5	7,9	39,5	52,6
group 3 (11 – 25 years)	38,9	0	22,2	77,8
group 4 (≥ 25 years)	29	4,2	29,8	66

The generalized results of the survey of biology teachers on the problem of implementation of experimental research in professional activities are illustrated by ***Fig.*** *2-6*. When clarifying the analytical position "research activities of teachers as a component of the self-education system", 96.3% of respondents indicated that this is one of its aspects. At the same time, the "distribution by experience" of teachers showed that two

senior groups of specialists are more active in this type of activity. Only 10% of members of the group "0-4 years" demonstrated this professional quality *(**Fig.** 2)*.

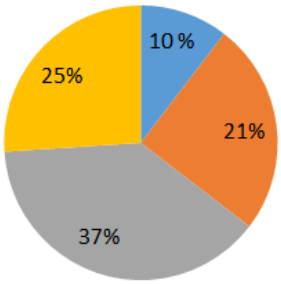

Fig. 2. Division of the teachers, who consider the research activity as the component of self-education

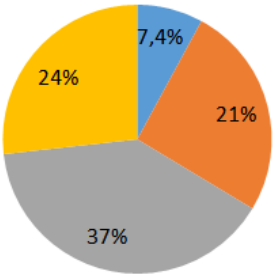

Fig 3. Division of the teachers by the implementation of the experimental research in the professional activity

(work experience: – «0-4», – «5-10», – «11-25», – «≥25»)
Source: Authors' own work

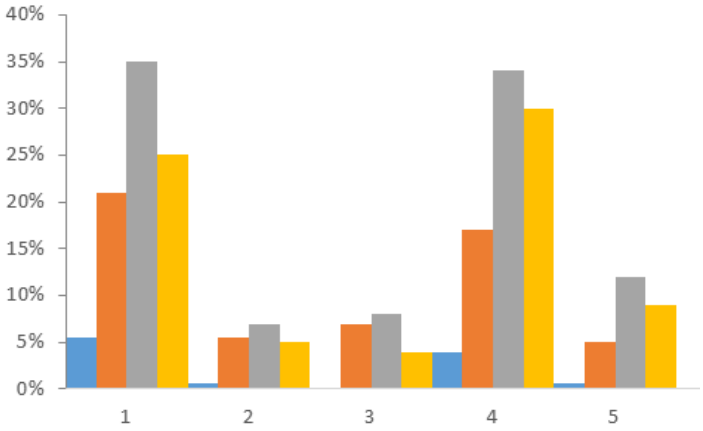

Fig. 4. Division of the teachers by the implementation of experimental research by means of various organizational forms (1- lesson, 2 - club classes, 3 - extracurriculars, 4 - creative hometasks, 5 – JAS. (work experience: – «0-4», – «5-10», – «11-25», – «≥25»))
Source: Authors' own work

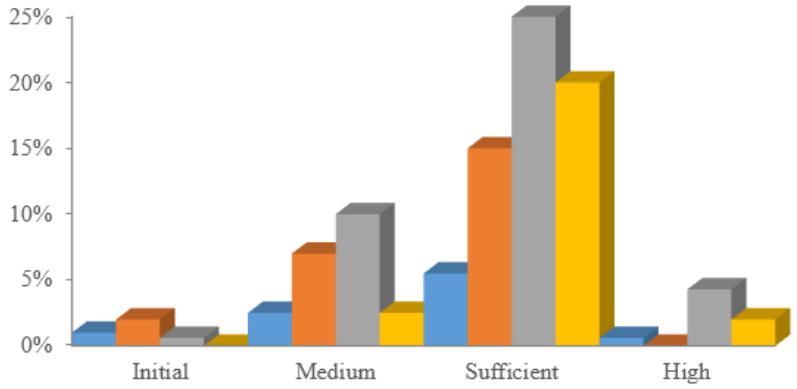

Fig. 5. Division of the teachers by levels of professional competence formation in the organization of research activities (work experience: – «0-4», – «5-10», – «11-25», – «≥25»)
Source: Authors' own work

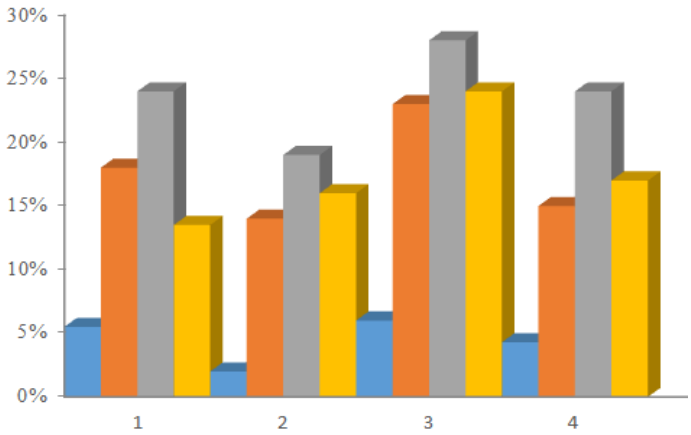

Fig. 6. Division of the teachers according to the skills that are necessary to be formed in the future biology teacher on the organization of experimental research activities in general secondary education (1 - organize all stages of scientific research, 2 - navigate in information sources, 3 - master new experimental techniques, 4 - organize appropriate activity of students on passing of scientific search stages, 5 - other variant of the answer (work experience: – «0-4», – «5-10», – «11-25», – «≥25»)
Source: Authors' own work

89.5% of all respondents say that they implement experimental research in the process of teaching students in biology. Thus, in the understanding of biology teachers, there is some discrepancy between the

awareness of the connection between the process of improvement of their research competence and its implementation in practice. At the same time, the "distribution by experience" of teachers fully corresponded to the same distribution according to the previous position. The share of the youngest specialists was the smallest in it again ***(Fig. 3)***. In order to understand if that's true, we analyzed the responses of teachers in terms of organizational forms during which such research is conducted. Among the organizational forms, the following are pointed out by biology teachers: lesson (83.3%), creative homework (74%), Junior Academy of Sciences (26.7%), school clubs (18.7%) and extracurriculars (18%). In other versions, the respondents singled out various competitions and research papers, preparation for environmental competitions, projects, etc. But such answers were single. According to the obtained data, biology teachers do not quite understand the essence of experimental research work of students. For example, it is difficult to fully organize it in the frameworks of the lesson. The last three forms are probably dominant, each of which is named by less than 30% of respondents. Regarding the distribution of respondents' groups by experience, no significant differences in the forms of the educational process were found. Respondents of the group "0-4 years". practically do not see the possibility of experimental work organization within the school clubs, extracurriculars and JAS. In comparison with the respondents of the two senior groups of specialists, the two junior groups could not name other organizational forms by the means of which experimental research is introduced into the educational process in biology ***(Fig. 4)***. The recent positions revealed by the survey indicate a lack of awareness of recent graduates compared to other groups of specialists in the organizational forms of experimental research and the low degree of formation of their research competence in general.

Assessing their own level of professional competence in the organization of research activities, 65.5% of respondents identified it as sufficient, 22% – medium, 6% of respondents – high, 4% of respondents – the initial level ***(Fig. 5)***. Based on the above, the presence of a sufficient level in most respondents' answers of the youngest group raises some doubts. The same assumption can be made for the group "5-10 years". Probably that is why among the main types of skills that respondents recommend to form in future biology teachers, regarding the organization of experimental research activities in general secondary education institutions, they indicate the mastery of new experimental methods – 80.9%; organize all stages of scientific research and organize the relevant activities of applicants – 61.1%; orientation in information sources – 50.6%. ***Fig***. *6* reflects the

"distribution by experience" of biology teachers in relation to the specified analytical position. The most active in terms of recommendations for improvement of the system of future biology teachers training for research is a group of respondents "11-25 years". All versions of the recommendations are named by about 25% of members of this group. The second and fourth groups of respondents pay the most attention to the position of "mastering of the new experimental techniques." More than 20% of respondents in groups 1 and 2 – positions "organize all stages of scientific research." All the above indicates the need to strengthen the experimental and research component of the future biology teachers training at the university.

The conducted analytical study to determine the state of the organization of experimental research activities in the teaching students in biology in general secondary education institutions showed that:

• most teachers of biology in different regions of Ukraine have a high level of teacher's ability to self-development; at the same time, younger respondents (0-10 years old) have this indicator less than their senior colleagues (11-25 and more years old);

• the youngest by the experience teachers represented the smallest share of respondents, which indicates a low degree of interest not only in passing the survey, but also in conducting professional experimental research activities;

• the vast majority of respondents also indicate that the improvement of research activities is a component of their system of self-education; at the same time, this position is not relevant for the youngest;

• the vast majority of respondents say that they implement experimental research in the educational process in biology; however, this indicator is not the same for specialists with different experience; respondents call the lesson the dominant organizational form of implementation of experimental research work in general secondary education institutions. This indicates that biology teachers of all groups are not thoroughly acquainted with the concept of experimental research ("experimental search"). It can be most fruitfully organized with students within the Junior Academy of Sciences, elective classes and clubs. In different groups of respondents this position is reflected differently; the youngest specialists in this matter are the worst oriented;

• more than half of the respondents assess the level of their professional competence in organization of research activities as sufficient. At the same time, teachers of different groups are not unanimous in this assessment. Based on the answers of the questionnaire, the youngest experts are clearly not objective in their own assessments;

• biology teachers of different groups experience the greatest difficulties in organization of all stages of scientific research, organization of the relevant activities of students to pass the stages of such research, in mastering of new experimental techniques. This is probably why they formulate these positions as recommendations for improvement of the preparation of future biology teachers for research activities.

Thus, the analysis of a survey of biology teachers of Ukraine with different teaching experience to develop the problem of self-education in the context of their research activities in general secondary education has shown the need to increase the level of preparation for such activities of future professionals in this direction. One way to solve this problem is to invent new formats for the training of future biology teachers, in particular, based on the principles of STEM education and open education. This approach allows you to create an extracurricular format of environmental orientation of such training. It can significantly increase the effectiveness of the implementation of education for sustainable development through these activities of applicants.

STEM education is a powerful new direction that is gaining intensive development in the global educational space. Ukraine is actively participating in this global educational trend not only at the practical level, but also at the state level: The Government of Ukraine has adopted the Concept for the Development of Science, Technology, Engineering, and Mathematics Education (STEM education). The document defines a set of measures related to the formation and development of skills in research and engineering, invention, entrepreneurship, early professional self-determination and readiness to make informed choices about future professions, …dissemination of innovations in education (Ministers of Ukraine, 2020). In the nearest future it is planned to update the standards of higher education in the field of knowledge "Education/Pedagogy" on the use of the latest pedagogical approaches to teaching and assessment, interdisciplinary teaching practices, ***teaching methods and tools that promote research and invention competencies.*** All of the above indicates that STEM education is becoming a separate government programme similar to that which has been active since the beginning of the XXI century in the United States and the United Kingdom (Scottish Government, 2012). Based on the name of the direction of education, it is considered a priority, primarily for the preparation of technical and mathematical specialities. This is quite relevant in the Ukraine due to the sharp decline in young people's interest in this area of public life. However, guided by the general institutions of the above concept, STEM education

can be considered as one of the effective ways to improve the quality of training of biology teachers for environmental research. The ecological area of life on the planet is one of the three dimensions of education for sustainable development. Thus, by focusing on the implementation of this area on the principles of STEM education, it is possible to improve the effectiveness of its implementation in the preparation of future biology teachers for research.

The term "STEM education" in the modern educational space is gaining more and more interpretation and thus becomes synonymous with the concept of "learning through research". The latter regarding the training of specialists in higher education institutions means the formation of their professional competencies by means of involvement in activities that have any research orientation. This given situation is due primarily to the lack of unambiguous definition of the concept by scientists. Only Turner K. (2013) defines it more or less clearly. He points out: "STEM education is an area of study but it is also a way of teaching and learning that is project-based, collaborative, and focused on solving real-world problems. STEM programmes educate the whole student, emphasizing innovation, problem solving, critical thinking, and creativity". Such research experiences promote the development of robust, integrated, conceptual knowledge by engaging participants in STEM practices (Brownell & Kloser, 2015; Litzinger et al., 2011).

Guided by the above, we believe that this concept covers not only the organization of the educational process by purely research teaching methods. The result is the acquisition by the individual of objectively new knowledge (which characterizes the creative level of educational achievements) and, most importantly, the creation of original scientific (scientific and methodological) work (product) as a result of their own research activities. It must be tested and can be put into practice. It is clear that this can be most effectively done in the process of long-term project experimental research activities. In view of the above, to train future biology teachers in the context of education for sustainable development, we have created a permanent scientific student group of STEM education "Cytoecologist" at Kherson State University. It consists of students – future teachers of biology. The group works within the laboratory of active forms of teaching biology and ecology of Kherson State University, which was founded in 2000. This group operates together with experienced researchers and teachers. This laboratory can be fully called STEM laboratory. In it, students determine the impact of various environmental factors by one of the most modern environmental methods – bioassay.

The strategy of sustainable development considers this problem today among the top priorities. The study of cellular and molecular mechanisms underlying the body's responses to the environment is one of the leading ways to solve it. This is the main focus of scientific interests of the STEM education group "Cytoecologist". Future biology teachers develop problems to determine the quality of water of different origins and the effectiveness of drinking water purifying in various ways, environmental safety of bottled water and new synthetic chemicals that have plant growth regulators, protective properties of such substances from positive low and high temperatures, microwave action (ultrahigh-frequency) radiation, hypoxia and other abiotic environmental factors, etc. Young scientists pay special attention to the action of small doses of factors.

The results of such research are used by future biology teachers to create original didactic developments for teaching students of biology and ecology. They form the main part of their research. But future teachers begin their scientific search from experimental research performance. It is in this process the mastery of research techniques begins and continues throughout their professional training at the university.

To solve the above problems, in the process of which original methods of phytotesting of environmental factors are created, various phyto- and zoo tests are involved *(**Fig.** 7-13)*.

Fig. 7. Wheat seedlings

Fig. 8. Sunflower seedlings

Fig. 9. Onion seedlings

Fig. 10. Corn seedlings

Source: Authors' own work

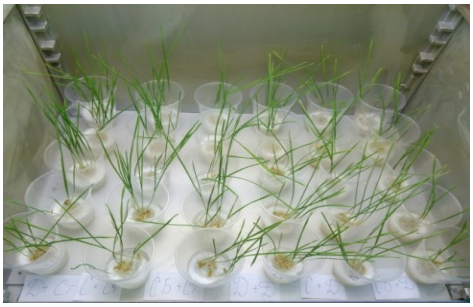

Fig. 11. Monocotyledons "on floating disks"

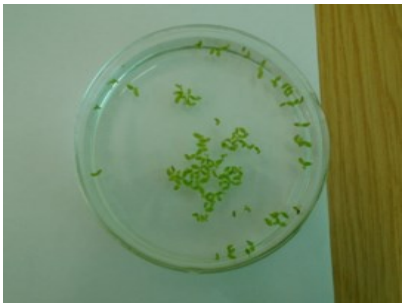

Fig. 12. Small Duckweed culture

Fig. 13. Zootests of guppy and ampullaria fry
Source: Authors' own work

The leading indicators of the effect of the factor on model plant systems are biometric parameters of phytotests. Their representative sample volumes are processed by future biology teachers with the use of Excel resource to obtain statistically significant information about the specified action. For example, the use of the model system "plant seedlings" involves the following sequence of actions: the selection by the appearance of mature seeds *(**Fig.** 14)*, tying it in a gauze bag *(**Fig.** 15)* and soaking in water *(**Fig.** 16)*, sprouting in a thermostat in Petri dishes *(**Fig.** 17)*, control of the sprouting process *(**Fig.** 18)*, determination of biometric parameters of the seedling *(**Fig.** 19)*.

Fig. 14. Seeds' selection

Fig. 15. The formation of the sac

Fig. 16. The seeds' soaking
Source: Authors' own work

Fig. 17. Germination in the thermostat

Fig. 18. Germination control

Fig. 19. Measurement of growth indicators
Source: Authors' own work

Students use a range of appropriate valid techniques to obtain quantitative cell-molecular indicators of environmental factors action on the model system. They make it possible to prove the mechanisms of this effect on the body reliably. They include such methods:

1) manufacture of compressed preparations of root tips for measuring mitotic activity, mutation level and intensity of protein synthesis according to the values of the nuclear biomarker. The successive steps contain **Fig.** *20-24*;

2) colouring of duckweed leaves to detect dead cells,

3) the method of detecting spare starch at the tips of the roots,

4) photocolorimetric determination of chlorophyll and protein concentration by Lowry and catalase activity (**Fig.** *25*), etc.

Fig. 20. Fixation of root tips

Fig. 21. Crushing of fixed material

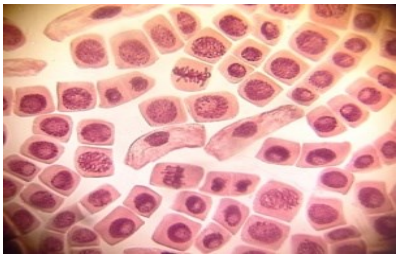

Fig. 22. Obtaining of the drug
Source: Authors' own work

Fig. 23. Medication quality control

Fig. 24. Microscopy of a temporary drug

Source: Authors' own work

Fig. 25**.** Determination of catalase activity (left) and chlorophyll concentration (right)

Source: Authors' own work

The research of the STEM education group "Cytoecologist" is part of the research of teachers of the Department of Human Biology and Immunology on the scientific and methodological topic "Scientific and methodological principles of students' training in biological and pedagogical specialities based on the principles of STEM education" and the scientific topic "Cytomonitoring of environmental factors by the biotesting method" of Kherson State University.

Therefore, the field of research of the STEM education group "Cytoecologist" is an experimental ecological search, the means of which are introduced into the training of future teachers of biology education for sustainable development.

Scientific and scientific-methodological literature contains different groups of principles of STEM education. Its analysis allowed us to identify the features of the functioning of this scientific group for their implementation.

Peculiarities of the above group are:

• ensuring the integrated training for the implementation of education for sustainable development in the training of future teachers-researchers in biology and ecology;

• formation in this process of a life stereotype, which orients the student to successful self-realization in the future profession and in other spheres of public life;

• gradual immersion of applicants in successive stages of scientific and experimental research, a significant increase of their motivation to participation in it, increasing the overall level of its research competence (for these, applicants begin working in a group from the 1st year of study; the group manager developed an algorithm for such involvement, which contains the elements of the manager's activity and activity of the student (group member) in each year of training);

• performance by applicants of a group of long-term research projects on a certain topic with the involvement of a range of biometric, cytological and physiological-biochemical methods throughout the period of their professional training in higher education establishments;

• the result of research is not only the practical part of midterms and qualification works, speeches at conferences and publication of articles; the leading result is the original development (methodological work), which has direct practical significance;

• performance of the research by means of simple, informative and valid methods of bio-assay, which creates an opportunity for future biology teachers to use them for development of didactic support for the process of teaching biology at school; its approbation during pedagogical practice or presentation activities in the laboratory and subsequently to use them in professional activities in order to introduce education for sustainable development in the learning process of general secondary education.

The functioning of the STEM education group "Cytoecologist" of Kherson State University is based on the principles of open education, which significantly distinguishes it from other similar student groups. Today, the term "open education" has a polysemy of definition. However, there is a general understanding of it. It is considered as an educational space, which is aimed at self-determination of pedagogical action methods. More often, open education is seen as distance. We take a broader view of this concept and believe that it is based on a number of principles. They were described by us earlier, their introduction into the work of the STEM education group "Cytoecologist" is revealed (Sidorovich, 2018). Such implemented principles include the use of informational learning tools. The work of the group is characterized by economic efficiency, flexibility, modularity, parallelism,

asynchrony, accessibility, coordination of education (a new role of the teacher). The applicant acts as a listener (subject) in a situation of varied educational opportunities from which you need to choose. These principles of open education are implemented through the organization of experimental research activities of group members due to the fact that all the technical equipment of the laboratory of active forms of teaching biology and ecology is absolutely accessible to group members. The functioning of the laboratory is organized in such a way that each student can work in it on one's own schedule, realizing one's individual trajectory of research activities. The selection and individual working plan of each student on the research topic necessarily corresponds to one's wishes when working in the STEM education group. Moreover, first-year students begin to work as part of dynamic micro-groups that perform research in different areas using different bio-assays. The result of such work is the independent choice of the model system and the direction of experimental work in the group by the applicant. Each student of the group plans the time, pace and intensity of experimental research work on the selected topic. Also, one determines the number of speeches at conferences and publications. The teacher only controls his capabilities and needs in order to increase the level of motivation in performance of the research. The latter aspect is very important in the implementation of the principles of free education. *The principle of parallelism* is implemented in the fact that the student, who builds an individual research trajectory, successfully combines group work with the implementation of the curriculum of basic professional training. *The economic efficiency* of open education in the functioning of the group is ensured by the fact that during all stages of scientific research the applicant receives professional knowledge in the process of activity. This is a guarantee of their greater reliability than those they receive through traditional learning. *The use of specialized (information) technologies and teaching tools* is widely implemented in the work of the STEM education group. It covers not only the use of Internet resources to compile literature reviews on the topic of research for its actualization. Computer technologies for measuring the size of cell, nucleus and nucleolus, statistical processing of quantitative data, creating presentations of the results of own research, site "Cytoecology" (Sidorovich, 2021), own YouTube channel "First steps in science: cytoecology" (Sidorovich, n.d.), etc. – also included in the equipment of experimental research activities of the group.

One of the principles of free education is *the new role of the learner*. The reflection of its implementation in the group work is that the direction, type of object (bio-assay), research methods and its general scheme, which is

created experimentally – all this is a free choice of the student. Due to the high-level organization of one's independent activity at each stage of scientific research there is an increase in one's own requirements for self-organization, motivation, skills of independent work. If necessary, a member of the group can receive a variety of assistance from the manager and other staff of the laboratory. However, the work of the research supervisor of the group is based on the principle of open education *(the new role of the teacher (or coordination of education))*. It is expressed in a complete change of functions of the supervisor. This person is the coordinator of the cognitive process during the student's first acquaintance with the group in general and with "one's own" research problem in particular. Supervisor controls the student's practice of research methods, usually as part of a dynamic micro-groups. The group manager is a consultant in the preparation of an individual task for the study and the initiator-consultant, who forms temporary micro-groups of students. They are formed, as will be described below, with different purposes to perform certain stages of the experimental search. The supervisor can help a member of the group to summarize the results obtained during the design of the publication, term papers and theses.

The leading organizational form of the group functioning on the principles of free education are *dynamic micro-groups* of its members. As already mentioned, they are created for a certain time for different purposes. The group has a "leader or senior" who organizes the work of the group and who reports to the supervisor on the achievement of the goal. The group is formed of students of different years of study. Temporary groups can have different purposes:

• "help another student (group member)" in determination of a significant number (sometimes more than 1500) of biometric indicators when studying the effect of the factor on the model system (**Fig.** *26*);

• "teach another student" to get acquainted with and master the biometric and cell-molecular techniques by the "younger" members of the group, the sequence of work with a particular phyto- and zootest, etc. (**Fig.** *27*);

• "conduct research together" to obtain integrated information about the action of the factor by means of several model systems or different cell-molecular techniques (**Fig.** *28*).

Such experimental group work forms a whole range of subject and general competencies of students, attracts future teachers to the teaching activity even before passing pedagogical practice in general secondary education institutions.

Fig. 26. Micro-group "help the other student"

Fig. 27. Micro-group "teach the other student"

Fig. 28. Micro-group "conduct the research together"
Source: Authors' own work

Another leading organizational form of the group's work is *information activities*. This is also an original format of open education, developed in the scientific student group "Cytoecologist". It is implemented by group members through their participation in:

• information messages about the group's work in various information sources (website of the Department of Human Biology and Immunology and the Faculty of Biology, Geography and Ecology of Kherson State University, Facebook, etc.);

• master classes on studying the effects of environmental factors by means of phytotesting for scientists (**Fig.** *29-31***)**;

• public speeches at conferences of various levels in the cities of Ukraine;

Fig. 29. Seedling biometrics

Fig. 30. Statistical data processing

Fig. 31. Manufactured microscopy of temporary drugs
Source: Authors' own work

• creation of video-presentations with various methods of bio-assays and directions of work of STEM education group for own YouTube channel "First steps in science: Cytoecology";

• career guidance activities of group members (extracurricular activities) during pedagogical practice (**Fig.** *32-34***)** and within the "Science Week at KSU", JAS and excursions of students to the laboratory of active forms of teaching biology and ecology.

Fig. 32. Demonstration of the

Fig. 33. Self-manufacturing drug

Fig. 34. Microscopy of the drug method of drug preparation
Source: Authors' own work

The format of free education of *Internet surfing* is widely used in the work of members. It involves an informational search of students for a specific purpose. Internet surfing provides the conditions for the development of skills of independent search and critical processing of the found information. It is a very effective form of biological scientific research. Therefore, such an independent assault on the information resource is carried out in the group not only to justify the need to perform a certain topic by means of analysis of literary sources. It is a leading one in the activities of group members when creating new methods of environmental testing in the laboratory.

The WIKI format or the creation of an information base with which a student can work independently is another organizational form of open education. This database is created by the teacher. This format is expressed in the functioning of the author's website "Cytoecology" (Sidorovich, 2021). Such a site contains a semantic selection of methodological and background information created by the supervisor, which allows the student to carry out

an independent scientific search. A video block of fragments of such material has been created on the youtube channel "First steps in science: Cytoecology" (APA Publishing Training, n.d.; Sidorovich, n.d.). Two collections of publications by members of the group, published in the editions of different levels ("Presentation of the results of the research group on cytoecology KSU problems at conferences and scientific periodicals") allow the student to get acquainted with what the group has already done in the chosen direction. In this way there is a certain orientation in the segment of this direction.

Another format of free education is involved in the work of the STEM education group "Cytoecologist". This is *educational co-working or working together space.* Under common work is understood the scientific search for a teacher-scientist and a young scientist (student) within the general educational platform. Such a platform is a cytoecology laboratory. An interdepartmental group on this problem works on it, a component of which is the student community of the "Cytoecologist" group. It is on this platform that scientists and students or micro-groups of students work shoulder to shoulder. The result of such work is a new scientific product (methodological improvements in the implementation of scientific research results in the educational process in biology or new methods or techniques of measuring the effects of environmental factors). The specified scientific product has direct practical value. Examples of such developments are methodological materials for a master class for students on phytotesting of drinking water quality, research project "Phytotesting of environmental safety of synthetic chemicals", instructional cards for classes on the original curriculum of the club "Aqua" for out-of-school education.

The effectiveness of the proposed innovative format of the student research group "Cytoecologist", the operation of which is based on the principles of free and STEM-education was found out during a survey of its graduates.

When assessing their own participation in the work of the group, respondents were distributed as follows: "5 points" were given by 85%, "4 points" – 10%, "3 points" – 5%. The vast majority of respondents (95%) use research skills in their professional activities. Among them, they call the leading ones:

• ability to update the research topic and motivate students to it;

• ability to work with different sources to obtain the necessary information for the work and the ability to teach it to students;

• experimental skills in management of students' research in class and performing the work for the Academy of Sciences;

• ability to develop author's methodical materials on the basis of the received experimental data which can be used in professional activity on a specialty.

Regarding the new formats of activity of the group members, the respondents suggested the use of various applications to increase the informatization of the group, for example, SeedCounter.

5. Conclusions

The student group of STEM education "Cytoecologist" as a format of extracurricular education has been introduced in the training of future biology teachers and has been successfully operating at Kherson State University for more than 10 years. The experience of its implementation in the process of these specialists training testifies to the viability of this format in the educational process of the university. Its basic principles (STEM education and open education) contribute to a significant increase in the level of motivation of students to participate in long-term scientific and scientific-methodological research. However, the scientific supervisor will focus on the invention of new forms of applicants' attraction to scientific research. The results of interviews with graduates of the group in recent years show that their preparation by means of the format of student research group on the principles of STEM education and open education helps to increase the level of their research competence, which includes experimental research skills. Group training ensures the formation of a research specialist stereotype.

The study allows us to indicate that:

1. Teachers of biology of Ukraine have insufficiently formed research skills and there is an urgent need for purposeful development of such skills during the training of specialists in this field. This in turn involves the development of effective forms of training of future biology teachers for research activities. Such forms in the study are considered as a means of implementing education for sustainable development.

2. One of the areas of implementation of education for sustainable development may be the formation of research skills within the student research group of environmental orientation on the basis of free and STEM-education.

3. These principles are realized in original formats of activity of members of group: dynamic temporary microgroups for realization of experimental search; format "information activitiy", Internet surfing, WIKI format, educational coworking or collaboration in space.

4. A survey of graduates of the group showed that in assessing their own participation in the work of such a group "85 points" were given by 85% of respondents. The vast majority of respondents (95%) use research skills in their professional activities, one of the areas of which is education for sustainable development. Respondents mentioned the ability to update the research topic and motivate students to it; ability to work with different sources of information and the ability to teach students; experimental skills for conducting research with students in class and during the performance for Junior Academy of Sciences; ability to develop on the basis of the received experimental data methodological achievements which can be used in professional activity on a speciality.

5. The experience of training the future biology teachers, presented in the article, is original and therefore promising, in our opinion, for implementation in the educational systems of European countries.

Thus, the proposed innovative format of training of future biology teachers can help to improve the organization of their research activities of environmental orientation and can be used as a means of education introduction to sustainable development in the educational process of universities.

References

Abdurakhmanov, G. M., Guseynova, N. O., Ivanushenko, Y. Y., Prokopchik, S. V., Kadieva, D. I., & Soltanmuradova, Z. I. (2017). Education for sustainable development as a basis for the formation of environmental worldview. *South of Russia-ecology development, 12*(3), 115 – 137. https://doi.org/10.18470/1992-1098-2017-3-115-137

Bangera, G., & Brownell, S. E. (2014). Course-based undergraduate research experiences can make scientific research more inclusive. *CBE–Life Sciences Education, 13* (4), 602–606. https://doi.org/10.1187/cbe.14-06-0099

Bascope, M., Perasso, P., & Reiss, K. (2019). Systematic review of education for sustainable development at an early stage: cornerstones and pedagogical approaches for teacher professional development. *Sustainability, 11*(3), 719. https://doi.org/10.3390/su11030719

Bezeljak, P., Scheuch, M., & Torkar, G. (2020). Understanding of sustainability and education for sustainable development among pre-service biology teachers. *Sustainability, 12* (17), 6892. https://doi.org/10.3390/su12176892

Brownell, S. E., & Kloser, M. J. (2015). Toward a conceptual framework for measuring the effectiveness of course-based undergraduate research

experiences in undergraduate biology. *Studies in Higher Education, 40*(3), 525–544. https://doi.org/10.1080/03075079.2015.1004234

Cebrián, G., & Mercè, J. (2015). Competencies in education for sustainable development: exploring the student teachers' views. *Sustainability, 7*(3), 2768 – 2786. https://doi.org/10.3390/su7032768

Cheruvelil, K. S., De Palma-Dow, A., & Smith, K. A. (2020). Strategies to promote effective student research teams in undergraduate biology labs. *American biology teacher, 82* (1), 18–27. https://doi.org/10.1525/abt.2020.82.1.18

Chisingui, A.V., & Costa, N. (2020). Teacher education and sustainable development goals: a case study with future biology teachers in an angolan higher education institution. *Sustainability, 12*(8), 3344. https://doi.org/10.3390/su12083344

Cipkova, E., & Karolcik, S. (2018) Assessing of scientific inquiry skills achieved by future biology teachers. *Hemistry-Didactics-Ecology-Metrology, 23* (1-2), 71 – 80. https://doi.org/10.1515/cdem-2018-0004

Du, X., Su, L., & Liu, J. (2013). Developing sustainability curricula using the PBL method in a Chinese context. *Journal of Cleaner Production*, *61,* 80–88. https://doi.org/10.1016/j.jclepro.2013.01.012

Evans C., Waring, M., & Christodoulou A. (2017). Building teachers' research literacy: integrating practice and research. *Research Papers in Education, 32*(4), 403 – 423. https://doi.org/10.1080/02671522.2017.1322357

Feitosa, R. A., & Dias, A. M. (2019). Articulation between teaching, research and extension: tutorial education program (PET) contributions for biology students. *Educacao & formacao, 4*(12), 169–190. https://doi.org/10.25053/redufor.v4i12.819

Glavic, P. (2020). Identifying key issues of education for sustainable development. *Sustainability, 12*(16), 6500. https://doi.org/10.3390/su12166500

Gramatik, N. V. (2020). Direction of the biotechnology course in the preparation of future biology teachers: regional context. *Revista Universidad y sociedad*, *12* (5), 45-52. http://scielo.sld.cu/pdf/rus/v12n5/2218-3620-rus-12-05-45.pdf

Grund, J., & Brock, A. (2020). Education for sustainable development in Germany: not just desired but also effective for transformative action. *Sustainability, 12*(7), 2838. https://doi.org/10.3390/su12072838

Hartadiyati, E., Wiyanto, Rusilowati, A., & Prasetyo, APB (2020). Pedagogical content knowledge (PCK) of prospective biology teacher on respiratory system material to education for sustainable development. *Journal of Physics: Conference Series, 1521*, 42034. https://iopscience.iop.org/article/10.1088/1742-6596/1521/4/042034

Hayat, M. S., Rustaman, N. Y., Rahmat, A., & Redjeki S. (2019). Profile of life-long learning of prospective teacher in learning biology. *Journal of Physics: Conference Series, 1157* (2), 022083. https://iopscience.iop.org/article/10.1088/1742-6596/1157/2/022083

Heim, A. B., & Holt, E. A. (2019). Benefits and challenges of instructing introductory biology course-based undergraduate research experiences (CUREs) as perceived by graduate teaching assistants. *CBE-Life Sciences Education, 18* (3), 43. https://doi.org/10.1187/cbe.18-09-0193

Hofman-Bergholm, M. (2018). Could education for sustainable development benefit from a systems thinking approach? *Systems, 6*(4), 43. https://doi.org/10.3390/systems6040043

Jain, S., Aggarwal, P., Sharma, N., & Sharma, P. (2013). Fostering sustainability through education, research and practice: a case study of TERI university. *Journal of Cleaner Production, 61,* 20 – 24. https://doi.org/10.1016/j.jclepro.2013.04.021

Jegstad, K. M., Gjotterud, S. M., & Sinnes, A. T. (2018). Science teacher education for sustainable development: a case study of a residential field course in a Norwegian pre-service teacher education programme. *Journal of adventure education and outdoor learning, 18* (2), 114-119. https://doi.org/10.1080/14729679.2017.1374192

Jurs, P., Lidaka, A., & Samusevica, A. (2017). Values education for sustainable development. *INTED2017 Proceedings*, *5768*. https://doi.org/10.21125/inted.2017.1356

Kabanov, O., Tokareva, J., Altunina, Y., Gorlova, O., Filonova, A., & Stoyanova, L. (2020). Education for sustainable development: self-regulating learning strategies in an online environment. *International journal of applied exercise physiology, 9*(12), 196–199. https://iranjournals.nlai.ir/bitstream/handle/123456789/774063/9EA0CFAFB7204B4CA6AD73BACAF06B18.pdf?sequence=-1&isAllowed=y#page=196

Khan, M., Sarmad, M., Ullah, S., & Bae, J. (2020). Education for sustainable development in humanitarian logistics. *Journal of humanitarian logistics and supply chain management, 10*(4), 573 – 602. https://www.emerald.com/insight/publication/issn/2042-6747/vol/10/iss/4

Koreneva, I. M. (2018). The core and features of «Education for sustainable development» phenomenon. *Ukrainian Educational Journal, 2,* 113 – 123. http://uej.undip.org.ua/upload/iblock/729/7298feb5ba4bafbef4bef5f8b6523530.pdf

Litzinger, T. A., Lattuca, L. R., Hadgraft, R. G., & Newstetter, W. C. (2011). Engineering education and the development of expertise. *Journal of Engineering Education, 100*(1), 123 – 150. https://doi.org/10.1002/j.2168-9830.2011.tb00006.x

Maryuningsih, Y., Hidayat, T., Riandi, R., & Rustaman, N. Y. (2019). Critical thinking skills of prospective biology teacher on the chromosomal basic of inheritance learning through online discussion forums. *Journal of Physics: Conference Series, 1157*(2), 022090. https://iopscience.iop.org/article/10.1088/1742-6596/1157/2/022090

Ministers of Ukraine. (2020). *The concept of development of science, technology, engineering and mathematics education (STEM education)*. Zakon Rada. https://zakon.rada.gov.ua/laws/show/960-2020-%D1%80#Text

Molderez, I., & Fonseca, E. (2018). The efficacy of real-world experiences and service learning for fostering competences for sustainable development in higher education. *Journal of cleaner production, 172,* 4397 – 4410. https://doi.org/10.1016/j.jclepro.2017.04.062

O'Flaherty, J., & Liddy, M. (2018). The impact of development education and education for sustainable development interventions: a synthesis of the research. *Environmental education research, 24* (7), 1031 – 1049. https://doi.org/10.1080/13504622.2017.1392484

Sari, D. P., Wulan, A. R., & Solihat, R. (2018). Developing 21st century student research skills through assessment matrix and edmodo in biology project. *Journal of Physics: Conference Series, 1157*(2), 022093. https://iopscience.iop.org/article/10.1088/1742-6596/1157/2/022093

Scottish Government. (2012). *Supporting Scotland's STEM education and culture.* Scottish Government. http://www.gov.scot/resource/0038/00388616.pdf

Sebastian-Lopez, M., & de Miguel Gonzalez, R. (2020). Mobile learning for sustainable development and environmental teacher education. *Sustainability, 12* (22), 9757. https://doi.org/10.3390/su12229757

Semichenko, V. (2020, October 1). *Psylist – psychological educational site. Methodology "Pedagogical education to self-development".* Psylist.net https://psylist.net/praktikum/00334.htm

Sidorovich, M. (2021, September 2). *Author's website M. M. Sidorovich.* http://marisidorovich.ucoz.ru/

Sidorovich, M. (n.d.). First steps in science: Cytoecology [YouTube channel]. YouTube.

https://www.youtube.com/channel/UCcsBUxWez9b9rOi63HfhHOg/about

Sidorovich, M. M. (2018). Professional training of natural science students in a classical university within a problem research group on the basis of open education. *Pedagogical almanac, 40,* 77 – *84.* http://nbuv.gov.ua/UJRN/pedalm_2018_40_13

Sinakou, E., Donche, V., Boeve-de Pauw, J., & Van Petegem, P. (2019). Designing powerful learning environments in education for sustainable development: a conceptual framework. *Sustainability, 11*(21), 5994. https://doi.org/10.1002/curj.59

Spell, R. M., Guinan, J. A., Miller, K. R., & Beck, C. W. (2014). Redefining authentic research experiences in introductory biology laboratories and barriers to their implementation. *CBE–Life Sciences Education, 13*(1), 102–110. https://doi.org/10.1187/cbe.13-08-0169

Thomas, I. (2009). Critical thinking, transformative learning, sustainable education, and problem-based learning in universities. *Journal of Transformative Education*, *7*(3), 245 – 264. https://doi.org/10.1177/1541344610385753

Tomio, D., Schroeder, E., & Silva, V. L. de Se. (2010). An experience of initial teacher training for science and biology from the exercise of research in science education. In L. G. Chova, D. M. Belenguer, I. C. Torres, (Eds.), *EDULEARN10: International Conference On Education And New Learning Technologies* (pp. 2202 – 2205). WOS:000318781702028.

Turner, K. (2013). *Northeast tennessee educators' perception of STEM education implementation* [Electronic theses and dissertations]. https://dc.etsu.edu/etd/1202

Weng, S., Liu, Y., Dai, J., & Chuang, Y. (2020) A novel improvement strategy of competency for education for sustainable development (ESD) of university teachers based on data mining. *Sustainability, 12* (7), e2679. *Sustainability, 12*(7), 2679. https://doi.org/10.3390/su12072679

World Commission on Environment and Development. (1987). *Our common future.* Oxford University Press. URL: https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html