BEST PRACTICE GUIDE OF STEAM METHODOLOGY IN ETWINNING PROJECTS FOR FUTURE TEACHERS

ABSTRACT

STEAM (science, technology, engineering, art, mathematics) is an increasingly popular way of schooling, in which the student, through an interdisciplinary approach to learning, becomes a creator of knowledge, not just a reproducer. However, this educational model lacks a well-described framework and methods, which makes it difficult for teachers, especially young ones, to implement it. The present study aims to fill this gap by presenting the idea of STEAM teaching on the example of eTwinning projects implemented at Kazimierz Nowak Elementary School in Dąbrówka, Poland, and analyzing them in terms of STEAM methodology, assessing the key skills achieved by students, and preparing a scenario for future teachers of an original lesson based on the STEAM model.

We examined the five basic elements that make up the STEAM method in four projects. Students' knowledge and skills before and after the project were compared by conducting in-depth interviews with 16 students. Educational effectiveness was compared with the core curriculum in the partner schools' countries. In addition, the research potential of the year-long project was evaluated. Based on the STEAM projects analyzed, it can be concluded that they provide a base of good practices on which to build an eTwinning STEAM project model, because project activities confirm that the arts can serve as a basis for hypotheses and scientific discoveries, students develop key competencies in many directions, curricula of various subjects are integrated, projects shape in students the competencies necessary for the next stage of education and prepare them to enter the labor market.

Key words: science lessons, STEAM, project method, eTwinning, school-university collaboration, science education

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INTRODUCTION

THE STEAM EDUCATIONAL MODEL

Today, traditional teaching methods have failed to keep up with rapid technological change and are no longer appealing to students. The World Economic Forum outlined the key skills required in the 21st century including complex problem solving, communication, critical thinking and creativity (Soulé, 2015). In order for students to stop having a passive and reproductive role in the learning process, changes in teaching practices are needed. One of the proposed contemporary educational models is STEAM (Science, Technologies, Engineering, Arts, Mathematics), which is a combination of different disciplines that focuses on integrated learning. This interdisciplinary education allows students to learn about the world more effectively (Yakman, 2008).

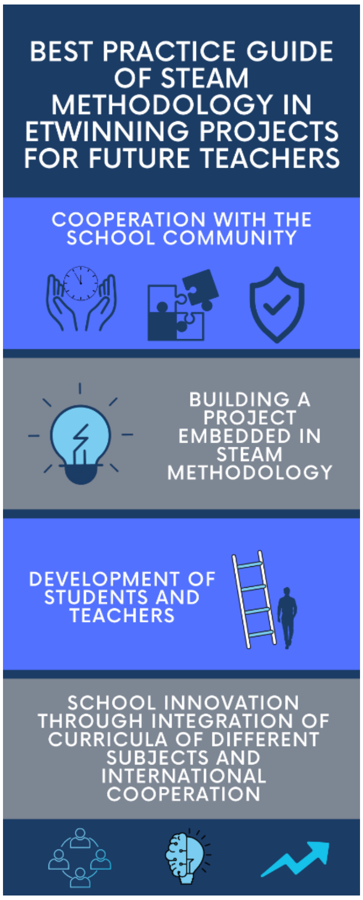

Fig. 1. An infographic with a core of practical advice for future teachers resulting from the analysed projects.

STEAM education is a response to changing realities. Integrating traditional life domains in an accessible way makes students more versatile and creative (Hong 2016). STEAM goes beyond the template of categorising subjects; consequently, the collaboration between disciplines is realistic and dynamic. This makes it easier for students to adapt to the world around them (Repko, 2008). At the core of this teaching method is the integration of knowledge and tools from different disciplines. Using this model allows students to observe, formulate hypotheses, plan, conduct experiments, and finally discuss the results and present them as a group (Herro and Quigley 2017).

STEAM effectively enhances the quality of education by increasing critical thinking skills and creativity, mainly by incorporating the arts into teaching (Perignat 2019). Education according to the STEAM model responds to the changing reality, and interdisciplinarity in teaching makes students more versatile and creative (Hong 2016).

Initially, the STEM education model (aka science club) was introduced in the early 2000s in the US and has been successful in increasing employability (Yakman, 2012). It has been noted that there is a correlation between raising the level of competence in STEM fields among students and the level of competitiveness in the global labour market (Khine, 2019). However, after this model had been in operation for some time, an expansion was proposed to include another discipline – the arts. All in order to stimulate students' creativity. This is how STEAM was created. In later years, it was pointed out that art in projects implemented according to the STEAM educational model is not only used to illustrate the completed activities of students, but also to serve as a tool for discovering scientific facts (Herro and Quigley, 2017). The arts, as a complement to STEM education, improves learning and develops the academic abilities of gifted students in science. The ability to imagine, interpret models and artistic sensibility makes scientific success more effective. A strong correlation has been shown between STEM science specialists and their artistic talent and craftsmanship skills (Root-Bernstein, 2015).

STEAM is currently a widespread education system in South Korea. Students in the country are known for their high scores on international tests like PISA (Program for International Student Assessment), and TIMSS (International Mathematics and Science Study of Student Performance) (Seung Hyun Choe, 2013)

As recently as 2010, Koreans were famous for their low interest in science and mathematics. The Korean Government began reforming the education system by specifically focusing on interdisciplinary teaching using technology. This led to the creation of the Korea Foundation for the Development of Science and Creativity (KOFAC), an organisation under the Ministry of Science, which is developing as a centre for teacher training and student support, promoting interactive and exploratory science activities (Yakman, 2012). In the light of the literature review, the STEAM educational model effectively influences the quality of education by improving critical thinking skills and creativity, mainly by incorporating the arts into teaching. It allows one to experience scientific research, the solution to a problem or hypothesis posed. (Perignat, 2019). STEAM education also benefits teachers by working together to relieve the burden of their responsibilities and the curriculum. STEAM education has been found to strengthen emotional bonds among students and teachers, who together find it easier to adapt to a changing environment. By supporting each other in innovation, teachers motivate each other (Hunkoog, Hong, & Song, 2016). By integrating subjects, the benefits of STEAM teaching for people with learning disabilities have been confirmed. In addition to developing skills and content knowledge, students have become more open-minded and confident by learning about new opportunities in areas of learning.

THE ETWINNING PLATFORM

Education for the 21st century should not only be knowledge-based and should not only take place at school. In 2005 the European Commission created the eLearning Programme, which gave rise to the eTwinning platform. This programme connects European schools - called twinning - that carry out a joint project using information and communications technology (ICT) (Raińska-Nowak, 2010). This involves using computer programmes, educational applications and interactive whiteboards to enrich and enhance the learning process (Afshari, 2009). The twinning project includes elements of curricula for different educational levels and can be implemented in the institution as an integrated cross-curricular pathway, which can correlate with the STEAM methodology.

The eTwinning Plus programme involves all the countries of the European Union, as well as many neighbouring countries, such as Turkey. As a result of cooperation between schools, learning becomes more interesting and students broaden their educational and social horizons (Gilleran, 2006). The use of the platform is a diversification of the traditional way of teaching and plays an important role in the development of psychosocial skills (so-called soft competences) and hard competences, such as language skills, which become more valuable in terms of the student's career choice. A narrow range of formal qualifications does not guarantee success at work, which is why improving soft competences is so important (Smółka, 2008). eTwinning projects lead to the increase of cultural and social awareness and trigger creativity during individual or group work. It is worth emphasising that by using technology (multimedia programmes, platforms and applications) during projects, the learning process becomes more effective (Kearney, 2015). Teachers can become part of this learning community through which they exchange experiences with other educational professionals. The eTwinning platform supports teachers with on-site training and online courses in such a way that the teacher acquires and expands both digital and didactic competencies. Each user of the platform has access to the TwinSpace, which is a space where it is possible to find a project partner and a database of good project practices (Gajek, 2009).

The eTwinning platform, through its wide range of training courses and initiatives, shows great potential for influencing the development of whole school communities, however, this influence remains unexplored. In Europe there are as many as 233 477 schools involved in the implementation of projects using the eTwinning platform (eTwinning Statistics 2021), which proves the high involvement of teachers and principals in their work with these tools.

The aim of this study is to: (1) to investigate the impact of the application of STEAM methodology in international eTwinning projects on teaching effectiveness, (2) to evaluate the learning outcomes achieved by the students participating in the sample project, (3) to provide good practices in STEAM methodology by showing a universal lesson plan based on the methodology in order to increase the quality of the implemented eTwinning projects and to provide an easier start for teachers with no experience in working with this platform. The proposed sample lesson scenario has been designed so that it can be easily implemented in any school.

METHODOLOGY

ANALYSIS OF THE STEAM PROJECTS' MATERIALS

In this study, four annual projects implemented in Kazimierz Nowak Primary School in Dąbrówka (Poland, Wielkopolska) were analysed: Aromatic Garden, Local and global change Agents, ORA-AMA-KO come together! and Wild networking – Wi-Fi of plants and fungi. The projects were carried out in consecutive school years from 2017 to 2021. In total, ca. 250 students from 8 countries took part in all 4 projects (*Local and global change agents*: 90 students, 7 teachers from 3 countries; *Aromatic Garden*: 51 students, 12 teachers from 7 countries; *ORA-AMA-KO come together!* 21 students, 3 teachers from 2 countries; *Wild networking – Wi-Fi of plants and fungi*: 144 students, 13 teachers from 3 countries). Their analysis consisted of an analysis of the projects' websites - thus the materials posted on the project's TwinSpace, including an evaluation conducted after the project was completed.

AN IN-DEPTH ANALYSIS OF THE PROJECT WILD NETWORKING – WI-FI OF PLANTS AND FUNGI

Evaluation of educational effects in the project 'Wild networking – Wi-Fi of plants and fungi'

Two surveys were carried out to verify pupils' knowledge and skills before and after the project *Wild networking – Wi-Fi of plants and fungi.* In total, 15 eighth grade students from Kazimierz Nowak Primary Schools were surveyed. Since 2017, the school has held the National Quality Label and the European Quality Label. At the same time, the institution has become an official eTwinning school. To date, six international, year-long science projects have been implemented.

The first questionnaire was conducted before the project and consisted of 15 questions and referred to the student's knowledge in biology. The second questionnaire was carried out after the project was completed and consisted of two parts, which concerned again the biological knowledge (9 questions) or learning outcomes of the project (10 questions). The questions from the survey can be found in Table 1. Student responses were analysed and visualised in Microsoft Excel.

Table 1. Set of questions in the survey designed for students before the project 'Wild networking – Wi-Fi of plants and fungi (questions 1-15) and after the implementation of the project (16-34)

Question number	Question content	Question type
1	What is your main source of knowledge about ecology? (TV, Internet, school, books, magazines)	Choice
2	Write a word or several words that you associate with the word 'ecology'.	Short answer
3	Are you aware of your environmental activities?	Choice (yes/no)
4	If you checked 'yes' list examples of your environmental efforts.	Long answer
5	Have you heard of the rhizosphere?	Choice (yes/no)
6	If you checked 'yes', explain the concept as you understand it.	Long answer

7	Have you heard of mycorrhiza?	Choice (yes/no)
8	If you checked 'yes', explain the term 'mycorrhiza' as you understand it.	Long answer
9	Do you think plants communicate with each other?	Choice (yes/no)
10	If you marked the answer 'yes', please write how?	Long answer
11	What effect does nature have on human functioning? Mark on the scale.	Scale (1-5)
12	Briefly justify your above answer.	Long answer
13	What impact do humans have on nature and the relationships within it?	Scale (1-5)
14	Briefly justify your above answer.	Long answer
15	Assess the importance of ecosystem biodiversity?	Scale (1-5)
16	Have you increased your knowledge of forest ecosystems?	Choice (yes/no)
17	If you checked 'yes', write briefly about what new things you remembered or what surprised you.	Long answer
18	Assess the importance of ecosystem biodiversity?	Scale (1-5)
19	Briefly justify your above answer.	Long answer
20	What effect do organisms in the forest have on the functioning of trees? Mark on the scale.	Scale (1-5)
21	Do you think plants communicate with each other?	Choice (yes/no)
22	If you marked the answer 'yes', please write how?	Long answer
23	What does the fungus gain during the process of mycorrhiza?	Long answer
24	Explain the term rhizosphere.	Long answer
25	Rate the activities completed during the eTwinning project in terms of attractiveness. Mark on the scale.	Choice (poor/average /good)
26	Mark on the scale how interdisciplinary the project was (it included content from many subjects)	Scale (1-5)
27	How much did you develop your ability to work independently during the project?	Scale (1-5)
28	How much did you develop your group work skills during the project?	Scale (1-5)
29	How much did you develop your math skills during the project?	Scale (1-5)
30	How much did you develop your computer skills during the project?	Scale (1-5)
31	How much did you develop your engineering (design, construction) skills during the project?	Scale (1-5)
32	How much did you develop your knowledge of nature during the project?	Scale (1-5)
33	How much did you develop your artistic skills during the project?	Scale (1-5)
34	How much did you develop your language skills during the project?	Scale (1-5)

RESULTS

ANALYSIS OF THE STEAM PROJECTS' MATERIALS

All of the projects were carried out on the international eTwinning platform with primary school students in grades 5-8, and the events implemented as part of the projects crossed various school subjects (biology, chemistry, geography, mathematics, fine arts, technology, foreign languages, native language). All four projects - (1) 'Aromatic Garden', (2) 'Local and global change Agents', (3) 'ORA - AMA - KO Come together' and (4) 'Wild networking – Wi-Fi of plants and fungi' had elements typical of STEAM projects (Table 2). The main problems solved in these projects were: garden function, ecosystem pollution problem, biological and cultural diversity, and interactions between organisms. The projects were interdisciplinary in all partner schools. The topics covered were related to natural sciences, based on the core curriculum of various school subjects. All projects enhanced students' environmental awareness and cultural knowledge. Using a variety of ICT tools, work was diverse, increasing the effectiveness of the learning. The following ICT programmes were used: Mentimeter; Padlet; Canva; video creation apps; Kahoot; StoryJumper; Minecraft; Arduino; Google Maps; PowerPoint; Ozobots; Coggle; Bubbl.us; WordArt.

The project assignments contributed to the development of critical thinking and cause and effect thinking. Art was present in each of these projects, which engaged and enhanced students' creativity (Table 2). In addition to the educational value, students deepened their social bonds by, for example, sending letters and Christmas cards, and organising online conferences between the communities of the partner schools. Distance and multiculturalism were not a barrier, and thanks to the teachers' integration of the participants, the projects developed not only soft competences, but also language skills.

Table 2. Characteristics of four projects according to the STEAM educational model implemented on the eTwinning platform at the Kazimierz Nowak Primary School in Dąbrówka.

Project STEAM	'Aromatic Garden'	'Local and global change Agents'	'ORA - AMA - KO Come together'	'Wild networking – Wi-Fi of plants and fungi'
Science	• Knowledge of aromatic plants • Aromatic plants (structure, meaning, use, observations) • Raising climate awareness (weather, flora) • Excursion to the botanical garden and Poznań Palm House • Training in setting up compost	• Use of lichen scales in determining air quality • Raising awareness of climate change, its significance and consequences • Write down commitments to stop the changes and implement them • Establishment of an EcoPatrol • Assess and protect biodiversity • Experience: Water quality in natural water bodies • Making compost • A trip to the botanical garden • Lessons about protecting water, forests, air	• Learning about tropical climate, flora and fauna • Chemical experiments in the form of a volcano • Learning about raw materials from tropical countries • Excursion to the Palm House • Experiment on the acidity of water • A geographic look at the biodiversity of Borneo, Amazon, Congo • Deepening climate awareness: EcoPatrol, organic dishes,	• Outdoor workshop about mycorrhiza and communication between plants and fungi • Field classes about the diversity of trees and fungi in the area around the school in Dąbrówka • Reconstruction of the forest ecosystem on the model by detailing the interactions between organisms from the underground and aboveground parts of the forest • Biology experiment: 'Is yeast a living organism?' • Online seminars with researchers from NS State University, Department of Electrical and Computer Engineering on plant communication and fighting fake news

Project STEAM	'Aromatic Garden'	'Local and global change Agents'	'ORA - AMA - KO Come together'	'Wild networking – Wi-Fi of plants and fungi'
Technologies	• Using Padlet, Canva, video creation apps, games: Kahoot, • Creating an alphabetical eBook using StoryJumper • Making photo reports • Sending letters from • 'Aromaticbook' and exchanging them between schools	• Creating action videos • Participation in conferences and thematic webinars • Trip to the Faculty of Biology UAM: laboratory classes on plants • Support for the fire-endangered Biebrzański PN (creation of e-cards sent to the park management) • A trip to Bory Tucholskie (local and regional biodiversity) and making a film about the Ecological School in Bory Tucholskie • Raising awareness and knowledge about renewables during teleconferences with partner schools and creating posters • - Creating an eBook with StoryJumper	• Exploring the rainforest on maps, Google Maps and wizards • Using the Internet to increase knowledge about rainforest biodiversity • Making presentations about Borneo, Amazon, Congo using PowerPoint • Coding and playing with Ozobot's • Creating mind maps using Coggle and Bubbl.us apps • Editing a music video for a project song	• Creation of an eBook using StoryJumper • Creating a word map using WordArt for Safer Internet Day • Using the platforms Mentimeter, Wordwall, Canva, VIMEO, Comicify, Padlet, Animato, • Programming and coding in Arduino • Video montage for Safer Internet Day and summary of project activities • Online seminars with researchers from NS State University, Department of Electrical and Computer Engineering.
Engineering	• Arranging gardens with aromatic plants • Building insect houses	• Design and creation of bird houses • Analysing water quality in natural bodies of water • Recycling cardboard boxes • Building a composter Microscopy • Designing a biogas plant using a 3D printer	• Constructing fauna models • Arranging teleconferences • Designing and building a time machine model • Designing and preparing ecological dishes	• Designing a forest model • Arranging the interaction of the mock-up forest (above and below ground parts) • Planning and conducting experiments on the life activities of fungi (yeast)

Project STEAM	'Aromatic Garden'	'Local and global change Agents'	'ORA - AMA - KO Come together'	'Wild networking – Wi-Fi of plants and fungi'
Arts	• Designing and creating logos, posters, infographics • Knitting ornaments for trees	• Creation of posters and infographics on climate change • Creation of models and graphics drawing attention to the problem of fires on the Biebrza river • Creating WordArt (word cloud images) • Creating an alphabetic eBook using StoryJumper	• Creating posters, infographics, comics • Making models and drawings of animals • Creative coding paths • Singing a composed song with instrumental accompaniment and jewellery that relates to the culture	• Interactive model of a forest ecosystem including underground and aboveground parts (living organisms made of origami, plasticine, paper, everyday objects) • Analysis of natural phenomena by means of artistic expression within the framework of outdoor workshops about mycorrhizae and communication between plants and fungi as well as climate change and field activities • Creating a guidebook on the culture-forming role of trees and mushrooms • Design contest for the project logo and poster • Creation of infographics on cybersecurity • Arranging a virtual herbarium of European trees • Creating a word map using WordArt for Safer Internet Day • Building project community by sending handmade Christmas cards between schools and joint multicultural egg painting before Easter.
Mathematics	• Measuring your garden establishment (surface area, potting volumes, etc.). • Calendar planning (reading and interpreting information from seed packages, among other charts, regarding the seeding performed)	• Analysing source data including percentages of polluted air and water • Analysing deforestation graphs • Planning a calendar • Measuring percentages and using fractions of substrates for chemical experiments	• Review flora and fauna in Borneo, Amazon, Congo (listing species) • Preparing proportions of chemical compounds to create a chemical volcano • Practicing using a scale when making a model • Performing stoichiometric calculations when performing experiments such as investigating water and air quality • Using the pH scale and colorimeter • Planning a calendar • Programming, coding	• Programming and coding in Arduino • Coding an Eco-world in Minecraft • Building a forest to scale • Preparing products, stoichiometric calculations needed for the yeast experiment

AN IN-DEPTH ANALYSIS OF THE PROJECT WILD NETWORKING – WI-FI OF PLANTS AND FUNGI

Among the tasks completed within the project were meetings with scientists, field classes, creating a model forest, Arduino coding classes, teleconferences between students, as well as open-air science-art workshops carried out as part of the 'Wild networking – Wi-Fi of plants and fungi' project. In the Kazimierz Nowak Primary School in Dąbrówka, it was organised for pupils in grades 5-8.

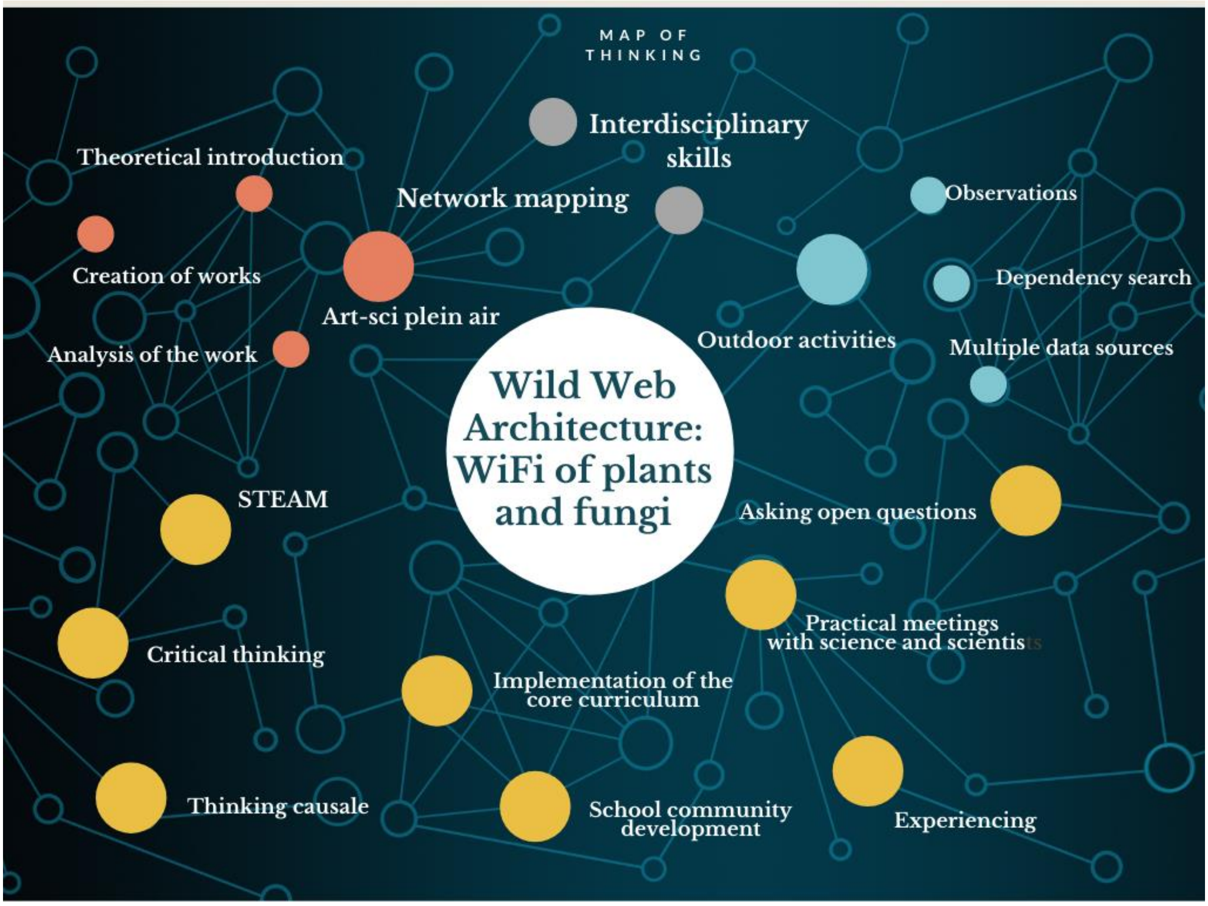

Fig. 2. Mind map presenting the activities of the project 'Wild networking – Wi-Fi of plants and fungi'.

The classes started with a review of botanical and mycological atlases, as well as a theoretical introduction, in which the teacher together with the pupils repeated the issues related to the structure of fungi and plants, mycorrhiza and photosynthesis. Then the communication of trees between individuals of the same species was discussed. Two purposes of sending this information were distinguished: a protective message e.g. against arthropods eating leaves, or a caring message e.g. increasing growth in seedlings of a given species. The conclusion of this part of the lesson was a reference to networking and comparing it to Wi-Fi and fixed Internet connection. After the theoretical part, students could choose a place in the school playground or park, where they will create an artistic work, in which they will include information about communication of plants and fungi. Each student was free to choose the object they wanted to depict on their artwork and the way they wanted to depict it. Students could not support themselves with inspirations from Internet resources during the workshop. They then proceeded with their work, and if they had any questions, they could consult their mentors about their scientific or artistic knowledge or skills. During the workshops, teachers of science, art, English, and also a lecturer from the University of Arts in Poznań were present. The students were given 90 minutes to complete their work.

After completing the practical part of the workshop, the students handed in their work and went home to do the last part of the workshop on communication in the world of plants and fungi. The students participated in a remote connection with researchers from the Faculty of Biology of Adam Mickiewicz University in Poznan, who not only during their lecture referred to the details of the cooperation of plants and fungi in the network, but also to the works created by the students, which were displayed during the meeting. The students included scientific information in the artistic expression they created, which was then pointed out to them.

In addition to the analysis of the questionnaire survey within the project 'Wild networking – Wi-Fi of plants and fungi', a sample lesson plan was created as a set of good practices and a lesson based on it was carried out. The lesson topics included recalling the structure of plants and fungi, learning about the elements that make up an ecosystem and designing forest models through collaboration. Students were involved in developing, planning and preparing a forest model for their region detailing the natural elements: biocenosis and biotope and the networks of interactions that take place between organisms.

The research work checked the presence of all the elements that methodologically make up a STEAM project, namely Science, Technologies, Engineering, Arts, Mathematics, as well as the interdisciplinary nature of the activities undertaken during the projects and their problem-solving. Educational effectiveness was compared to the core curriculum in force in the countries of partner schools. Additionally, for the project 'Wild networking – Wi-Fi of plants and fungi', which was conducted in the school year 2020/21, the research and educational potential of the applied research tool – a year-long project – was presented. The project demonstrates high quality, as indicated by the award in the eTwinning Poland Project of the Year competition.

EVALUATION OF EDUCATIONAL EFFECTS IN THE PROJECT 'WILD NETWORKING – WI-FI OF PLANTS AND FUNGI'

All 15 respondents completed two surveys. For most of the students surveyed (60%), school is their main source of knowledge about nature, followed by the Internet (26.7% of respondents). No student cited magazines or books as sources of knowledge acquisition.

In the pre-test, 100% of the respondents did not know the term rhizosphere. In the post-test, every student knew and correctly defined rhizosphere. In turn, 93.3% of the students knew that plants communicate with each other and were able to argue their indication correctly in both pre- and post-test. Initially, 66.7% knew mycorrhiza very accurately, and after the project 100% of the students could define it.

73.3% of students were able to explain the so-called importance of biodiversity in forest ecosystems. Nature was found to have a significant impact on human functioning (80%) and correctly pointed out examples: without nature, humans cannot survive (without oxygen, food, water, etc.). 73.3% of the respondents recognised the influence of man on the relationships in nature and, as a result, on its functioning.

Initially, 73.3% of the respondents believed that biodiversity was important to the functioning of forest ecosystems, and later 93.3% were able to demonstrate the importance of diversity in nature. The vast majority of students, 93.3% are aware of their pro-ecological activities. The most frequently mentioned pro-ecological activities are segregating waste, using reusable shopping bags, setting up a garden with melliferous plants and composting. A post-project survey of students diagnosed (1) their progress in expanding their knowledge, (2) their acquisition of new information-technology, computer science, mathematics, engineering, language, and art skills, (3) their ability to work independently or in a group, and (4) their ability to evaluate the attractiveness of the project and send feedback. Most students (80%) overall increased their knowledge of forest ecosystems. Among the messages they remembered the most were issues related to plant communication. While 80% of respondents emphasised the importance of biodiversity for the functioning of ecosystems, the rest rated it as good (13.3%) and moderately important (6.7%). Students justified their opinions mainly by the stability and higher resilience of ecosystems to threats, while taking into account the importance of diversity for human functioning. Considering all the organisms in the forest, students said that the interactions between them and trees are very important (100%). As many as 93.3% of the students believe that plants communicate with each other through mycorrhiza, or symbiosis, which was mentioned repeatedly. All the respondents correctly named the gains of fungus during the process of mycorrhiza. Almost every student (86.7%) could explain the term rhizosphere. During the project the most attractive task according to the students was the interpretation of the interactions underground, i.e. the creation of artistic works of art - posters and a model forest, field activities and workshops with the Arduino system. The least attractive task turned out to be creating an eBook, as well as designing a project logo. Meetings with scientists and the creation of a logo were considered a constant, good element of the project. Students rated the extent to which they deepened their skills during the project. Individual work (53.3%) was rated higher than group work (26.7%), which may be related to the fact that the project took place during remote education and educational lockdown.

According to the respondents, their mathematical skills on average (66.9%) developed. The distribution of computer skills development was even on the scale, both weakly, moderately and strongly. 40% of students said that their knowledge of engineering and English was moderately developed. More than half (53.3%) of the respondents had enhanced their knowledge of nature and 66.7% said they had deepened their artistic skills. The project was rated 86.7% as strongly interdisciplinary.

LESSON SCENARIO

The lesson is implemented according to the STEAM educational model.
Grade: 8 primary school
Topic: ‘Natural Wi-fi network - the rhizosphere’.
Time: two lesson units

1. General Objectives: To learn about mycorrhiza and other connections between organisms in comparison to the Wi-Fi Internet network
2. Specific Objectives:

a. Knowledge Student:
   - Defines the term mycorrhiza
   - Explains the term rhizosphere
   - Describes the cultural role of plants and fungi
   - Describes the structure of fungi
   - Lists the dangers of a lack of seeds on and in the earth
b. Student Skills:
   - Depicts the natural network of connections as the rhizosphere
   - Demonstrates biodiversity in forests
   - Compares biocenosis and biotope
   - Distinguishes between elements belonging to a biocenosis and a biotope
   - Analyses the effects of fungi on building biodiversity in an ecosystem
   - Develops skills to speak on a given topic
   - Develops critical thinking

3. Attitudes: The student:
   - Is aware of the value of biodiversity
   - Develops pro-ecological attitudes
   - Contributes to the protection of biodiversity
   - Culturally expresses his/her opinions about

4. Work methods: Discussion, guided conversation, brainstorming, lecture, presentation, working with own resources and model
5. Form of work: individual, group.
6. Teaching aids: presentation, Mentimeter.com, photos, technical and artistic equipment

7. The course of the lesson

The preparatory phase
The teacher checks the attendance, then begins the theoretical part going over the structure of mushrooms and the concept of an ecosystem. In order to activate the students on the Mentimeter.com platform, they have to write down associations with the word Internet (Wi-Fi). Posing a problem question: Are there interactions between organisms? Based on the discussion, conclusions can be drawn about the network that occurs in nature.

Implementation phase
Introduce the terms mycorrhiza and rhizosphere. Implementation of the project: Designing a model of the forest. Brainstorming on how to plan an ecosystem containing a network between organisms and how to distinguish between biocenosis and biotope. Divide students into groups to prepare the various elements: scaffolding of the model, elements of animate and inanimate nature, and networks and assembly. Student work requires the use of each element of the STEAM educational model:
- Science: ecology (biotope, biocenosis, interactions between organisms i.e. mycorrhiza, rhizosphere)
- Technology: Mentimeter.com, film/eBook
- Engineering: construction of a mock-up, connection of underground network, design of forest elements

- Arts: creation and execution of a forest mock-up with elements of animate and inanimate nature and special attention to creating networks between organisms such as plants and fungi
- Math: scale, measurement, area, structural loading

Concluding phase
Checking the quality of the completed forest mock-up, inspecting all elements entering the ecosystem. Emphasising the interaction between organisms, presenting the network and the real representation of reality. The final product of the lesson is the model and the production of a film/eBook on the project with photos.

DISCUSSION

Thanks to the eTwinning platform, education with the help of projects according to the STEAM teaching model increases students' awareness and improves competencies by gaining new skills. Although the potential of the STEAM model is increasingly recognised in schools in different countries, its definition remains ambiguous (Perignat and Kenz-Buonincontro, 2019), it can refer to interdisciplinarity in teaching, but in the future more letter abbreviations may appear in STEAM to denote particular scientific disciplines, attitudes or skills of students. This is an evolving model and is not a closed set. In the analysed projects in Table 2. (Characteristics of four projects according to the STEAM educational model implemented on the eTwinning platform at the Kazimierz Nowak Primary School in Dąbrówka), which were implemented in previous years at the same school with the same students, it was found that they contain all the elements that make up a methodically interdisciplinary STEAM project.

The research showed that students' participation in the 'Wild networking – Wi-Fi of plants and fungi' project enabled them to learn about the diversity of biotic interactions and the process of communication between plants and fungi, while developing soft and hard competencies. This was undoubtedly made possible by using the STEAM educational model and the work of the teachers to plan and designate the main project activities. One of the results of the educational project are students' records in the form of images of biological facts about the formation of interactions, the structure of the root (rhizosphere) and fungal network, the process of communication between plants and fungi and its effects, the diversity of interactions in the ecosystem and human participation in them. The collated student images were presented at the Plant Biology 2020 International Congress. Art can be a tool for discovering and describing scientific facts (Herro and Quigley, 20, 2017; LaJevic, 20, 2013). Like experiments in science, art can provide knowledge about the reality under study (Sharapan 2012, Smith and Paré 2016, Kant et al. 2018, Karabey et al. 2018). Incorporating creativity into STEAM projects shows students the environment in interesting and detailed ways. Our results support the views of other researchers seeking effective educational models and show that arts education promotes learning gains (Remer 1996, Burton et al. 2000, Root-Bernstein 2015, Costantino 2018). Thus, in our opinion, art should be closely integrated with science.

It was found that students, using the STEAM project method, mastered new knowledge at a level higher than the core curriculum for this age group in Poland (Regulation of the Minister of National Education of 14 February 2017 on the core curriculum) and analogously to partner countries Turkey and Portugal. This demonstrates the power of the project, in which art has become a tool for discovering nature and the students' creative potential is developed.

The transdisciplinary project was rooted primarily in the current problem of communication between organisms. The problem of communication also emerged between humans, during the COVID-19 pandemic, which led to increased online communication. For the students, as at present for each of us, learning about the emergence in evolution of communication between plants and fungi, the physiological and molecular mechanisms by which communication occurs, and its importance in the life of organisms can provide a knowledge base for improving online communication in the future. One student aptly illustrated that communication between fungal hyphae and tree roots underground is the equivalent of our Wi-Fi. This is because nature is a base of ready-made solutions created in the process of evolution, which can be a model for creating new technologies to facilitate our online communication. Due to social constraints, online project work skills have been developed. This does not change the fact that many areas of human life and beyond have been improved through connectivity and relationship networking. A survey of students showed that school is their main source of information. It is important to shape their ability to search for reliable knowledge and build social relations, e.g. during The Safer Internet Day. Already at primary school level, students can use scientific journals and scientific literature browsers such as Google Scholar.

The implemented project 'Wild networking – Wi-Fi of plants and fungi' in the school year 2020/21, despite many difficulties due to the prevailing pandemic and distance working, led to a multitude of interactions. Interactions consisted of teleconferences, challenges conducted both nationally and internationally, and maintaining the project website. The content covered related to nature's relationships, which students learned about and experienced through a variety of tools. Organised activities for students and other organised actions helped them to understand the place of humans in the ecosystem and consciously involve students in learning about the ecosystem and taking action to protect it.

The whole enterprise of educational projects is created with the aim of educating and raising young citizens of the world who are aware and open to new opportunities. Very often we forget about the teachers who create and organise all this. Only 30% of teachers admit that they feel appreciated for the work they do. Working according to the STEAM education model is very challenging when the country's traditional education system divides learning into detailed subjects. The teacher's role is to develop the teaching content independently, combining the learning areas into a whole. The organisation of work for the school year must take place in advance and be approved by the teaching staff headed by the principal. Therefore, teachers during the vacations do not sit idly by, but inspire themselves, create new concepts for educational projects and seek cooperation. This involves a lot of organisational effort. The best way to implement the STEAM educational model is for teachers of multiple subjects to work together, e.g. foreign language, mathematics, chemistry, biology, computer science, art, etc. The involvement of teaching staff on team activities strengthens motivation and contributes to the effective implementation of teaching goals (Pitula, Waligóra, 20, 2017). A teacher acting as a mentor for a student often forgets about their own well-being, which can end in professional burnout. Teachers' cooperation can prevent early burnout through social support and relief from responsibilities (Lubranska, 20, 2012). The eTwinning programme, which brings together schools from Europe and teachers eager to collaborate and create innovations, comes to the fore.

All activities embedded in the STEAM methodology allowed for effective integration of knowledge and skills from different school subjects, which confirms the interdisciplinary character. Moreover, this project, which is embedded in the STEAM methodology, raised students' environmental and cultural awareness. Working with the STEAM method is not easy from a didactic point of view, given the small number of biology lessons per week. It requires the teamwork of not only teachers from one school, but in this case teachers from different countries. The completed projects have awakened in students a desire to learn about the diversity of the world. STEAM projects of this kind prove the innovativeness of school activities implemented by teachers, in which not only scientific experience but also artistic experimentation becomes a tool for explaining and interpreting the reality surrounding students. In this way, the message of environmental education is strengthened, and the environmental culture of the young generation is built.

Based on the analysed projects, it can be stated that they constitute a good practice base on which the eTwinning STEAM project model can be built because (1) the project activities confirm that arts can serve as the basis for hypotheses and scientific discoveries, (2) pupils develop key competences in many directions, (3) curricula for various subjects are integrated, (4) the projects develop in pupils the competences necessary at the next stage of education and prepare them to enter the labour market.

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