BABEȘ-BOYLAI UNIVERSITY

FACULTY OF PSYCHOLOGY AND EDUCATIONAL SCIENCES

DOCTORAL SCHOOL "DIDACTICS. TRADIȚIE. DEVELOPMENT. INOVATION"

STEM-BASED INTEGRATED APPROACH THROUGH SERVICE LEARNING PROJECTS IN PRIMARY SCHOOL

Doctoral thesis abstract

Doctoral student: Marinela Lenuța Bărnuțiu (actual name, Sârca)

PhD supervisor: Prof. univ. dr. habil. habil. Liliana Ciascai

Cluj-Napoca

2024

CONTENTS

Introduction

The doctoral thesis entitled "Integrated STEM-based approach through service learning projects in primary school" is structured in six chapters divided into two main parts: theoretical clarifications and research. Part I starts with an introduction to the topic of the thesis and an argumentation on the choice of the topic after which the issues of integrated approach to learning content, STEM education and service learning are explored in depth. The first chapter analyzes the history of integrated teaching-learning, the opening of the school curriculum towards the integrated approach, practices of the integrated approach at home and abroad with application to the primary cycle. The second chapter presents the general framework of STEM/STEAM/STREAM education and the third chapter defines community service (CS) projects. The second part of the thesis describes the research conducted, organized into three categories: preliminary research, formative intervention, and extension research. Chapter four presents the preliminary research that guided the organization of the formative intervention with the two groups of students, experimental and control. Chapter five presents, in detail, the experimental research carried out at the level of experimental and control classes in the county of Sălaj and the valorization of the model identified by the previous research in an intervention carried out at the level of beginning teachers. The last chapter includes general conclusions on the research carried out, the relation of the realized research results to the international ones, as well as the original contributions, limitations and future research directions.

Keywords: integrated STEM approaches, STEAM/STREAM, service-learning projects, intervention, teachers, students, primary education.

Argument

Pupils, especially primary school pupils, are full of curiosity, energy and a wealth of information, but the current education system no longer meets all their knowledge needs. The raw transmission of some knowledge is insufficient, these generations need to develop interdisciplinary skills in order to cope with the demands of tomorrow's society. As a result the integrated STEM approach with its STEAM/STREM/STREAM developments (Science, Technology, Reading/Robotics/Reflective Learning, Engineering, Arts and Mathematics) seems to be a solution for school knowledge and implies *recalibration of* education systems at home and abroad. Moreover, students' increasingly poor results in PISA tests are a reason for reflection and reform of the education system.

Specialized studies confirm the effectiveness of STEM education, which is successfully applied in many developed countries around the world. The challenges faced by today's society and the relation of schooling to preparing for the professions of the future make STEM literacy a must. Countries such as USA, UK, Japan, Indonesia, Indonesia, Thailand, Singapore have long been turning their attention towards such literacy (Bybee, 2010; Pimthong & Williams, 2018; Royal Society, 2014; Tang & Williams, 2019).

The new educational policies in Romania promote, in addition to the general competences: "learning to know", "learning to be", "learning to do" and social responsibility, i.e. "learning to live together with others". One of the greatest needs of the Romanian education system is the successful application in practice of the knowledge and skills acquired in the instructional-educational process, by supporting the members of the community to which they belong. Pupils leave school with a considerable amount of knowledge, but find it very difficult to put it into practice in everyday life (Ministry of Education [MoE], 2023; Oros, 2023).

In recent years, education specialists have been promoting volunteering and community service learning projects (SLP), a new methodology that is not just about "doing" but about "doing well", being effective, being an "agent of change". The promoters of these initiatives are NGOs, which have started to implement educational projects that challenge students to learn through service learning in the context of broad STEM projects; the heart of these learning projects being the very solving of common problems using the skills acquired in school (New Horizons Foundation, 2021, p. 9).

In our country, attempts to implement STEM-based education and SLP are sporadic (a few teachers with initiative and NGOs, a few training programs), in contradiction with international educational practices that systematically promote STEM in education. Integrated STEM approaches are based on the consideration that the world cannot be discovered and understood by students only through the perspective of a single discipline, i.e. disciplinary approaches. Most of the problems encountered in life, in today's and tomorrow's society, require knowledge and skills from STEM and SLP domains. The integrated STEM approach together with SLP develops students with the necessary real-life problem-solving skills, enabling them to access future STEM careers designed to benefit the community (Bărnuțiu & Ciascai, 2020; Gumenykova et al., 2019; Margot & Kettler, 2019; Mirea et al. 2021).

Chapter 1. Teaching-Learning based on Integrated Approaches

Since the beginning of the 20th century, progressive movements in both Europe and America have sought to remedy the disadvantages of class and lesson-based education by promoting integrated approaches. Curriculum integration has attracted the interest of scholars since the last century, J.J. Rosseau (1700) advocated a curriculum that would be tailored to the needs and interests of the students, based on the specific learning experiences of everyday life. A few decades later, J.Fr. Herbart took a further step towards an integrated approach by arguing for the need for "subject correlation" (Ciolan, 2008).

In the early 1900s, the emergence of new trends in pedagogy represented by inquiry and discovery-based learning, as well as the theories of Meredith Smith and John Dewey that referred to experiential learning, paved the way for the integrated approach (Kysilka, 1998; Ciolan, 2008).On the European continent, more specifically in Belgium, the pedagogue Ovide Decroly proposed a model of content organization that focused on the formation of interest centers that target themes grouped around basic needs. Freinet continued Decroly's method, calling it the interest complex method. Freinet's contribution to European educational practice has thus become significant.

In 1935, the National Council of Teachers of English (NCTE) attempted to define the process of integration. According to NCTE, integration is about combining content with everyday learning experiences. In the same vein, Drake and Burns, in their book Meeting Standards Through Integrated Curriculum, gave a very simple definition of the integrated approach as "making connections between subjects and real-life issues" (Drake & Burns, 2004, p.8).

Successful social integration, today and in the future, can no longer be achieved through monodisciplinary learning, the integrated approach is important (Borzea, 2017). The interest in the integrated approach has returned as a topical one. In the formation of the contemporary human personality, it is necessary to focus in education on complex issues and gradually adopt new teaching strategies aimed at leading to the development of integrated approaches to the teaching-learning process (Csorba, 2013, p. 21).

Internationally, developed countries tend towards an integrated curriculum. Such an education meets the expectations formulated by the OECD (2018, p.2): school should prepare students for occupations that do not yet exist, for the use of technologies that have not yet been created, and for solving problems that cannot yet be anticipated. Curiosity, motivation for learning, the practice of deep learning, metacognition and self-regulation, open-mindedness and respect for oneself and others are traits that define the profile of the pupil prepared for tomorrow's society.

The Finnish curriculum reform (The Finnish National Agency for Education, 2014) also proposes a hybrid approach at the small school level. Within this Finnish pupils acquire competences in individual knowledge areas and transversal competences. Multiliteracies, ICT skills and entrepreneurial skills are indispensable for 21st century education. The last competence refers to the participation of young schoolchildren in realizing a sustainable future with a view to shaping environmentally responsible behaviour. The Finnish curriculum aims to develop a set of democratic knowledge and values. The development of thinking and learning to learn skills, cultural competences and respect for the fundamental rights of human society are the most important transversal skills/competences targeted by the new integrated curriculum.

The Swedish curriculum aims to develop students' values and knowledge with an emphasis on promoting human rights and fundamental democratic values. It is adapted to each child's needs and focuses intensively on developing the ability to empathize, promoting originality and expressiveness.Self-confidence, creativity and curiosity are stimulated through play and problem solving. The ability to take initiative and take responsibility is a specific teaching activity designed to develop Swedish pupils' independent working skills. Developing digital skills is essential, along with developing an understanding of cultural diversity within the country.

American education is centered on the slogan "No Child Left Behind (NCLB)" and focuses on reading and math, with other areas of instruction receiving less attention. Learning standards guide states and school districts on the goals students must meet in order to reach Adequate Yearly Progress (AYP). Curricula differ from state to state. School districts also select curriculum guides and textbooks that reflect a state's learning standards. Many U.S.

teachers use innovative strategies such as discovery learning, inquiry learning, experimentation, and other methods designed to develop critical thinking, promoting integrated approaches (Bărnuțiu-Sârca & Ciascai, 2021; Hasni & Potvin, 2015; Lamberg & Trzynadlowski, 2015).

The curricular reform in Romania, applied in 2013 to the primary cycle, has updated and adapted the contents and teaching strategies at the level of all curricular areas. One solution seems to be the integration of curricular areas and subject contents, as a result of which teaching-learning activities require reorganization. The classic monodisciplinary lessons are being replaced by integrated activities at the level of a day or a week, if the contents allow it. The design and organization of integrated educational activities should start from the problems and challenges of everyday life and not from the academic aspects of the study disciplines specifies the Ministry of National Education [MEN] (2013).

Education experts have not come up with standard models for developing and organizing integrated activities that can be used in the classroom, requiring creativity from the teacher. On the website of the Ministry of Education there are some examples of activities that can be proposed to primary school students, but they are organized in a classical monodisciplinary manner, but using innovative teaching strategies (Bărnuțiu-Sârca & Ciascai, 2021).

The Romanian curriculum approach at primary level is predominantly integrated in the first three years of study. In the last two years of study and in the middle and high school cycles, the transition to a monodisciplinary approach is made. The first three years of primary education aim to build fundamental literacy and numeracy skills, while the last two years aim to build the basic skills needed for further education. Science is studied from the fourth year onwards, and in the last year pupils learn the basics of history and geography. Throughout the 5 years of study, Romanian pupils participate in English, arts, moral and civic education and music. In second and fourth grade, pupils are subject to national tests (Cucoș, 2014; MEN, 2013).

In an integrated approach the teacher has to think, over the course of a week, broad, multi-, inter- and transdisciplinary activities and design integrated activities based on the disciplines of language communication, mathematics and environmental exploration, visual arts and practical skills and music and movement. As a result, mathematics is studied in direct relation to the natural sciences; the lessons aim to approach a topic from several disciplinary perspectives. For example, in a Communication in Romanian lesson, in addition to objectives aimed at developing communication skills in Romanian, specific objectives are proposed for mathematics, science, arts, music or even physical education (Bărnuțiu-Sârca & Ciascai, 2021).

Over time researchers have described several levels of curriculum integration. Drake and Burns (2004), Ciolan (2008) and Borzea (2009) describe multidisciplinary, interdisciplinary and transdisciplinary curricular approaches.

Vasques' model of levels of integration (2014) extended by Delaforce (adaptation, 2016) mentions five broad levels of integration. Starting from the already known levels, monodisciplinarity, multidisciplinarity, interdisciplinarity, transdisciplinarity the authors add a new highly complex level namely neodisciplinarity which aims at creating new sets of knowledge and skills that help students to solve real problems in everyday life.

At primary level, integrated activities are essential in terms of pupils' constant need to discover and explore the world around them. This is a time when young children are bursting with curiosity and their receptiveness and interest in the new is at its peak. The way in which teachers deliver information, knowledge and content is the hallmark of a complex, responsive, dynamic and flexible educational activity. More often than not, primary school teachers conceive a vertical integration at the expense of horizontal integration, which is more difficult to conceive and apply in the classroom (Ciolan, 2008). Also, the way frequently used by teachers to implement the integrated approach in the classroom is to organize integrated educational projects over longer periods of time or to use thematic instruction (using a theme as a one-day organizer).

According to Drake and Burns (2004), the teachers who will put the models of the integrated approach into practice are those who are always looking for innovative and interactive teaching-learning-assessment strategies, teachers who are constantly asking themselves how they can actively involve students in the teaching process. Integrated approaches involve the use of collaborative strategies to stimulate creativity and critical thinking in young learners. Implementing integrated activities at primary school level is extremely demanding work for teachers. In developing and implementing such an activity, the teacher has to make use of a variety of material, financial and human resources, innovative methods and processes, and collaborative forms of organization. The strategies must also be chosen in such a way as to facilitate the formation of interdisciplinary skills in young schoolchildren: teamwork, entrepreneurship, critical thinking, problem-solving, decision-making, etc.

In an ever-changing society, the obstacles and difficulties that pupils will face in 30 years' time when they enter the world of work cannot be anticipated with any certainty, especially as in 20-30 years' time some of the existing professions will disappear and others will appear which have not yet been invented. It is up to teachers to equip pupils with a set of "survival" tools (Paul, 2020, p.5). Consequently, it becomes particularly important for teachers to communicate continuously and openly with their students, to support them in solving new problem situations and to appreciate the effort and solutions found (Pâinișoară, 2017).

Chapter 2. STEM/STEAM/STREAM education

The challenge for the modern world is *accelerated change*, and massive technologization has forced education systems around the world to adopt curriculum reforms based on key objectives such as scientific, technological and engineering literacy.

Tomorrow's citizens need to be critical and flexible thinkers in order to be able to cope effectively with the broad technologically developed society (Beavis, 2007; Bryan et al., 2011; Bybee, 1997; Chan, 2010; Gee, 2010; MacDonald, 2016; Tytler, 2007). In this regard, governments and ministries of education in several countries are working intensively to create STEM learning opportunities, but teachers are the decisive factor in the successful implementation of such school programs.

One study reveals that in 2015, approximately 8.6 million Americans were employed in STEM fields, 93% of whom were paid more than the national median wage (Fayer et al., 2017). Of note, employees in STEM fields were more likely to apply for, receive, and commercialize patents (Thomasian, 2011). However, there has been a steady shortage of engineering and science specialists due to students' low interest in the hard sciences, which has forced the US government to rethink the education system. As a result, the USA was the first country to implement STEM education in schools.

STEM education involves an equal focus on the disciplines of Science, Technology, Engineering and Mathematics. Although the acronym STEM seems to be on everyone's lips, being an extremely popular trend in American education and beyond (Ostler, 2015), specialists in the field have so far failed to provide a clear and unanimously accepted definition of STEM education (Bender, 2017; Pope, 2019).

The integrated STEM approach is advocated by many education experts including the National Science Teachers Association (Eberle, 2010), which sees STEM education as a complex of four disciplines that are *woven* together to help students solve real-life problems.

In 2016, the authors Siekmann and Korbel defined STEM education through two perspectives: either a traditional monodisciplinary approach or an integrated approach of all four disciplines. The first approach encompasses education in any field defined as *STEM* that brings together two or more disciplines with the aim of promoting long-term technological innovation, competitiveness and prosperity (Xie et al., 2015). The second, more complex approach aims to treat STEM education as a unitary whole, thus emphasizing the logical and conceptual connections across different STEM domains (Honey et al., 2014; National Academy of Science [NAS], 2007; Xie et al., 2015). The integrated approach prioritizes interdisciplinarity and the applicability of academic and real-world concepts in school contexts (Tsupros, 2009).

The aim of STEM education is to develop STEM literacy, i.e. the skills to actively engage students in discussions related to the domains of the hard sciences and their implications for everyday life. Students who discover the world around them for themselves through experimentation will become independent, learn to think scientifically, be able to apply particular modes of critical thinking, and make interconnections (Caldwell & Pope, 2009). A truly integrated STEM approach is, in fact, an interdisciplinary or even transdisciplinary approach, which continually allows students to make interconnections between as many disciplines as possible on a given topic (MacDonald, 2016; STEM Task Force Report, 2014).

STEM education is an international response to the need to adapt to today's society and a growing trend. It has naturally taken hold at secondary school, high school and university levels, where students have the disciplinary knowledge and skills to enable interdisciplinary and integrated approaches. However, young pupils' contact with STEM subjects needs to be initiated as early as pre-school and primary level, mainly due to their open minds for knowledge and their interest, still unperverted by digital media, in interacting with the outside world.

Over time it has been recognized that STEM education does not cover all the domains necessary for integration in today's society, as a result, new derivative concepts have emerged, such as, STEM +, STEAM (by including the Arts), STREAM (by including Reading) or

SHTEAM (Science, Technology, Engineering, Arts and Humanities, and Mathematics), or even CSTEM (Communications, Science, Technology, Engineering, and Mathematics), these movements allow for a broad multidisciplinary approach (Johnson et al., 2015, p. 6 and p. 18). Also, the integrated STEM/STEAM/STREAM approach can continually take on new forms by adding other disciplines into the system that can facilitate how students perceive the world around them. For example, all subjects studied in the primary cycle can be gradually added: Geography, History, Religion, Civics, Robotics or, optionally, English.

On an individual level, teaching science to young school children gives a clear sense of the surrounding reality, helps students to understand natural and technological phenomena more clearly, creating a bridge to an inquisitive mind that asks questions and seeks answers. Likewise, it improves STEM literacy skills and, last but not least, increases young learners' interest in STEM subjects (Bybee, 2013).Ostler (2015) states that science is an effective way of learning about the surrounding world through the information provided by facts and phenomena. In the same vein, he defined mathematics as a comprehensive way of observing the interactions and processes of science using elements of logic(Ostler, 2015).

Technology and Engineering are two areas that are under-utilized in K-12 education in order to produce an authentic STEM experience in the classroom.
Engineering is related to the fields of research, design, production, development, construction, management, administration, sales, operation, etc. and aims to meet the needs of society through the purposeful application of engineering science, technology and techniques to provide solutions to the problems we face. The International Technology and Engineering Education Association (ITEEA) emphasizes that "technology is the branch of knowledge that deals with the creation and use of technical means and their interdependence with life, society and the environment; drawing on subjects such as industrial arts, engineering, applied sciences and pure science" (ITEEA, 2019, p.9).

The arts are considered to be very important from ancient times to the present day, representing an intrinsic part of the way people operate with the world around them through drawing, music and, not least, dance (Bamfort, 2009).

Literacy, i.e. knowing a language (reading), is essential for understanding science, technology, engineering and mathematics (Hanauer & Curry, 2014). Researchers Palmer and Lister, in their collective work, *STEM in the primary curriculum, take* a similar position, stating that in order to understand mathematical, scientific or technological concepts and terms, pupils need to develop effective communication skills, they need to be able to express themselves clearly (Palmer & Lister, 2019).

The integrated STEM/STEAM/STREAM approach, by the nature of integrative activities, makes it possible to develop complex performance skills, interdisciplinary skills. These include: inquiry, research, interpersonal skills, communication, systems thinking, problem solving, design and construction, analysis, synthesis, evaluation, problem solving, critical reflection, group work. Also, through the integrated STEM/STEAM/STREAM approach at the primary cycle level the following integrative concepts are grounded: interdependence, regularity, sustainability, balance, cause/effect, patterns/patterns, change/continuity, order, cycle, conflict/cooperation, system, perceptions, and diversity (Drake & Burns, 2004).

Most of these concepts develop gradually, through practice and engaging students in STEM/STEAM/STREAM activities that require their active participation in discovering the world around them through hands-on experiments and activities. Every day, young learners discover the interrelationships between objects, phenomena or processes; they observe the regularity and cyclicity of some phenomena; they observe certain causes that produce different effects, discover patterns and models by which they can act, etc.

Integrated activities require qualitative evaluation methods that are different from the classical ones that are predominantly used. Ioan Ceghit (2002) and other experts in education propose a succession of alternative evaluation methods, aimed at "qualitative evaluation", methods that can be successfully used in the evaluation of integrated activities: project, exhibition organization, investigation, portfolio, and online evaluation tools.

Chapter 3. Service-Learning Projects (SLP)

In the view of several authors, the essence of service-learning pedagogy is that community service learning aims to combine community service with academic learning and academic outcomes (Erickson & Andreson, 1997; Furco, 2002).

Regina and Ferrara (2017) defined community service-learning through three broad key characteristics: centering on community needs, actively involving students in the full development of the project, and linking the curriculum to community need (Regina & Ferrara, p.11, 2017).

According to the authors, the stages of a service-learning project are: motivation, diagnosis, mapping and planning, project implementation and finalization.

Following the application of SLP in the classroom, it was found that the model needed to be adapted. The author of this paper proposes to adapt the model by introducing additional steps, such as: matching community needs with curriculum provisions, defining project goals, designing STEM-based service learning activities, sharing results and, last but not least, making necessary revisions.

For teachers to enjoy a successful implementation of learning projects, it is essential to start from the current school curriculum (general competences, specific competences, contents) and then add the element of "Community Service".

A variety of SL projects can be implemented in the primary cycle, given the flexibility of the timetable and the possibility of inserting parts of the project into the lessons. The empathy, interest and curiosity of young children support the implementation of this type of project.

Community service learning projects based on the integrated STEM approach provide an exciting and enjoyable learning opportunity that allows students to contextualize the knowledge and skills acquired in the classroom; it is the perfect setting in which young school children develop their interdisciplinary skills and civic spirit.

Chapter 4. Preliminary research

The results obtained in the context of the preliminary research were analyzed in three stages:

Stage I - Documentation and analysis of the curriculum at home and abroad;

Phase II - Survey of Primary and Pre-school teachers' views on Integrated Approaches to STEM, STEAM, STREAM (called STEM+ in this paper). pretest-posttest study;

Stage III- Analysis of the integrated activity projects realized by teachers after the formative intervention.

Table 4.1.

Structure of preliminary research

Period	Activities
January 2020- May 2021	Documentation: literature, discussions with teachers and academics. Curriculum analysis. This analysis took the form of a publication, not included in this research.
June 2021	Development and testing of the teacher questionnaire designed by the PhD student (Annex A1).
1- July 15, 2021	Voluntary application of the teachers' questionnaire. Elaboration of integrated activity projects by the group of teachers volunteering to participate in the STEM4SL summer camp.
July 15 -30, 2021	Analysis of the answers to the questionnaire. Analysis of the projects proposed by the teachers who applied to participate in the STEM4SL summer camp using the evaluation grid developed by the PhD student (Annex A2).
August 1-6, 2021	STEM4SL summer camp in face-to-face format (formative intervention)
August 9-27, 2021	STEM4SL summer camp online (formative intervention)
August 30 - September 10, 2021	STEM4SL summer camp participants' review of their STEM integrated activity projects. Re-taking the questionnaire.
September 11 - October 1, 2021	Evaluation of revised projects using the grid in Annex A2. Individual interviews to clarify results. Data processing and interpretation. Communication of results to participants.
October 1 - November 1, 2021	Elaboration of the integrated activity model ~~necessary for~~ the formative intervention.

Preliminary Research Objectives

O1. To identify teachers' views on the integrated STEM approach before and after the formative intervention carried out during the STEM4SL summer camp.

O2. Design, realization and analysis of the results of the formative intervention carried out in the context of the STEM4SL summer school.

O3. Elaboration of the draft model of the formative intervention model applied to the students in the experimental group, based on the literature in the field and the analysis of teachers' opinions.

Assumption 1

The STEM4SL summer camp formative intervention is changing teachers' beliefs in favor of STEM education.

Assumption 2

The formative intervention program prompts the development of correct STEM/STEAM/STREAM and SL based activity projects.

Note: The appropriateness of integrated approaches and the success of STEM/STEAM/STREAM integration is accomplished using the analysis grid (Appendix A2).

First part of preliminary research

Primary and pre-school teachers' views on the integrated STEM approach

In Romania, research studies in the fields of STEM, STEAM and STREAM are quite scarce. Among Romanian specialists interested in STEM education and with results in the field we mention Babos & Ciascai (2020). Balint-Svela & Zoldos-Marchiș (2022), Ciupercă & Stanciu (2020), Istrate et al. (2019), Mirea et al. (2021), Pâinișoară et al. (2020), Ulmeanu et al. (2021).

After analyzing: (i) the literature (Yildirim & Türk ,2018; Hebebci, 2021 Altan & Altan & Ercan, 2016) and (ii) of the homework assignments completed by PIPP Conversion students at the Science and Didactics of Science Discipline disipline of Babeș Boylai University, (iii) of the discussions with teachers from the county of Sălaj in the context of methodical activities and (iv) of the individual interviews with fellow teachers we found that teachers have little knowledge related to STEM, have difficulties in identifying and utillizing knowledge from the fields of Engineering and Technology and do not carry out STEM integrated activity. As a result, we proceeded to develop a questionnaire related to STEM and STEM education.

Pre-testing (teacher survey)

The research aimed to compare the opinions of teachers participating in the STEM Summer Camp activities held in August 2021, before and after the formative intervention conducted at the camp.

The preliminary survey was carried out using the questionnaire ,,STEM+ and STEM+ education" (a saddle-sized questionnaire: STEM/STEAM Knowledge and Service Learning, STEM/STEAM Teacher Profile, Curriculum Linkage to STEM/STEAM Education.
Life and STEM/STEAM Integrated Approaches, STEM/STEAM Integrated Approaches-Methodology and Vision, Preschool/Primary Education and STEM/STEAM Integrated Approaches) designed by the PhD student, using the literature in the field. The questionnaire was submitted to the attention of three experts in the field of STEM+ education and applied for testing purposes on a group of 14 teachers, after which the necessary corrections were made. The questionnaire was then administered to 150 participating teachers on a voluntary basis.

Second part of preliminary research

Formative intervention (STEM4SL Summer Camp)

After a detailed analysis of the results of the applied preliminary survey, the foreign literature and the curriculum, we started an intervention aimed at training teachers and gathering information on the model of integrated STEM approach through SL projects applied in the formative intervention applied to an experimental group.

The formative intervention carried out in the summer of 2021 included a group of 76 teachers voluntarily enrolled in the STEM summer camp conducted under the auspices of the STEM. TRADITIONS whose president is the PhD candidate and author of this paper. The activity was organized face-to-face for one week and continued for another three weeks online. In this context, teachers were introduced to the basic elements of the STEM/STEAM/STREAM integrated approach, could discover examples of good practice from home and abroad, as well as effective teaching strategies and STEM integrated design models. Participants were able to observe the architecture of old houses presented by professors and students from the Faculty of Architecture UBB Cluj-Napoca in partnership with the Association ,,Save the blue houses of the Barcăului valley". They could also realize their own STEM projects. On the last day of the camp, together with the participants, we conducted outdoor experiments in the local forest.

The results have been systematized in three strands:

1. Critical analysis of the integrated project models developed by the participants in the preamble of the course and after the completion of the course, by means of an evaluation grid (see Annex A2).

These results were achieved in the context of two phases:

- Phase I (interventional): participants were involved in activities that allowed them to review their knowledge of the integrated approach (integrative concepts, interdisciplinary skills), to clarify their knowledge of STEM domains and to develop models of integrated based on these domains.
- Stage II (post-intervention): over a period of two weeks participants revised their initial projects and sent them to the trainer for evaluation.
- Stage III a: analysis of the projects realized by the participants after the formative intervention. This analysis was carried out by relating the scientific content and interdisciplinary skills mentioned in the projects developed after the end of the summer camp activities (see Annex A2) to the projects initially developed and to the knowledge, instructions and models provided by the trainer.

The results showed the preference of the participating teachers to focus in the final projects on the areas with which they were familiar (90%): exact subjects, arts and practical skills, language and literature, with engineering and technology being less well represented. Also, while in the initial projects multidisciplinary (68.42%) and interdisciplinary (33.33%) approaches predominated in the final projects, integrated approaches emphasized the two-dimensional (vertical and horizontal) correlation of domains (55.26%). The teachers participating in the training also had difficulties in identifying and formulating the interdisciplinary skills (46.05%) to be included in the STEM/STEAM/STREAM projects.

2. Directions for developing teachers' STEM skills

Focus groups and individual interviews revealed: the need for repeated training with a focus on gaps in participants' knowledge and skills (94.73%); the need for access to resource materials (96.05%); training in teaching strategies used in integrated STEM/STEAM/STREAM approaches (80.26%) and increased interest in STEM-Service-learning projects (84.21%)

3. Perception of STEM/STEAM/STREAM activities based on proposed projects and individual interviews (Annex A3)

As it emerges from the analysis of the final projects carried out and the individual interviews (20 participants), it was found that teachers understand STEM/STEAM integration as an innovative way of thinking about teaching mathematics and science at the primary level. In other words, they frequently center integrated approaches on these subjects. The innovative element is to capitalize on the co-existence with technology, engineering and the arts. However, teachers find STEM/STEAM integrated approaches difficult to conceive and implement in primary school.

Last part of preliminary research

Post-testing

The same questionnaire was administered at the end of the intervention. The results of the preliminary and final survey were statistically processed and the results compared.

For all six dimensions that characterize the integrated STEM/STEAM approach, improvements are observed in the post-test stage compared to the pre-test stage. The greatest difference between the mean scores in the post-test stage and the mean scores in the pre-test stage is recorded for the dimension STEM/STEAM Teacher Profile (0.40), followed by the dimension Life and the integrated STEM/STEAM approach (0.26), Integrated STEM/STEAM approaches - methodology and vision (0.25), Linking the curriculum with STEM/STEAM education (0.19), Pre-school/primary education and integrated STEM/STEAM approaches (0.15) and STEM/STEAM knowledge and Service Learning (0.08). In other words, the activities proposed and implemented between the preliminary and final stages achieved the purpose for which they were designed.

Discussion of results

As a result of the activities in which the teachers participated and the results obtained, we can say that the participants' perceptions and knowledge of designing and carrying out the proposed activities based on the integrated STEM/STEAM approach have significantly improved.

The activities on learning about the concept and defining elements of the integrated STEM approach were new for the participating teachers. Even though some of the teachers had knowledge about the integrated STEM/STEAM approach, the training activities explored aspects that were improved through practice.

Activities realized through the Summer Camp had a major and positive impact on teachers. There was a change or improvement in the way of promoting and stimulating students' interest in the integrated STEM/STEAM approach, in the way of designing STEM-based instruction and integrated activities.

In terms of curriculum, the training activity has brought knowledge and models of activity that fit into the programs of curricular subjects.

The participation in the proposed activities made the teachers aware of the importance and complexity of integrated approaches, of the need to open them to STEM and to the community.

The explanation for all the acquisitions (knowledge, skills, values, etc.) can be found in the contact with various products that capitalize on STEM, the contact with architecture teachers, local community representatives and the collaboration between them and with others. As a result, participants state the need to access courses on integrated STEM and SLP approaches.

The knowledge gained from the activities led teachers to carry out more frequent (weekly, monthly) integrated STEM/STEAM activities, most often in areas such as art, environmental protection, practical skills. The feedback received from participants indicates a high degree of difficulty in integrating engineering and technology knowledge.

In other words, the activities proposed in the intervention plan have brought added value to teachers in terms of knowing, designing, realizing and implementing activities involving integrated STEM/STEAM approaches.

Preliminary Research Findings

Preliminary research findings are as follows:

(i) The research *The views of primary and pre-school teachers on integrated STEM approaches* show that primary teachers are interested in integrated STEM/STEAM/STREAM, but above all they consider that training in the field is desirable. Participants are confident that this knowledge can serve as a basis for building and strengthening a community of creative and competent teachers in the field of STEM-based integrated approaches.

Participants argue that the interdisciplinary skills promoted by STEM education thoroughly prepare students for life and their future careers.

We found that teachers' familiarization with integrated approaches led them to assert that the implementation of monodisciplinary or multidisciplinary approaches in the classroom does not contribute to the significant development of students' cognitive skills, which are necessary to prepare them for integration into tomorrow's society. Instead, integrated approaches stimulate students to study by facilitating reference to their life experience.

(ii) *The STEM 2021 summer camp formative intervention* facilitated understanding of STEM concepts and component domains, deepening integrated design, developing integrated STEM/STEAM/STREAM activity projects, and relating them to community needs. This relationship served as a motivator for integrated, private approaches from both teacher and student perspectives. As a result, the participants' interest in designing and implementing STEM/STEAM/ STREAM lessons in the classroom linked to community-based learning increased.

The participants in the formative intervention were open to implementing STEM education in the classroom, although the way of grounding the integrated activity is different depending on the learning environment. Teachers working in urban environments tried to introduce activities from the fields of Engineering and Technologies in their projects, building the whole integrative approach on exact subjects such as math or science. Teachers working in rural areas, on the other hand, prefer to base their instructional and educational approach on subjects such as Romanian Language and Literature, Arts or Mathematics.

The findings from the preliminary research are consistent with those of other studies and research in the field. Thus, Rahman et al. (2021) advocate for a careful and responsible processing of the content covered by the integrated STEM approach in order to make it attractive to their students. Kazu and Kurtoglu Yalcin (2021) identify the following shortcomings related to STEM integration: insufficient teacher preparation, confusion between technology and IT, misunderstanding of the relationship between the scientific method and the technological method, lack of interdisciplinary teams in schools. The cited source points out that the strengths of STEM integrated approaches are: promotion of 21st century skills, anchoring STEM knowledge in life, the existence of a set of factors that foster interest and knowledge in STEM: local culture, group of friends and colleagues, family, local industrial development and patterns in society, close relationship between STEM integrated approach and local culture. Ültay et al. (2021) emphasize the importance of implementing training courses in STEM integrated approach.

Developing the Model of STEM/STEAM/STREAM Activities through SL Projects based on Preliminary Research

After analyzing the integrated activity projects proposed by teachers at the STEM4SL summer camp, it could be observed that, in general, at the primary level, teachers carry out integrated educational projects using predominantly the webbed curriculum (Forgarty, 1991). A central theme is used as an organizer of instruction at the level of a day or a week across several subjects of study. By using this kind of integrated approach it is easier to make interconnections between concepts and ideas from different subject areas, to promote correlation between subjects belonging to different curricular areas, and to increase the motivation for learning of the pupils because of the interesting themes.

Although such activities are loved by the little ones, the effort put in by teachers is considerable, as it requires continuous planning, updating and designing, focusing equally on outcomes and process.

The proposed project model involves the integrated STREAM+CIG approach (STREM and Civics, History and Geography), being designed in such a way that it solves a current problem of the community (service learning part) of which the school/class where the formative intervention is realized is part (see Annexes B1, B2, B3).

The structure of the project is a complex one organized in five main stages: Brainstorming, Investigation, Application, Creation and Reflection.

Table 4.3.1

Structure of activities implemented in the experimental group

Project milestones	Activities undertaken
Brainstorming	The teacher and students conducted a needs analysis of the community they are part of and chose a theme of the STREAM integrated activity project oriented towards community service.
Investigation	The students researched from various sources (parents, other teachers, community members, representatives of community institutions, etc.). This documentation served as a basis for designing STEM activities for the community.
Apply	The project has been implemented under the conditions and for the purpose set out in the previous phase.
Creating	The students have created a product (reading corner, school garden, bird corner, seating area, leaflets, flyers and community outreach activities).
Reflection	Students made a reflection journal during the realization of the activity and completed it at the end of the activity. These reflections concerned the impact of the activity on the community, the difficulties encountered and how to overcome them, possible further developments of the project, suggestions for other projects, etc.

Chapter 5. Experimental Research on the Impact of STEM/STEAM/STREAM Integrated Teaching through Service Learning Projects on the Academic Performance of Primary School Students

The experimental research was carried out in the school years 2021-2022 and 2022-2023 in grades II and III and III and IV respectively.

The target group consisted of 8 primary school teachers, who worked in 8 classes (156 pupils - randomly selected) in five schools in the county of Sălaj.

Research Question

Q.1. How does the instruction of students through integrated STREAM approaches oriented to Service Learning influence the cognitive processing corresponding to Bloom's taxonomic Bloom's levels? What about their knowledge in the areas of Mathematics, Science, Language and Communication, Technology and Engineering?

General Research Objective

To determine the impact of integrated STEM/STEAM/STREAM Service Learning-oriented STEM/STEAM activities on the quality of primary school students' cognitive processing and academic achievement.

Means of achieving the objective

Formative intervention program based on STREAM and Service Learning integrated teaching with impact on students' cognitive processing (Bloom's Taxonomy) and students' knowledge.

The majority of STEM literature refers to improving students' knowledge and skills, having a considerable effect on their academic success (Kazu & Kurtoglu, 2021; Mustafa et al., 2016; Putica, 2024; Tașdemir, 2022). Zeng et al. (2018) find that STEM education contributes to improving students' thinking and cognitive ability. Mustafa et al. (2016) advocate the use of project-based learning in integrated STEM/STEAM/STREAM approaches. Studies also report students' disinterest in careers in science and scientific literacy, despite the material resources made available to schools by the government (Börner et al., 2018; Kayan-Fadadlelmula et al., 2022; Van Laar et al., 2017; Wang et al., 2011).

Assumption 1

Students who participate in the STREAM community-based integrated activity-based intervention program have a higher (statistically significant) level of cognitive processing **than their peers** who do not participate in this program.

Independent variable: formative intervention program based on STREAM integrated approach for the benefit of the community.

Dependent variable: level of cognitive processing.

Hypothesis 2. There are statistically significant differences between the experimental and control groups in the level of cognitive processing in the categories of Comprehension, Recall and Application (low-level thinking skills).

Hypothesis 3. There are statistically significant differences between the experimental and control groups in the level of cognitive processing in the categories Analyzing, Evaluating and Creating (high-level thinking skills).

Assumption 4

Recall is a predictor of elementary students' attainment of Bloom's Taxonomy comprehension.

Assumption 5

Comprehension is a predictor of primary school students' attainment in applying Bloom's Taxonomy.

Assumption 6

Application is a predictor of primary school students' attainment in Bloom's Taxonomy analysis.

Assumption 7

The analysis is a predictor for primary school students' achievement of Bloom's Taxonomy assessment level.

Assumption 8

Assessment is a predictor for primary school students' achievement of the level created in Bloom's Taxonomy.

Assumption 9

There are statistically significant differences in the experimental group between pre-test and post-test in terms of the results obtained in the subjects Communication in

Romanian/Romanian Language and Literature, Mathematics, Science and technical-applicative (Engineering and Technology).

Application of the Model of STEM/STEAM/STREAM Activities through SL Projects developed in the Preliminary Research

The themes proposed by teachers in previous research mainly refer to the seasons, winter holidays, Easter or environmental protection. The method involves the choice of a daily topic of interest, approached from the point of view of all the subjects on the timetable that day, but also of activities in the fields of Engineering and Technology. The proposed activities for the experimental group are presented in Annexes D1, D2, D3.

The general structure of the projects is outlined below:

- Identifiers.
- STREAM pillars involved.
- Aim.
- Project objectives.
- Partners involved.
- Diagram of activities based on STREAM integrated approaches.
- Description of the five main stages of the project.
- Description of the proposed activities

Research Methodology

In the present study an experimental design is implemented in which the independent variable is represented by the formative intervention program applied to the experimental group (Table 5.7.1.) and the dependent variable is represented by the score on the three tests applied (Annexes E1, E2, E3). The test scores were calculated using the matrix of specifications and performance descriptors presented at the end of the assessment tests in Appendices D1, D2, D3, D4.

The strategies used in the two large projects implemented in the experimental group integrated a variety of methods: experimental, brainstorming, questionnaire-based surveys oriented towards community members, problem solving, investigation, role play, etc. Students were organized in groups, teams, but also in groups and individuals.

Table 5.7.1.

Experimental design

The moment / Evaluation group	**Pretest**	**Formative intervention 1**	**Intermediate test**	**Formative interventio n 2**	**Posttest**
Experimental group	The interdiscipli assessment test nara	STEM/ SLP-oriented STREAM	The interdiscipli-nara	STEM/ SLP-oriented STREAM	The interdiscipli-nara
Control Group	The interdiscipli-nara	Traditional method	The interdiscipli assessment test nara	Traditional method	The interdiscipli-nara

Data Collection and Processing

Data collection was based on knowledge tests. The collected data are processed using the IBM SPSS Statistics 20.0 statistical program IBM SPSS Statistics 20.0, at a 95% confidence level and a statistical significance level of 0.05. The results obtained are presented at stage and class level.

The instruments used to assess the achievement of the objectives of the formative intervention are the interdisciplinary tests (the tests contain items specific to all STEM disciplines) that measure the level of cognitive processing involved in learning. The research instruments consist of 5 items, most of which have sub-items. The items measure the level of cognitive processing according to Bloom's taxonomy that develops in the participants. The tests are designed according to current school curricula. The students have 100 minutes to solve the tasks, according to the following structure: 50 minutes to solve the items of the first part of the test, 10 minutes break, followed by another 50 minutes to solve the items of the second part of the test.

The presentation of results starts with the validation of the research instrument, continues with the presentation of descriptive analyses (absolute and relative frequencies, mean value, standard deviation, minimum and maximum value), correlational analyses, regression analyses and T-student tests.

Validation of the tool

The research instrument (see Appendices D1, D2, D3, D4) is a new instrument, the author's own, validated by calculating the Cronbach Alpha coefficient that determines the consistency of the scale and analyzing the main components that determine the way of construct formation and item grouping.

The responses are represented by scores from 1 to 7 (minimum 1- maximum 7), where 1 was the equivalent of the grade applied to the primary grades Insufficient (I) and 7 was the Very Good (FB). This scoring system requires validation of the research instrument. In the validation analysis of the instrument, 11 items are included, those that follow the same response form (1-7). In the literature, the minimum accepted value of the Cronbach Alpha coefficient is 0.7. In this case the Cronbach Alpha coefficient value is 0.963, much higher than the minimum accepted value, so the validation process is a confirmed successful.

The validation and elimination of items consists in identifying those items that by eliminating them lead to a higher value of the alpha coefficient in the *Cronbach's Alpha Result* column *if the item is eliminated* and that have an insignificant impact i.e. the value in the *Total Item Correlation Corrected* column is less than 0.20 or negative. The results presented in Table 5.3. do not meet the two mentioned criteria, so in the Principal Component Analysis we use all 11 items.

From a methodological point of view we will apply Principal Component analysis to determine how the types of congnitive processing are formed, we will take into account Bloom's taxonomy model on which this research tool was built.

The rotation method used is Direct Oblim which confirms the existence of a correlation between the generated components. The values computed by the Kaiser-Meyer-Olkin Measure of Sampling Adequacy test, the Bartlett Test of Sphericity and the initial eigenvalues in the Total Explained Variance table validate the correctness of the applied analysis. The types of cognitive processing that are formed are given by the eigenvalues for which the value exceeds 1.

The Bartlett test of sphericity confirms the application or non-application of item number reduction. Since Sig.=0.000<0.05 the procedure of item number reduction is not necessary. In the present case, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy test value is 0.936 higher than the minimum accepted value 0.4, so Principal Component Analysis is still applied.

For the pre-test and post-test baseline, the constructs were subjected to correlational and regression analysis to highlight associations and influences within them.

Comparative pre-test and post-test analysis in the experimental group

Table 5.6.

Differences between pre-test and post-test means in the experimental group

	Differences in pairs					t	df	Sig. (2-tailed)
	Media	Standard deviation	Std. mean error	95% confidence interval of the difference				
				Low	High			
Evaluation	-.64103	.92546	.10479	-.84968	-.43237	-6.117	77	.000
Create	-.70513	.95495	.10813	-.92044	-.48982	-6.521	77	.000
Analysis	-.70513	1.05817	.11981	-.94371	-.46655	-5.885	77	.000
Recall	-.58974	1.12164	.12700	-.84263	-.33685	-4.644	77	.000
Deal	-.73077	.93521	.10589	-.94163	-.51991	-6.901	77	.000
Apply	-.70513	.98177	.11116	-.92648	-.48377	-6.343	77	.000

Source: own processing with IBM SPSS Statistics 20.0

Paired t-test results indicate statistically significant differences ($p<0.05$) between the means of the cognitive processing categories in the post-test and the means of the cognitive processing categories in the pre-test:

- $p=0.000<0.05$ indicates the existence of a statistically significant difference between the mean of the post-test and the mean of the pre-test, the difference between them being 0.64 points.
- $p=0.000<0.05$ confirms the existence of a statistically significant difference between the mean of Creation of new contexts obtained in the post-test stage and the mean of Creation obtained in the pre-test stage, the difference between them being 0.70 points.
- $p=0.000<0.05$ captures the existence of a statistically significant difference between the mean of the Analysis of New Situations obtained in the post-test stage and the

mean of the Analysis obtained in the pre-test stage, the difference between them being 0.70 points.

- p=0.000<0.05 shows the existence of a statistically significant difference between the mean of Recall of main ideas obtained in the post-test and the mean of Recall obtained in the pre-test, the difference between them being 0.58 points.
- p=0.000<0.05 states that there is a statistically significant difference between the mean of the post-test and the mean of the pre-test, the difference between them being 0.73 points.
- p=0.000<0.05 indicates the existence of a statistically significant difference between the mean of Application of the concepts from the text obtained in the post-test and the mean of Application obtained in the pre-test, the difference between them being 0.70 points.

According to the results of the paired T-test, the didactic activities carried out brought significant improvements in all six categories of cognitive processing

Figure 5.7.4.

Evolution of cognitive processing in the experimental group

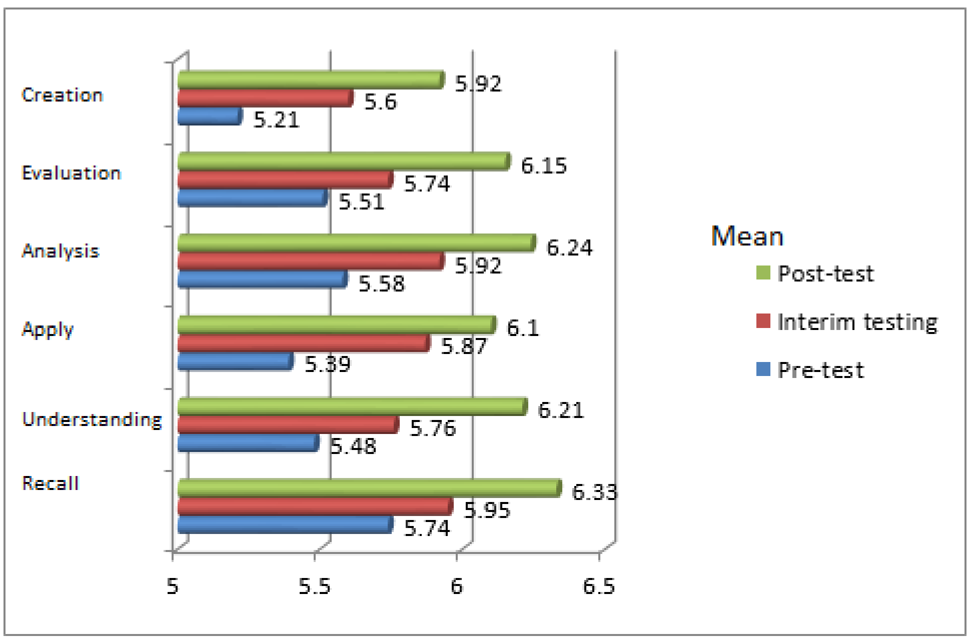

Figure 5.7.4. shows the evolution of the experimental group in terms of the level of cognitive processing illustrated by the three tests applied during the formative intervention.

Comparative post-test experimental and post-test control analyses

Table 5.7.32.

Descriptive analysis (comparative post-test)

	Stage Post-test	N	Media	Standard deviation	St. error of mean
Evaluation	control post	78	5.9103	1.00887	.11423
	exp. post-test	78	6.1538	1.26980	.14378
Create	control post	78	5.2308	1.12727	.12764
	exp. post-test	78	5.9231	1.37481	.15567
Analysis	control post	78	6.0769	1.07835	.12210
	exp. post-test	78	6.2436	1.22936	.13920
Recall	control post	78	5.8718	1.23119	.13940
	exp. post-test	78	6.3333	1.10096	.12466
Understanding	control post	78	5.4487	.94865	.10741
	exp. post-test	78	6.2179	1.18044	.13366
Apply	control post	78	5.5769	1.03847	.11758
	exp. post-test	78	6.1026	1.24410	.14087

The t-test for the two groups, experimental and control, shows that there are significant differences in the level of cognitive processing for Creation [t(154)= -3.338, p<0.005], Recall [t(154)= -2.468, p<0.005], Comprehension [t(154)= -4.486, p<0.001] and Application [t(154)= -2.865, p<0.005].

Table 5.7.33.

Analysis of equality of variances and means (post-test)

	Levene's test for equality of variances		t-test for equality of means						
								Mr.	
	F	Mr.	F	Mr.	F	Mr.	F	Low	High
Evaluation	6.786	.010	-1.327	154	.187	-.24359	.18363	-.60635	.11917
Create	3.657	.058	-3.439	154	.001	-.69231	.20130	-1.0899	-.29463
Analysis	.727	.395	-.900	154	.369	-.16667	.18516	-.53245	.19911
Recall	5.077	.026	-2.468	154	.015	-.46154	.18701	-.83098	-.09210
Understanding	1.661	.199	-4.486	154	.000	-.76923	.17147	-1.1079	-.43049

Apply	.642	.424	-2.865	154	.005	-.52564	.18349	-.88813	-.16315

The t-test for the two groups, experimental and control, shows that there are significant differences in the level of cognitive processing for Creation [t(154)= -3.338, p<0.005], Recall [t(154)= -2.468, p<0.005], Comprehension [t(154)= -4.486, p<0.001] and Application [t(154)= -2.865, p<0.005].

As regards the validation of the last hypothesis, a series of statistical tests were carried out, with the following results:

- in the case of pretesting, for the subjects Communication in Romanian Language/Romanian Language and Literature mE=5.53; mC=5.50 (t=.113, DF=128.55, p=.910) and Mathematics mE=5.46, mC=5.64 (t=.783, DF=158.89, p=.435) results obtained do not differ statistically significantly for the two groups (experimental and control-comparison); the two groups differ statistically significantly, at pretest, in Science mE=5.48, mC=5.99 (t=-2.258, DF=142.35, p=.025) and Technical subject mE=5.53, mC=6.07 (t=-2.414, DF=154, p=0.017) as a result of the differential emphasis on the two subjects, teacher characteristics and school environment.
- In the post-test, there are statistically significant differences at the level of the two groups (experimental and control-comparative) in the subjects Communication in the Romanian Language/Romanian Language and Literature mE=6.20, mC=5.50 (t=4.461, DF=136.275, p=0.00) and Mathematics mE=6.21, mC=5.60 (t=3.289, D=154, p=0.001), given the fact that most of the STEM activities in the proposed projects are based on the two subjects; also, at post-test there are no statistically significant differences between the two groups in Science mE=6.13, mC=5.76 (t=1.966, DF=154, p=0.051) and the technical domain mE=6.15, mC=5.87 (t=1.491, DF=154, p=.138); the experimental group's emphasis on the subjects of English Language and Mathematics weighted on the results in Science and Technical domain.

Experimental research results

At the sample level of the present research, the research instrument applied in the three stages (pre-test, intermediate, post-test) is validated by means of specific consistency and reliability coefficients and can be used in future research.

The results show statistically significant improvements in Bloom's six categories of cognitive processing: Evaluation, Creation, Analysis, Recall, Recall, Comprehension, and Application between the scores obtained in the pre-test stage and the scores obtained in the intermediate stage, between the scores obtained in the intermediate stage and the scores obtained in the post-test stage, and between the scores obtained in the pre-test stage and the scores recorded in the post-test stage in the experimental group.

In other words, the didactic activities carried out between the pre-test and the post-test led to the improvement of students' Assessment, Creation, Analysis, Recall, Comprehension and Application skills, and were very successful.

Following the analysis of the results with reference to the ability of students to correctly solve the items specific to Communication in Romanian Language/Romanian Language and Literature, Mathematics, Science and the technical-applicative domain (Engineering and Technologies), there are statistically significant differences between the scores obtained in the pre-test and the scores obtained in the post-test. Statistically significant differences can also be observed for the items in the technical-applicative domain (Engineering and Technologies) between the scores obtained in the pre-test stage and the scores obtained in the intermediate stage.

Formative Research Findings

The results partially confirm the hypotheses (I1-I8). Thus, the experimental and control groups do not differ in the post-test in terms of the processing corresponding to the Analyze and Evaluate levels of Bloom's Taxonomy of the cognitive domain. We attribute this to current intervention and control practices exercised by primary school teachers. That is, teachers place less emphasis on developing their students' (self-)evaluation and analytical skills. Assaraf and Orion (2010) point out that Analysis is a level of cognitive processing that is more difficult for primary school students to achieve. As for Evaluation, where the two groups do not differ statistically significantly, it involves value judgments about the relationships in the components identified on the basis of analysis (items and relationships between items) and as a result is influenced by Analysis (as also revealed by our research on cognitive processing at the two levels).

The pretesting showed the high ability of the students in the experimental group to understand the message of a text and to solve simple work tasks involving the recall and evaluation of information and content transmitted in the instructional-educational process. In situations where students are put in the position of analyzing, creating or applying knowledge in concrete situations, they encounter real difficulties.

In the intermediate test, students in the experimental group are able to recall information from the given texts more easily, even if they are more complex. The students analyze and compare the given information correctly, but they have difficulties in solving the mathematical problem in the test, as well as in solving the work tasks that require creativity.

The post-test shows increased average scores on all tasks for most of the participating students. Most of the students can easily solve most of the work tasks, with an increase in interest in STEM-based work tasks and an awareness of community issues.

Concerning the students' ability to correctly solve specific tasks in Communication in Romanian Language / Romanian Language and Literature, Mathematics, Science and even Engineering and Technologies, we can observe an increase in the scores obtained in the post-test stage compared to the pre-test stage. In the case of Engineering and Technology, differences can also be observed between the scores obtained in the pre-test stage compared to the mid-test stage, which reinforces the need for the introduction of a STEM and SL based curriculum in the primary cycle. Results obtained confirm hypothesis 9.

As for the results obtained by the students in the control group, the scores obtained in the initial tests were approximately the same as those of the students in the experimental group, but after the final test they did not show any increase in their creation, evaluation and application skills.

Expanding research -

The STEM Integrated Approach Model proposed to teachers in the framework of the Summer School - Initiating Beginning Teachers in the STEM/STEAM Integrated Approach, Zalău 2023

Based on research with students and teachers, a two-dimensional integrated approach model has been proposed which has as its components: the STEM subjects, approached sequentially (vertical approach), the connections between the subject from which the integration starts at a given moment and other integrated subjects (horizontal approach). The model also includes, in terms of design, the contents of the disciplines, the questions that can be formulated to motivate students and stimulate them to participate in the lesson, the monodisciplinary and interdisciplinary skills for each discipline addressed at a given moment in relation to other disciplines.

The thematic map for each STEM product is associated with this model. The role of the thematic map is to provide an overview of the disciplines covered by the STEM/STEAM integration.

The integrated STEM approach model was applied to participating teachers at the Summer School held July through August 2023 (July 24 - August 30). The Summer School started with face-to-face activities (one week) and continued with online activities organized according to teachers' requests and availability. The activities were attended by 26 beginning teachers selected from a larger group based on their response to the requirement to complete an integrated approach project**.**

Research objective: Transfer and test the optimized model developed based on the results of the formative intervention and preliminary research.

Hypothesis

The training of beginning teachers conducted during the Summer School significantly improves the design of STEM/STEAM teaching activities.

The structure of the Summer School activities was as follows:

- pre-testing, which was carried out on the basis of an integrated activity project proposed by the participants. These projects were analyzed using a grid developed by the PhD student (see Annex F3);

- a formative intervention consisting of STEM training activities. The intervention involved the choice of a STEM product to be realized and for which the following activities were structured: (i) making the STEM product accompanied by the technical data sheet; (ii) making STEM skills explicit; (iii) making STEM/STEAM monodisciplinary contents explicit; (iv) making a multidisciplinary thematic map; (v) integrated approach model (see Annex F2).
- Final testing consisted of revisiting the initial projects from the perspective of integrated STEM/STEAM approaches.

Discussion of results

The results confirm the hypothesis. The model designed on the basis of the conducted research proves to be useful in STEM training activities. It is found that the participating teachers still have difficulties in formulating interdisciplinary skills, differentiating between Engineering and Technology. As a result they give more extension to the areas of Arts, Reading and Science Writing, Mathematics and Environmental Exploration, and Mathematics and Science respectively. The fact that the teachers involved critically analyze the interdisciplinary correlations, selecting only those that are useful for the students, should be mentioned as meritorious.

Research findings

The teachers' participation in the activities helped them to more easily realize the transfer of integrated STEM/STEAM approaches from teaching activities into everyday life. At the post-test stage they were able to establish a transfer between their knowledge in STEM/STEAM areas and the solution of certain problems in everyday life.

Limitations of Research Conducted in the Context of Formative Interventions

This paper has reached relevant conclusions regarding teachers' views on STEM Education and community service-learning projects, the development of a STREAM integrated approach model that can be used in the community, and the application of this model to the primary grades. The results obtained have a number of methodological, practical and theoretical implications that are important for the literature at home and abroad. The existing limitations are due to internal and external factors.

The first limitation is due to the small number of teacher subjects included in the formative interventions. Thus, while 150 teachers participated in the survey, only 76 teachers participated in the two formative interventions, i.e. 26 teachers.

The second limitation concerning the students participating in the research is the structure of the two samples: the experimental sample included students from three rural schools and one urban school, while the control group included students from three urban schools and one rural school.

Rural teachers' openness to new teaching approaches is lower, which is a limitation of the present research. In fact, the doctoral student wanted to co-opt more teachers in her research but was faced with their refusal.

Another limitation refers to the fact that the randomization was done on classes and not on subjects, which would have made the research more difficult. Another limitation is also the absence of a follow-up study, due to external factors such as long periods of teachers' strike and the focus on remedial activities or activities to fix and consolidate knowledge to ensure successful promotion to higher education.

The small sample of students participating in the experimental research and the analysis of known subdomains (Bloom's Taxonomy) resulted in higher R^2 values for regression tests.

Although this paper presents a number of international studies that have substantiated the research, the lack of such studies in the country presents a limitation in terms of how to approach the topic in relation to the characteristics of Romanian education. This limitation should be taken into consideration by curriculum co-designers who should integrate STEM education into the school curriculum.

Highlighting Doctoral Student Contributions to STEM and SLP Domain Development

The PhD student's contributions to the development of the two fields consisted in:

- publications (articles in conference volumes and journals, books and chapters in books);

- extra-curricular educational projects at local and county level in the areas mentioned;
- research conducted (surveys and product analysis of teachers, analysis of cognitive processes developed in students);
- training course accredited by the Ministry of Education;
- the establishment and activities of the Association Ș.T.I.M. TRADITIONS;
- interactive working platform for teachers ;
- A community of learning and exchange of best practice in the above areas (2700 members from home and abroad).

As a result of the preliminary and experimental research we have brought to the forefront the integrated STEM approach through Service-Learning projects in the county of Sălaj, as well as at national and international level through the publications mentioned at the beginning of this paper.

Selected bibliography

.

Bărnuțiu, M., & Ciascai, L., (2020). Primary and pre-school teachers' views on STEM based approaches, Conference Education, Reflection, Development, Seventh Edition, *European Proceedings of Social and Behavioral Sciences*, Babeș-Bolyai University.

Bărnuțiu-Sârca, M., & Ciascai, L. (2021). A Comparative Study of Primary Curriculum of Finland, Singapore, USA and Romania. In Albulescu & C. Stan (Eds.), Education, Reflection, Development- ERD 2021, 2, (pp. 441-452). European Publisher. https://doi.org/10.15405/epes.22032.44. https://doi.org/10.15405/epes.22032.44.

Beavis, C. (2007) Writing, digital culture and English curriculum. *L1 Educational studies in language and literature*, *7*(4), 23-44.

Bender, W. N. (2017). *20 Strategies for Increasing Student Engagement*. Learning Sciences International.

Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Science Education*, *95*(6), 1049-1065.

Bloom, B. S. (Ed.). 1956. *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain*. David McKay Co Inc.

Börner, K., Scrivner, O., Gallant, M., Ma, S., Liu, X., Chewning, K., Wue, L., & Evans, J. A. (2018). Skill discrepancies between research, education, and jobs reveal the critical need to supply soft skills for the data economy. *Proceedings of the National Academy of Sciences*, *115*(50), 12630-12637. https://doi.org/10.1073/pnas.1804247115 https://doi.org/10.1073/pnas.1804247115

Borzea, P., A. (2017), Curriculum integration and the development of cognitive ability, Ed. Polirom.

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices*. Heinemann: Westport, CT.

Bybee, R., W. (2010). Advancing STEM education: A 2020 vision. *Technology and engineering teacher*, *70*(1), 30.

Bybee, R. W. (2013).*The case for STEM education: Challenges and opportunities*.

Cain, K. (2009). Making sense of text: skills that support text comprehension and its development. *Perspectives on language and literacy*, *35*(2), 11-14.

Caldwell, H., & Pope, S. (2019). *STEM in the primary curriculum*, Sage Publishing.

Chan, T. W. (2010) How East Asian classrooms may change over the next 20 years. *Journal of Computer Assisted Learning, 26*(1), 28-52.

Ciolan, L. (2008) *Integrated learning*. *Fundamente pentru un curriculum transdisciplinar*, Polirom Publishing House.

Ciolan, L. & Ciolan, L. E. (2008) Pedagogy of primary and pre-school education.Integrated approaches in primary education, Ministry of Education, Research and Youth University Training Program in Pedagogy for Education, https://pdfcoffee.com/demersuri-integrate-in-inv-primarpdf-pdf-free.html

Cucoș, C., (2014) *Pedagogy*, 3rd edition, Ed. Polirom.

Curry, M. J., & Hanauer, D. I. (Eds.) (2014). *language, literacy, and learning in STEM education: Research methods and perspectives from applied linguistics* (Vol. 1). john Benjamins Publishing Company.

Dewey, J., (1916). Democracy and Education. New York, Macmillan.

Drake, S., & Burns, R. (2004) *Meeting standards through integrated curriculum*. ASCD.

Drake, S., (1993). *Planning Integrated Curriculum: The Call to Adventure*. Alexandria, VA: Association for Supervision and Curriculum Development.

Erickson, J. A., & Anderson, J. B. (1997) Learning with the community: Concepts and models for service-learning in teacher education.

Forgarty, R., (1991a). *The Mindful School: How to Integrate the Curriculum*. Pallantine, Skylight Publishing.

Furco, A., & Billig, S. H. (Eds.) (2002) *Service learning: The essence of the pedagogy*. IAP.

New Horizons Foundation (2021). Schools in the Community. https://www.noi-orizonturi.ro/2022/11/02/scoli-in-folosul-comunitatii-2022-2023/

Gee, J. P. (2010) Learning by design: Games as learning machines. *Interactive Educational Multimedia*, (8), 15-23.

Hasni, A., & Potvin, P. (2015). Student's Interest in Science and Technology and its Relationships with Teaching Methods, Family Context and Self-Efficacy, *International Journal of Environmental & Science Education*, 10(3), 337-366.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.) (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. DC: National Academies Press.

Johnson, C. C., Peters-Burton, E. E., & Moore, T. J. (Eds.) (2015). *STEM road map: A framework for integrated STEM education*. Routledge.

Kazu, I. Y., & Kurtoglu Yalcin, C. (2021). The effect of stem education on academic performance: A meta-analysis study. *Turkish Online Journal of Educational Technology-TOJET*, *20*(4), 101-116.

Sellami, A., Fadlelmula, F. K., Abdelkader, N., & Al Thani, M. F. (2021). A critical review of research on STEM education in Qatar. The International Journal of Humanities Education, 20(1), 19. Kysilka, M. L. (1998). Understanding integrated curriculum. *Curriculum journal*, *9*(2), 197-209

Lamberg, T., & Trzynadlowski, N. (2015). How STEM academy teachers conceptualize and implement STEM education. *Journal of Research in STEM Education*, *1*(1), 45-58.

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, *6*(1), 2.

McKinsey Report, (2017). mckinsey.com/industries/public-and-social-sector/our-insights/how-to-improve-student-educational-outcomes-new-insights-from-data-analytics (accessed June 10, 2021).

Mustafa, N., Ismail, Z., Tasir, Z., Said, M. and Haruzuan, MN (2016). A meta-analysis on effective strategies for integrated STEM education. *Advanced Science Letters, 22* (12), 4225-4228. https://doi.org/10.1166/asl.2016.8111 https://doi.org/10.1166/asl.2016.8111

OECD (2018). Finland. Paris: Organization for Educational Development and Cooperation, http://www.oecd.org/finland/.using a complex designed system. IJ STEM Ed 7(3). https://doi.org/10.1186/s40594-019-0201-4. https://doi.org/10.1186/s40594-019-0201-4.

Ostler, E. (2015). *STEM education: An overview of contemporary research, trends, and perspective,* Cycloid Publication.

Paul, A. (2019). Technology Scouting and Inventions Patenting With Impact on the Agrifood Future: INACO-Institutional Innovation for Competitiveness in Romania. In *Agrifood Economics and Sustainable Development in Contemporary Society* (pp. 347-366). IGI Global.

Paul, A. (2020).The jobs of the future.Job market opportunities in tomorrow's world https://inaco.ro/wp-content/uploads/2020/10/Ghidul-meseriilor-viitorului-Editia-a-IIIa-INACO-Sep-2020-red.pdf

Palmer, P., & Lister, S. (2019). Foreign languages and STEM. *STEM in the Primary Curriculum,* 81.

Pâinișoară I., O. (2017) *Teacher's Guide*, Polirom Publishing House.

Pimthong, P., & Williams, J. (2018) Preservice teachers' understanding of STEM education, *Kasetsart Journal of Social Sciences*.

Putica, K. (2024). Meta-analysis of the effects of stem teaching approach on the development of 21st century competencies related to learning of natural sciences. In *International Scientific Conference STEM/STEAM/STREAM Approach in Theory and Practice of Contemporary Education, University of Kragujevac, Faculty of Education in Jagodina, May 31 2024*.

Rahman, N. A., Rosli, R., & Rambley, A. S. (2021). Mathematical teachers' knowledge of STEM-based education. *Journal of Physics: Conference Series*, *1806*, 012216. https://doi.org/10.1088/1742-6596/1806/1/012216

Regina & Ferrara (2017). Handbook of Service-Learning in Central and Eastern Europe for involved teachers and students, New Horizons Association.

STEM Task Force Report.(2014). Innovate: A blueprint for science, technology, engineering, and mathematics in California public education. *Dublin, CA: Dedicated to Education Foundation.*

Tang, W., T. (2019). STEM Education Landscape: The Case of Singapore, *Journal of Physics: Conf. Series* 1340 ,012002 doi:10.1088/1742-6596/1340/1/01/012002.

Tashdemir, F. (2022). Examination of the effect of STEM education on academic achievement: A Meta-analysis study. *Education Quarterly Reviews*, *5*(2).

The Royal Society (Charity). (2014). *vision for science and mathematics education*. The Royal Society Science Policy Centre, London, England.

Tsupros, N., Kohler, R., & Hallinen, J. (2009). STEM education: A project to identify the missing components. *Intermediate Unit*, *1*, 11-17.

Tytler, R. (2007). Re-imagining science education: Engaging students in science for Australia's future. *Teaching Science*, *53*(4), 14-17.

Van Laar, E., Van Deursen, A. J., Van Dijk, J. A., & De Haan, J. (2017). The relation between 21st-century skills and digital skills: a systematic literature review. *Computers in Human Behavior*, *72*, 577-588. https://doi.org/10.1016/j.chb.2017.03.010

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: teacher perceptions and practice. *Journal of Pre-College Engineering Education Research, 1*(2), 1-13, https://doi.org/10.5703/1288284314636

Xie, Y., Fang, M., & Shauman, K. (2015). STEM education. *Annual review of sociology*, 41, 331.

Zeng, Z., Yao, J., Gu, H., & Przybylski, R. (2018) A meta-analysis of the effects of STEM education on students' abilities. *Science Insights Education Frontiers, 1* (1), 3-16. https://doi.org/10.15354/sief.18.re005 https://doi.org/10.15354/sief.18.re005