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STEM centre as a factor in the development of formal and non-formal STEM education

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Abstract. The article is devoted to the study of STEM education. It is one of the important directions of educational reform of the XXI century and can be implemented through the integration of formal and non-formal education. The authors of the paper study the ecosystem of formal and non-formal STEM education. Researchers have identified the main characteristics of this ecosystem such as the harmonious combination of formal and informal components of STEM learning, increasing the motivation of students to STEM sciences, constant updating of educational programs and professional development programs for teachers; use of non-formal education approaches; constant connection with external communities of STEM professionals; building partnerships between schools and non-formal institutions. The authors have developed the main components of the model of functioning of the educational STEM centre as an education ecosystem. In particular, they are educational research, assessment (evaluation), research projects, innovative teaching methods, programs for training, undergraduate education, teacher training, mentoring, services, communications, cooperation, infrastructure, connection, networking. To assess the extent of the impact of various forms of formal and non-formal learning activities on the results of the implementation of STEM education, an expert survey was conducted. The results of the survey are systematized, illustrated with the help of infographics, statistically significant relationships between individual parameters of the proposed model are established. To test this model in practice, an experiment was conducted. It lasted from 2016 to 2020. Researchers have confirmed the hypothesis that STEM education gives the best results due to a combination of formal and non-formal levels. Therefore, their STEM centre promotes STEM education among the general public, training and retraining of educators involved in STEM, development of STEM competencies of pupils and students.

1. Introduction

21st century society is changing quite rapidly. It requires an appropriate level of education. Traditional formal education may not always provide the necessary opportunity to overcome learning problems. As a result, both formal and non-formal education are becoming increasingly important. In the countries of the European Union, considerable attention is paid to the legislative regulation of non-formal education. The development of non-formal education is facilitated by such world organizations as the United Nations, UNESCO, the European Union, the Council of Europe and others. The Memorandum of the European Commission provides recommendations for the development of non-formal education, which is an important component of the concept of lifelong learning, allows young people to acquire relevant competencies and adapt to the challenges of modern society [1].

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Non-formal education is a complement to formal education and is necessary to increase the positive attitude of pupils and students to their meaningful knowledge in various fields, in particular it is relevant for the STEM field. There are a growing number of non-formal STEM subjects (science, technology, engineering, math) around the world. The United States spends more than 3 billion dollars a year on STEM education, with 32 percent of that amount (157 millions dollars) spent on non-formal STEM education [2]. Non-formal learning STEM events for children are organized in different places and contexts, such as museums, libraries, computer clubs, Fab Labs, youth centres, conferences or universities [3].

2. The literature overview

In recent years, various countries have gained extensive experience in the development of STEM education. Analysis and research allow to summarize and present its most significant characteristics. American education strategists T. Lund and M. Steins say there is no need to try to integrate STEM activities into existing learning units. Instead, traditional content blocks should be deconstructed and existing experiences reconstructed using innovative methods of both formal and non-formal STEM learning [4].

To enhance the positive behavior of students in the STEM field, non-formal education has been recognized as a necessary complement to formal education received at the school. J. Petnuchova [5] defined non-formal education as a learning process that is initiated by individuals and is a by-product of more organized activities. It may not have specific learning objectives. A visit to a museum, a summer technology camp and a Girl Scout are examples of non-formal education. Non-formal education allows students to study in a calmer environment, with greater readiness and less structure compared to formal education received at school. These benefits provide the high potential of such training. Mohr-Schroeder et al. reported that students are more interested in choosing a STEM field for a career after participating in non-formal STEM education [6, 7].

Experts J. McConnell and T. Kelly note that a better future for STEM education requires well-trained and proactive teachers who can share their knowledge and experience in teaching and mentoring students. Therefore, they must constantly receive opportunities for professional development. This will help develop their desire and talent to teach STEM [8]. In particular, Farzana Aslam and others believe that participating in STEM education activities helps teachers understand and develop their own sense of identity as STEM professionals. Educational activities enable teachers to interact with leading scientists and gain access to modern research [9].

Universities also implement professional development programs for teachers. The main goal of these programs is to identify key STEM competencies of teachers for the effective use of non-formal education approaches [10]. Teachers are changing the way formal content is conveyed and thus transforming their own STEM learning experience. This allows students to better understand STEM subjects and improve academic performance [11, 12].

Implementing STEM training is too difficult for any single educational institution. Schools in different countries are actively using non-formal educational activities in the field of STEM [13].

Therefore, museums, zoos, nature centres, aquariums, and planetariums are among the thousands of informal research institutions in the United States that regularly engage young people in observing, learning, and using STEM knowledge and skills. This is because they provide a wealth of resources not available in any classroom. As a result, informal research institutions across the United States have partnered with public schools. Affiliate programs cover a variety of STEM subject topics in primary and secondary school [14].

Lithuanian scholars R. Bilbokaite, V. Slekiene and I. Bilbokaite-Skiauteriene noted that during the implementation of education reform in their country, much attention is paid to the development of non-formal education [15]. That's why STEM centres are being created there. According to the experience of researchers, these centres can attract more than a third of all students. The development of research skills in students justifies the need to create an author's STEM centre with open access. More than 90 percent of respondents agreed to take part in the work of this centre. All these students are interested in in-depth study of physics, chemistry, biology, mathematics, computer science, technology. Therefore, they agree to attend a variety of non-formal extracurricular activities. Researchers have identified that the most interesting forms of learning in the STEM centre are self-tests and experiments, participation in research of scientists, solving practical problems in preparation for competitions, exams, teamwork students.

3. The main results of the study

The STEM centre plays an important role on the Ternopil Volodymyr Hnatiuk National Pedagogical University (TVHNPU) campus. It brings together institutional efforts to create the conditions for STEM learning and support consumers of educational services. Scientists of the Department of Computer Science TVHNPU have created a model of functioning of the educational STEM centre (see figure 1). This model was tested during 2016-2020 at the Faculty of Physics and Mathematics of TVHNPU. Research [16] shows that the centre has become the main educational platform for the development of STEM education in our region. In this

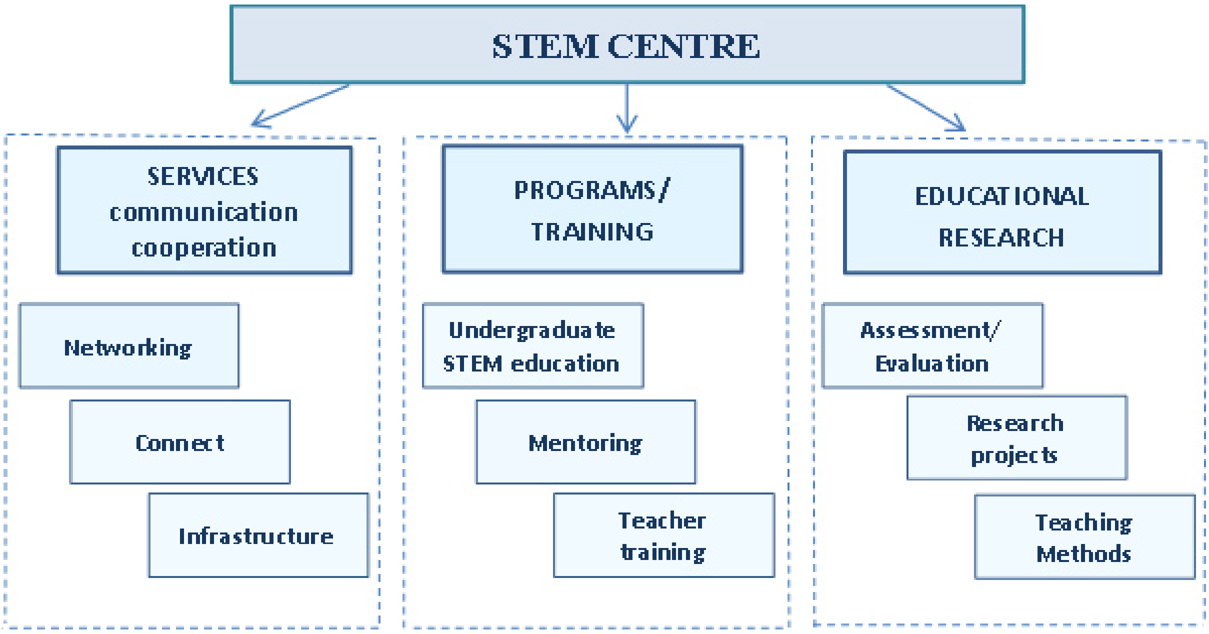

Figure 1. A model of STEM education centre functions.

study, we consider the established STEM centre as an educational ecosystem of formal and non-formal education. We substantiate the use of the concept of ecosystem of formal and non-formal education. Today, the ecosystem approach extends to all sectors of society, including education. The modern model of learning is in crisis. Traditional education needs to change. This is because it is not easy for graduates to find their jobs. One of the solutions may be to develop an ecosystem approach to education and to organize a STEM centre as a provider of such education. Today, the concept of "ecosystem" is still evolving and there is no clear definition. We view the learning ecosystem of formal and non-formal STEM learning as an emerging practice for the future. The educational ecosystem of the STEM centre is a complex entity that includes both the community of education providers and those who learn, develop and evolve, and a new management paradigm for organizing the process of STEM education and training future teachers. This paradigm will help to ensure the maximum realization of the potential of each person and at the same time the maximum demand from society.

We have created a platform for the operation of individual STEM components. The platform was designed and created in a context of diversity of people and initiatives. At that time, there were almost no ready-made solutions for the functioning of individual STEM components as a whole. The STEM Research Centre of the Faculty of Physics and Mathematics has become a place of emergence of initiatives, development of many projects and a platform for communication of various stakeholders. It aggregates resources for teaching STEM disciplines in schools and universities. Members of the centre are constantly searching for methods and approaches to the implementation of STEM, analyze and systematize the various experiences of successful educational STEM practices.

In the process of reforming pedagogical education at Ternopil Volodymyr Hnatiuk National Pedagogical University, we tested and implemented some STEM practices such as

- Cooperation with pilot STEM schools. Each such school has its own unique context, operating conditions, principles. Their implementation characterizes STEM education at the level of an individual school. Scientists of the Department of Computer Science advise the management of individual schools on the implementation of an innovative model of STEM education in their educational institution.
- Effective career guidance among pupils and students. Young people have the opportunity to get acquainted with modern and promising professions, try themselves and decide on their future profession.
- Development of motivating activities such as scientific picnics, Olympiads, competitions, STEM festivals, STEM excursions, STEM workshops, etc.

Let's analyze the main components of the STEM educational centre model as an ecosystem of formal and non-formal education.

Formal component. Educational Research, Assessment/Evaluation, Research projects, innovative Teaching Methods. We focus our research at the STEM centre on improving and enhancing the effectiveness of learning in science, technology, engineering and mathematics through the use of innovative learning strategies. One of the most difficult parts of the STEM curriculum is to create a context for students to gain experience and practice in the process of critical and creative thinking. In our opinion, the use of tools of innovative learning strategies provides an effective methodology for the formation of these high-level thinking skills such as

- Use, recognize and analyze models.
- Focus on inquiry and investigation.
- Communicate effectively.
- Understand multiple connect areas.
- Plan - Act - Understand - Evaluate.

Today we are following such strategies for effective STEM learning.

- Tracking and researching changes over time (changing elements over time, focusing on models and trends).
- Teamwork to solve problems.
- Recognition of the general structure, patterns in different situations (application of ideas in different areas of the curriculum).
- Studying data, finding cause-and-effect relationships.
- Simulation, analysis and data graphs construction.
- Mapping the structure of systems, the use of computer models.

- Use, recognition and analysis of models.

Formal component. Programs/Training. Educational policy in the direction of STEM, educational programs, elective courses. We believe that the basic level of implementation of formal STEM education in the Pedagogical University is the planning of modern educational programs, curricula, individual special courses of choice. Here are some important principles that we use to develop programs for such special courses

- use of "open" tasks that allow students to seek solutions in various fields of knowledge, tasks and problems. There are usually many solutions to these problems;
- moving from solving practical and specific problems to concepts of a higher level of abstraction, ideas and theories;
- use the appropriate mathematical apparatus to find a solution to the problem, focusing on argumentation, proof and logic; application in discussion and solution of problems of digital technologies and computational thinking;
- the possibility of organizing make-up, conducting experiments, constructing from improvised materials using design thinking, engineering design;
- organization of teamwork, presentation of the results to the group, discussion and mutual evaluation in the group.

There is a purposeful reform and correction of educational programs at the Department of Computer Science of TVHNPU. STEM disciplines are included in the programs of specialties "Computer Science", "Mathematics", "Physics", "Chemistry", "Biology". In particular, such special courses are taught as "3D-modeling", "3D-printing", "Design thinking", "Fundamentals of robotics", "STEM projects" and more. They are about the integration of knowledge from different fields, and the development of the practice of students and masters on STEM projects. These special courses are designed to teach students how to solve real problems.

Informal component. Programs / Training. Teacher training. Professional development of teachers in the field of STEM education.

Most teachers receive training mainly in only one discipline. We believe that this is a serious challenge for educators and educational administrators interested in promoting integrated STEM learning. Therefore, retraining of teachers and managers is required to deploy STEM programs. As a result, we organized advanced training of teachers in the STEM centre of the Faculty of Physics and Mathematics. In the STEM centre of TVHNPU we have tested

- training programs for teachers;
- methodologies and methodical materials for employees of educational institutions;
- forms to exchange of experience of teachers practicing STEM education.

These are developments on the introduction of innovative learning technologies, case-technologies, interactive teaching methods, problem-based methods for the development of critical and systems thinking, inquire based learning.

In general, the result of advanced training was the development of STEM education models for different educational levels, the creation of cases of scientific and methodological materials, cases on the implementation of end-to-end STEM subjects and STEM lessons and excursions, mastery of interactive teaching methods, professional competence in STEM training. We believe that training in research STEM practices and the involvement of teachers in real research and engineering university projects "Smart Greenhouse", "Smart Home", "Smart Weather Station" were important. These projects were created jointly by teachers of the Department of Computer Science and Methods of Teaching and students majoring in "Computer Science". All participants in these projects worked together to create models of smart objects, prototyping and researching their capabilities. This means that retraining took place, not in a closed educational system, but in interaction with university scientists. A feature of the practice was the involvement in the educational process of those who can include practice in their actions and show how to do it.

The context and space of modern STEM training is constantly expanding. It is increasingly going beyond the curricula of schools, universities and formal education in general. Ambiguous boundaries between formal and non-formal learning have forced the university and STEM centre researchers to develop clear strategies, practices for combining both formal and various forms of non-formal education such as trainings, workshops, seminars, workshops, excursions, startups, projects, hackathons, distance learning courses, webinars, etc. In the study, non-formal education will be considered in such contexts as Programs / Training. Teacher training; Services. Communications, cooperation.

Non-formal education. Services. Communications, cooperation. Expanding communication on STEM education. The content of this communication is determined by a wide range of issues, from meeting participants, sharing their experiences, identifying problems and difficulties, and ending with communication on new educational content, development of new programs and concepts, etc. Today, a variety of formats of such communication are in demand, such as speeches, discussions on current issues, exchange of experiences and presentation of methods, techniques, practices, working groups and joint projects. All these issues need to be discussed.

In our opinion, various actors must be involved in the promotion and implementation of STEM education. These are government agencies, local communities, small businesses and corporations, individual educational institutions and networks, public associations, associations and professional communities, individual educators. Each of them chooses his strategy of action, taking into account the general situation, their own interests and capabilities.

Such cooperation within the STEM centre was conducted by teachers of the Department of Computer Science of TVHNPU in cooperation with the Institute for Modernization of Educational Content of the Ministry of Education and Science of Ukraine (Kyiv), Ternopil Municipal Methodological Centre for Scientific and Educational Innovations and Monitoring, Ternopil City Administration Education and Science, the Department of Education and Science of the Ternopil Regional State Administration, the Directorate of General Institutions of Secondary Education of the United Territorial Communities.

To create and develop relationships between different actors, we have considered factors such as

- building links between different educational institutions and academic entities to allow students to participate in internships and work on real projects;
- construction of effective communications according to the scheme university - school - community - regional government;
- creating continuity in STEM processes from school to university; this is a factor in increasing the applied value of choosing STEM professions;
- organization of various events for active communication, exchange of experience and search for partners for joint action; creation of resource platforms where new developments, models, samples are concentrated; so they become available for study and application;
- educational management, grants, leadership in education; promoting STEM education among the public and especially among adolescents and other potential stakeholders.

One of the interesting startups to promote ideas about STEM education was the grant project "Promotion of STEM professions". It was supported by the British Council's Active Citizens program. Within the framework of this project, the organization of interactive educational excursions, field schools, forums, festivals, STEM workshops took place. The organizers of these events demonstrated new initiatives, achievements and prospects in the development of STEM professions. The startup has increased the awareness of secondary school pupils with some STEM professions. Among them are a 3D printing engineer, an architect of the Internet of Things, a civil engineer. As a result of the project, more than 300 high school pupils from Ternopil and Ternopil region were involved. This project has helped increase the number of students of mathematics, science, technical specialities at universities in our region. We anticipate that universities will be able to train future professionals with STEM skills. They will be ready to implement modern innovative projects in Ukraine and abroad. Conducting educational campaigns aimed at promoting STEM professions will provide an opportunity to realize the creative potential of young people to solve problems in non-standard ways, focusing on the needs of communities, to ensure their sustainable development.

4. Study results and statistical processing

To achieve the research purpose, we carried out a survey study that targeted highly experienced teachers, methodologists and instructors (i.e., experts) of informal and non-formal learning type, who have sufficient experience in the field of STEM education. We followed an intensity sampling approach and collected responses from 130 experts from educational institutions of our region. The experts were recruited electronically through e-mail or were personally approached and invited to participate in the study during various educational events held in the STEM centre of our faculty for educational institutions of the region in the framework of formal and non-formal education.

In order to design our survey, we first investigated the nature of formal and non-formal STEM education across the existing literature and established several dimensions. The study dimensions analysed in this paper, with the related survey questions and predetermined responses categories, are displayed in table 1.

We divided the educational achievements of pupils and postgraduate students into four categories, which we described in more detail in table 2. The postgraduate students are teachers who improve their professional skills in various courses, trainings, seminars, etc.

Experts could make multiple choices by answering questions of our survey. The survey data are entered in the Excel table, which can be accessed using the link `https://docs.google.com/spreadsheets/d/1wvUPRLJKRvhepn_xpVZIxPevLNqRV2cc`. The obtained data were grouped and summarized according to the required criteria for the study. For statistical processing of the received data and their graphic visualization the IBM SPSS Statistics v23 software was used.

Generalized information on the particle (as a percentage of the number of experts surveyed) of subjects in the study of which methods of formal and non-formal STEM education are used is given in table 3. It shows that there are only 2 subjects in which STEM education methods are used the most. This is mathematics and computer science, which is quite natural in terms of the fundamentally of these subjects in STEM education.

According to experts, the goal of educational activities is not always achieved according to the success criteria specified in the survey (see table 4). Experts believe that the result of educational achievements according to criteria P1, P2, P3 and P4 does not exceed 50%. The lowest achievements are according to criterion P4 (Professional and innovative qualities) - 27.69%. This is due to the target audience of the study - primary school pupils, secondary school pupils and teachers who are involved in activities to improve professional skills in the field of STEM education. Students from higher education institutions were not involved in our study, as a completely different list of subjects taken from university curricula should be used to assess their STEM achievements. This is the subject of a completely different study.

In terms of formal and non-formal education, the coverage of curricular subjects is shown in figures 2 and 3.

When using STEM methods of education, the ratio of formal and non-formal learning

Table 1. The investigated dimensions and the related survey items and response categories.

Dimension	Survey question	Predetermined responses
Categories of experts	What category of experts do you belong to?	**PST:** Primary school teacher **SST:** Secondary school teacher **HSL:** High school lecturer **AV:** STEM education ambassador or volunteer **IM:** Instructor or methodologist
Target audience categories	What target audience did you work with in formal and non-formal STEM education?	**PSP:** Primary school pupil **SSP:** Secondary school pupil **PGS:** Postgraduate student
Covered curricular subjects	Please indicate which curricular subjects are covered during the activity	I explore the world / Technology / Mathematics / English (or another foreign language) / Literature / Art / Physics / Chemistry / Biology / Geography / Computer Science / Humanities and social sciences
Learning activity type	What type of learning activity do you use?	Formal Non formal
The purpose of learning activities	What qualities or competencies have you been able to improve as a result of your work?	**P1:** Competences in natural sciences and technologies **P2:** Personal and communicative qualities **P3:** Socio-pragmatic motivation **P4:** Professional and innovative qualities

activities reaches half for most of the subjects covered (see figure 3). Only for the humanities and social sciences, the percentage of non-formal learning activities is much lower (only 28.57%). This is due to the specifics of the subject and the willingness and the readiness of teachers to use the methods of STEM education in teaching their subjects.

If we analyze how much the purpose of educational activities is achieved in terms of STEM education, the following conclusions can be drawn on the basis of survey data (see figure 4). P1 competencies are best formed when using methods of STEM education in such subjects as "I explore the world", "Technology" and "Mathematics". This is a logical conclusion, if we take into account the characteristics of the P1 competences and the content of these subjects. For natural sciences ("Physics", "Chemistry", "Biology", "Geography") and "Computer Science", P1 competencies are observed at the level of 30 percent. The formation of P2 qualities is best manifested (more than 50%) in the study of "English" (or another foreign language), "Literature", "Art" and "Humanities and social sciences". At first glance, the formation of P3 qualities (from 28% to 52%) may seem a bit strange when studying the subjects "Physics", "Chemistry", "Biology", "Geography" and "Computer Science". But this is due to the fact that the study of these disciplines in the framework of STEM education uses the project method, which is often focused on solving practically significant problems of economic, social, environmental content. P4 competencies are formed at the level of 10% to 25% in all subjects,

Table 2. The investigated dimensions and the related survey items and response categories.

P1: Competences in natural sciences and technologies	**P2: Personal and communicative qualities**	**P3: Socio-pragmatic motivation**	**P4: Professional and innovative qualities**
• mathematical competence; • competencies in natural sciences; • interdisciplinary approach, integration of knowledge from different disciplines; • design skills; • possession of digital tools and information technology; • algorithmic thinking; • possession of modern programming technologies	• organizational skills; • ability to cooperate; • ability to make optimal decisions; • developed skills of critical thinking; • use of digital communications; • ability to lead a discussion; • presentation qualities; • ability to reflect	• prospects for successful employment; • the presence of purposeful motivation for creative self-development and lifelong learning; • steady interest in natural and mathematical sciences and engineering (motivation to continue education in science and technology); • vital competencies necessary for successful self-realization; • social and civic activity; • environmental literacy and healthy living	• skills of design and research activities; • mastering the techniques of modeling and engineering design; • ability to select tools, methods and technologies for solving practical problems in accordance with the needs of a particular professional activity; • understanding the importance of STEM education for professional activities; • readiness to accept and implement innovations in professional activities; willingness to solve practical problems that meet the modern needs of society

except “I explore the world”. The subject “I explore the world” is studied in the first grade and at this age it is too early to talk about future career guidance.

As can be seen from figure 5, methods non-formal learning activity in the field of STEM education are most often used (68% - 70%) with primary and secondary school pupils. For teachers who are undergoing training in the field of STEM education, the methods of learning activities in the vast majority of cases (approximately 75%) are traditional, formal.

If you work with the target audience of categories PSP, SSP and PGS within the STEM education, then in 50 percent and more cases the formation of educational achievements

Table 3. Percentages of covered curricular subjects.

I explore the world	Technology	Mathematics	English	Literature	Art	Physics	Chemistry	Biology	Geography	Computer Science	Humanities & social sciences
10.77	15.38	47.69	16.15	13.08	16.15	18.46	15.38	20.00	15.38	52.31	10.00

Table 4. Percentages of the success indicators of learning activities.

P1	P2	P3	P4
46.92	32.31	36.92	27.69

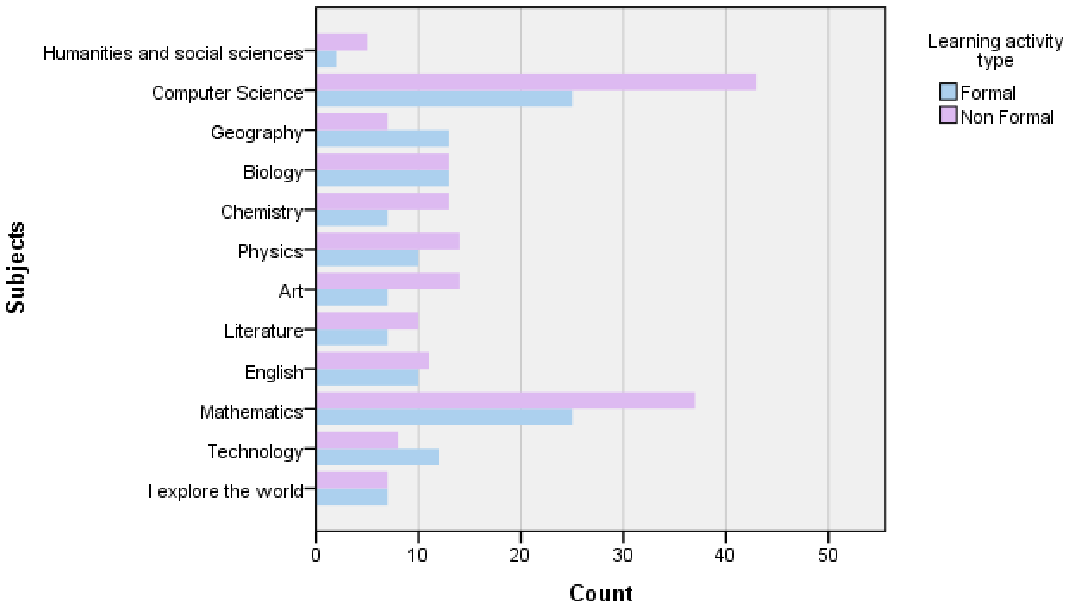

Figure 2. The coverage of curricular subjects by formal and non-formal education (absolute values in the number of observations).

according to criteria P1 - P4 is provided by methods of non-formal learning activities (see figure 6).

For investigating whether the type of the learning activity can be associated with the target

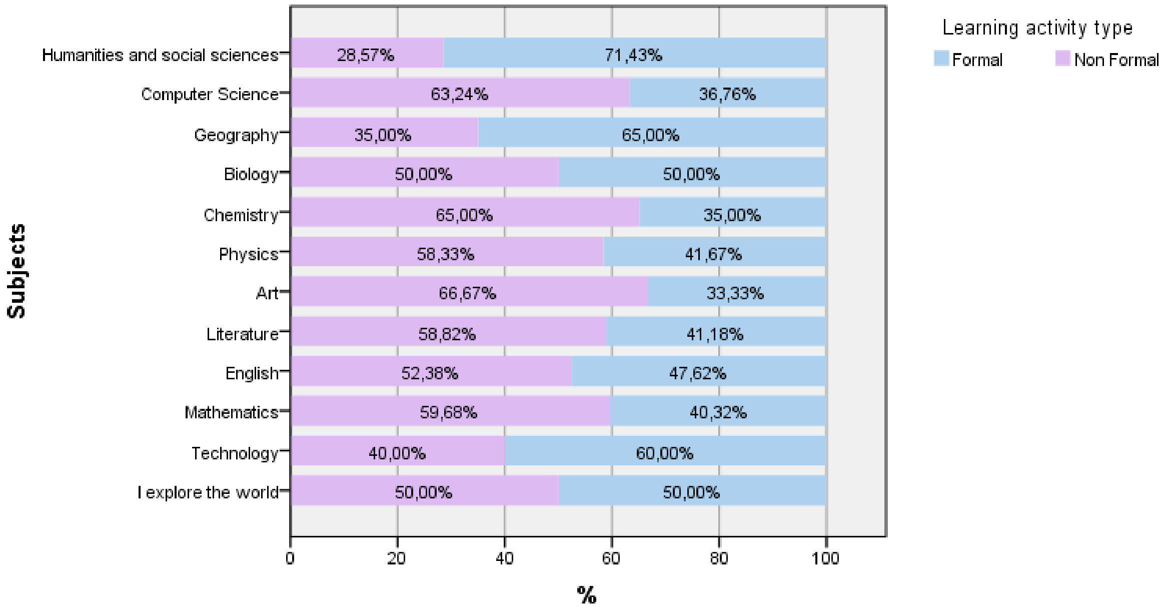

Figure 3. The ratio of formal and non-formal learning activity in the study of curricular subjects.

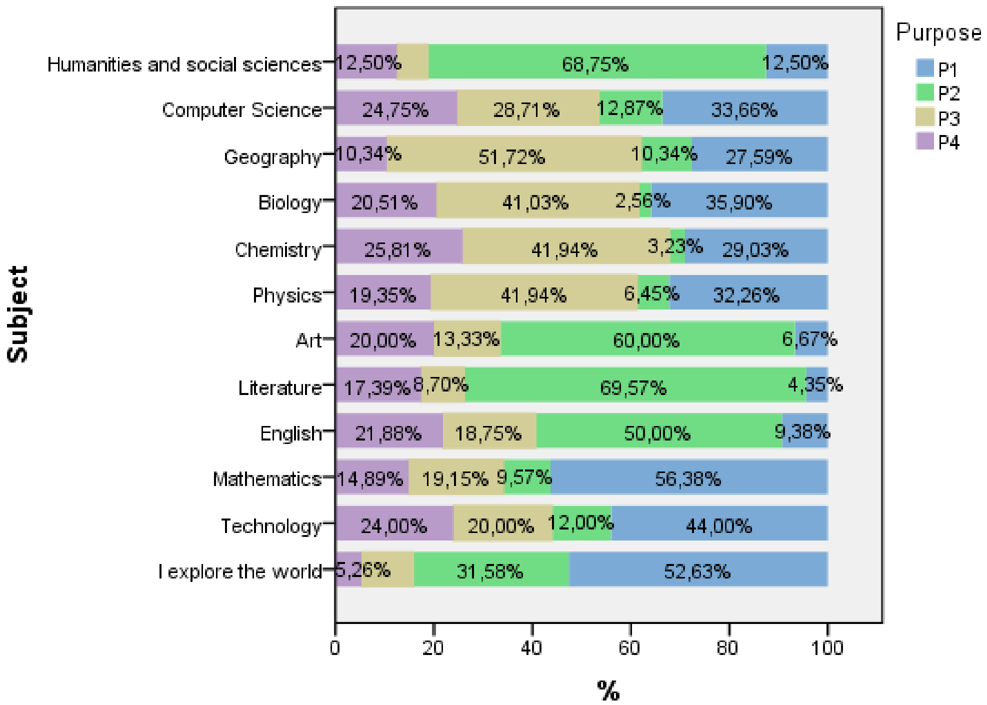

Figure 4. Achieving the purpose of learning activities.

audience, the covered curricular subjects, and the main purpose of the activity, we applied Spearman's correlation analysis. Crosstabulation Subject – Purpose is shown at table 5. At the intersection of rows and columns is the number of relevant observations (cases).

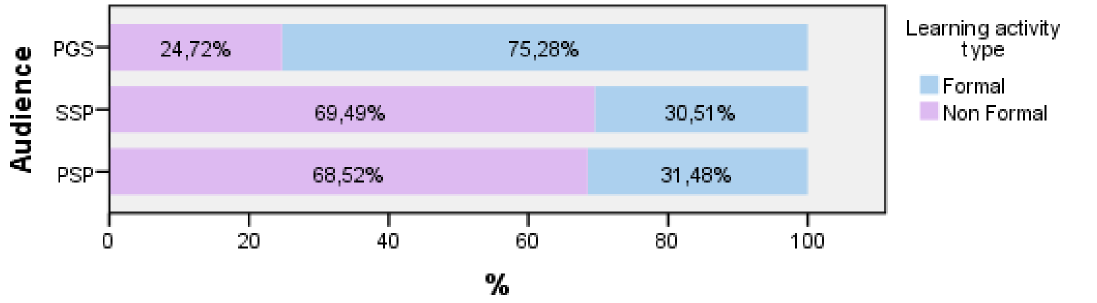

Figure 5. Coverage of the target audience by methods of formal and non-formal learning.

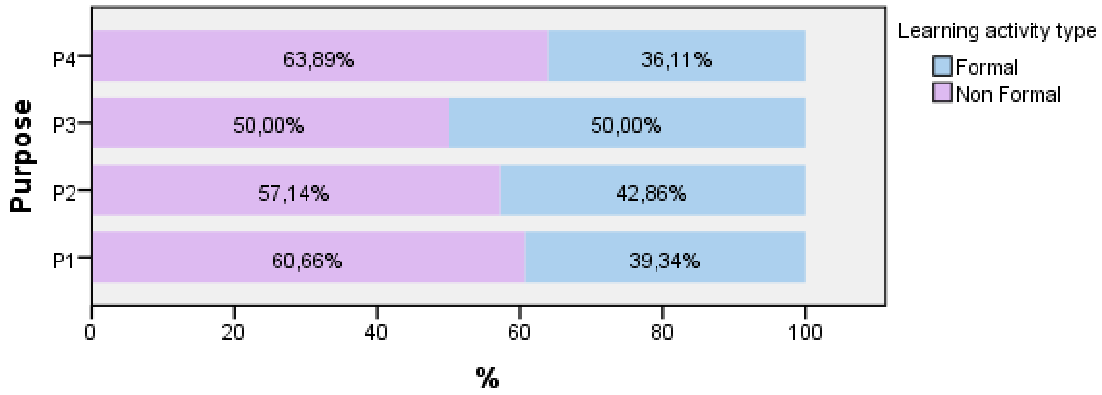

Figure 6. Coverage of the target audience by methods of formal and non-formal learning.

Table 5. Percentages of covered curricular subjects.

Subject	**Purpose**				**Total**
	P1	**P2**	**P3**	**P4**	
I explore the world	10	6	2	1	19
Technology	11	3	5	6	25
Mathematics	53	9	18	14	94
English	3	16	6	7	32
Literature	1	16	2	4	23
Art	2	18	4	6	30
Physics	10	2	13	6	31
Chemistry	9	1	13	8	31
Biology	14	1	16	8	39
Geography	8	3	15	3	29
Computer Science	34	13	29	25	101
Humanities and social sciences	2	11	1	2	16
Total	**157**	**99**	**124**	**90**	**470**

The obtained results (r=0.15; p=0.001) suggest that there is a connection between the achieved learning outcomes and the subjects in the study of which the STEM approach was used at the level of significance 0.001 (statistically significant level). The value of the correlation coefficient r=0.15 shows that the relationship between the achieved results and the subjects at this stage is still weak. This situation can be explained by the fact that STEM education is currently at the initial stage of implementation in terms of its coverage of the vast majority of secondary education institutions. There are only a few training centres where STEM education yields significant results, as these centres have a well-developed relevant infrastructure and interested and trained staff. Cramer's coefficient $V = 0.355$ with the level of statistical significance $p = 0.000$ indicates a positive relationship between the purpose of learning and subjects. It is obvious that this connection will be stronger if the STEM approach in the teaching of school subjects is implemented in further with greater concentration of efforts of all persons involved.

Table 6. Crosstabulation Audience - Subject

Subject		**Audience**		**Total**
	PSP	**SSP**	**PGS**	
I explore the world	10	0	2	12
Technology	10	2	4	16
Mathematics	12	26	13	51
English	4	9	5	18
Literature	2	8	5	15
Art	3	8	6	17
Physics	0	17	4	21
Chemistry	0	10	4	14
Biology	0	15	6	21
Geography	0	15	4	19
Computer Science	5	34	15	54
Humanities and social sciences	0	8	3	11
Total	**46**	**152**	**71**	**269**

We examined whether a relationship exists between the target audience and the covered curricular subjects (see Table 6). For examining the association of the variables a chi-squared independence test was used (Cramer's $V = 0.408$, $\chi^2(22) = 89.522$, $p = 0.000$), which shown that significant association between the target audience and the covered curricular subjects exists.

5. Conclusions

The analyzed current domestic and world practical experience in the implementation of STEM education shows that the implementation of STEM - learning is too difficult for any individual educational institution. Therefore, schools in different countries, along with formal, actively use non-formal education in the field of STEM. The main characteristics of the integration of formal and non-formal education are highlighted in the paper. The study created a model of integration of formal and non-formal education at the level of educational environment, content, relevant educational processes and tested it on the example of the functioning of the educational STEM centre as a whole ecosystem. It includes educational research, assessment/evaluation, research projects, innovative teaching methods, programs/training, STEM education policy, educational programs, elective courses, undergraduate STEM education, Teacher training, Mentoring, Services, Communications, Cooperation, Infrastructure, Connect, Networking. The functioning of the research STEM centre of TVHNPU according to the proposed model of the educational ecosystem has led to: creation of a modern educational environment: STEM learning tools, e-learning courses, STEM projects, STEM cases, which provide personal and developmental content of learning; involvement of students in solving real problems and situations by means of computer mathematical modeling, (international project DEDIMAMO); promoting the concepts of STEM education among the general public, increasing the intensity of communication on the topic of STEM education; proper training of teachers and professional development of STEM educators to work in new integrated conditions, development of technological, career and life skills, skills in the field of advanced technologies. The study shows that the results of the introduction of STEM methods of education in the teaching of school subjects are influenced by various forms of both formal (to a lesser extent) and forms of non-formal learning activities (to a lesser extent). The impact of the use of STEM education methods on learning outcomes according to the criteria proposed in the surveys is statistically significant, but this link is currently weak. This is due to the fact that the introduction of STEM education in the study of school subjects is relatively recent and it is too early to talk about the massive scale of implementation. The further development of STEM education requires the concentration of efforts of all parties involved in education for the development of appropriate infrastructure (according to the proposed model) and the training of motivated teachers. In the future, research is relevant on the inclusion in educational STEM programs of practitioners who have good STEM skills and have their own experience of going beyond traditional teaching practices.

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