"BABEȘ-BOLYAI" UNIVERSITY

FACULTY OF PSYCHOLOGY AND EDUCATIONAL SCIENCES

THE "DIDACTIC. TRADITION. DEVELOPMENT. INNOVATION"

EXTENDED ABSTRACT OF THE DOCTORAL THESIS

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Cluj-Napoca

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THE IMPACT OF STEM/STEAM/STREAM ACTIVITIES IN SCIENCE IN PRIMARY EDUCATION

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STATEMENT

The undersigned Ioana-Aurelia Sabou (Baboș), having the capacity of doctoral student of the "Babeș – Bolyai" University, declare the following:

- Doctoral thesis with the title "**THE IMPACT OF STEM/STEAM/STREAM ACTIVITIES IN SCIENCE IN PRIMARY EDUCATION**" was achieved by strictly observing the four values of academic integrity - honesty, responsibility, replicability and validity of knowledge.
- The similarity analysis of the doctoral thesis was carried out at the Doctoral School "Didactics. Tradition, Development, Innovation", using the Turnitin Report.
- The thesis complies with the writing standards specified in the APA Publication Manual (7th Edition), except for the spacing of 1.5 lines.

The published studies address the issue of the present research and are cited in the thesis.

Date Signature

8.05.2026

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LIST OF ABBREVIATIONS AND ACRONYMS

APA	American Psychological Association
ANOVA	Analysis of variance
B	Good
D	The difference between two averages
DF	Degrees of Freedom (Degrees of Freedom)
EU	European Union
F	F Statistics
F	Gender Female
M	Gender Male
FB	Very good
GC	Control group
GE	Experimental group
I	Insufficient
IC	Confidence interval
IBL	Inquiry Based Learning
M	Media
M_ pre	Average at Pretest
M_pos	Posttest Average
MEM	Discipline "Mathematics and environmental exploration"
MS	Mean squares
n/n	Number of members in a sample
Crt. no.	Current Number
p	Probability value (p- value)
p.	Page
PIPP	Pedagogy of Primary and Preschool Education
pp.	Pages
S	Enough
SD	Standard Deviation

SPSS	Statistical Package for the Social Sciences (Pachetul Statistic pentru Științele Sociale)
SS	Sum of squares
Std. Error	Standard Error
SEM	Standard Mean Error
STEM	Science, Technology, Engineering, and Mathematics
STEAM	Science, Technology, Engineering, Arts and Mathematics
STREAM	Science, Technology, Reading, Engineering, Arts and Mathematics
TEAM	Theory of Multiple Intelligences
t	Statistics of the t-test (statistical test)
Vs.	Versus

SUMMARY

In recent decades, STEM education has become a central pillar of international education policies (Ostler, 2015), supporting lifelong learning and promoting active, student-centered teaching environments (Rahm, 2016). In order to strengthen interdisciplinary connections and enhance students' creativity and critical thinking, the integration of Arts and Science Reading has been introduced, leading to the development of extended frameworks such as STEAM and STREAM (Hunter-Doniger, 2018; Root-Bernstein, 2011).

In Romania, STEM with its STEAM and STREAM extensions is gaining ground including in primary education, among students interested in exploring, experimenting and applying concepts in real contexts (Anabousy & Daher, 2022; Duo-Terron et al., 2022).

The thesis entitled THE IMPACT OF STEM/STEAM/STREAM ACTIVITIES IN SCIENCE EDUCATION WITHIN PRIMARY EDUCATION addresses the complex issue of experimental investigation.

The thesis is organized into two main components: a theoretical section and a practical research section that encompasses the formative intervention. The three theoretical chapters aim to clarify the key concepts employed, including experimental activities, observation, scientific thinking and integrated STEM/STEAM/STREAM approach. In addition, they delineate the distinctions between formal and informal experiment activities. The section also provides illustrative examples of these concepts, suitabbly adapted to the level of primary education.

The preliminary research intended to investigate theachers and students/future teachers perceptions about learning in natural sciences and learning through investigation. Based on the results of these researches, an investigation guide applicable to teaching activities in primary education was developed, used in the formative investigation. The guide approaches the experiment in a STEM context, indoor activities and outdoor activities, aiming to develop students' thinking and critical thinking abilities, as well as to and increase students academic performance.

Key-words: investigation, experiment, primary school, natural science, school performances.

CHAPTER 1. THEORETICAL FRAMEWORK

1.1. LEARNING IN THE DISCIPLINE OF SCIENCE IN PRIMARY EDUCATION

1.1.1 Research Context and Issues

The need of man to continuously adapt to new situations, processes and professional challenges, requires that the school, in addition to its informative function, pursue the development of students' intellectual abilities, critical thinking and their independence (Dewey, 1977). An essential contribution to achieving this goal is made by experimental activities carried out in both a formal and non-formal setting. The experimental approach facilitates the systematic and gradual training of students' thinking in solving various problems (Maltese & Tai, 2010) and in familiarizing them with the procedures of scientific knowledge of the scientist's abilities. As Sadler (2011) points out, the development of experimental skills begins as early as primary grades, when children's development falls within the stage of concrete operations (Saçkes et al, 2011).

In Romania, research on extracurricular science activities for primary school students is limited; however, there are several studies that have aimed to assess the impact of science activities implemented in school. These studies have shown that the availability of scientific materials in the classroom is not in itself an impact factor on students' performance in the natural sciences (Saçkes et al., 2011). However, teaching natural sciences through experiment and investigation has a positive impact on students' performance and attitudes to science (Akınoğlu & Tandoğan, 2007; Kaderavek et al., 2020). Also, studies (Patrick et al., 2009) show that the use of experiment and scientific investigation increases both students' interest and motivation for learning natural sciences and their perceived scientific competence (Patrick et al., 2009). Data on perceived competence come from research conducted in primary schools involved in science and civic education projects anchored in real contexts (Doyle & Zakrajsek, 2019). The results indicate that the active participation of students in such authentic learning experiences contributes significantly to strengthening knowledge and understanding of scientific concepts, as well as to increasing their interest and motivation for the study of science.

1.1.2 Scientific Thinking and Method

Scientific thinking involves quantifying, explaining, and making predictions about factors existing in the environment (Paul & Elder, 2006). According to Paul and Elder (2006), scientific thinking is based on the idea that the same cause, if it manifests under the same conditions, will generate the same result. Thus, the scientific approach involves, in principle, the same main steps: observation, preparation/design of the experiment, measurement, formulation of physical laws, identification of similar phenomena, formulation of hypotheses or theories, testing and refining hypotheses, and establishing theories that can be verified by other researchers. The development of scientific thinking in children has been intensely studied over the years, the initiator of this research direction being considered Piaget, who investigated how children develop their scientific thinking about time, distance, number, motion, space, causality or living things (Zimmerman & Klahr, 2018). Studying the development of scientific thinking in preschoolers and students is difficult, because at this stage children go through accelerated changes on multiple levels of development. For example, thought and language are considered either distinct or closely interconnected processes. Most commonly, language is seen either as a tool for expressing and explaining thought, or as a means of influencing and shaping it (Fedorenko & Varley, 2016). Thinking implies the existence of complex and well-consolidated operative structures, which are formed gradually, through experience and cognitive maturation. This perspective is in line with the theory of cognitive development proposed by Jean Piaget, according to which children's thinking evolves in stages, from concrete actions to increasingly abstract logical operations. Piaget argues that the acquisition of knowledge results from processes of assimilation and accommodation, through which the child gradually builds increasingly complex cognitive structures. Thus, the development of scientific thinking is not a spontaneous process, but reflects a progressive transition between various cognitive stages, from pre-operational thinking to operational-concrete and later operational-formal thinking, where the capacity for abstract reasoning necessary for scientific learning arises (Paul & Elder, 2006; Zimmerman & Klahr, 2018).

1.2. IN-SCHOOL AND OUT-OF-SCHOOL EXPERIMENTAL ACTIVITIES IN PRIMARY EDUCATION

1.2.1 Inquiry/Research-Based Learning

Research is a systematic and rigorous process of building new knowledge through investigation. Scientific research includes various ways in which scientists study the natural world and propose explanations based on evidence derived from their work (Ennis, 2011). The construction of knowledge through research is based on the discovery of new knowledge, the validation of existing theories or the solution of specific problems by collecting, testing, analyzing and interpreting data (Ciascai, 2010). Research involves critical thinking, methodological precision, and a continuous effort to expand human understanding. Faced with unknown phenomena or situations, researchers formulate investigable questions, based on which they design and carry out research approaches, using mathematical and technological knowledge as tools for analysis, knowledge and communication (Facione, 2011). Following these processes, they develop logically substantiated explanations and arguments, supported by empirical evidence, and the results obtained, together with the procedures used, are communicated to the scientific community, contributing to the development of knowledge (National Research Council, 2011). Through investigation, the observation or analysis/study of a phenomenon, a situation or a particular case is carried out, in order to collect facts and data (Șuteu & Ciascai, 2024).

We deduce from the considerations formulated above that learning through investigation is not just a simple method, but a whole methodology. This provides opportunities to develop students' knowledge, understanding, and interest in science (Ültay & Çalık, 2012). Inquiry-based teaching assigns the primary role of decision-maker to the teacher. It structures the investigative activity: selects the skills needed to be developed by the students, organizes the work environment, formulates challenging research problems and questions for the students, which make them interested and curious, selects the working methods (problematization, exploration, observation, experiment) that can be used by the students, guides the students or ensures their autonomy.

1.2.2. Experimental Activities and their Typology

Learning through experimental activities is one of the most productive ways to build new knowledge in the training/development of scientific skills (Ciascai, 2023).

Experimental activities integrate all practical and methodical approaches used for observing, manipulating, and controlling variables for the purpose of verifying a hypothesis, discovering a law, or understanding a scientific phenomenon. Experimental activities are structured activities. These involve the use of systematic and controlled observation, along with experimentation (Ciascai, 2010).

Controlled observation is a research method in which the investigator observes and records phenomena in a controlled environment without actively manipulating variables and minimizing external influences. Ciascai (2000) disputes the veracity of this statement by showing that observation can take the form of experimentation (Marquet et al., 2022) and that simple explorations are closer to observation than experiment. For example, the dissolution of a sugar cube in water by mixing with a teaspoon leads to a finding and represents an experimental observation, in which the experimenter manipulates a variable. As a result, in the present paper we consider observation as a controlled approach of collecting data and facts necessary to test a hypothesis.

The experiment represents a controlled intervention on a phenomenon, carried out under predetermined conditions, with the purpose of observing its manifestations, analyzing the causal relationships, identifying the laws that govern it and validating scientific hypotheses (Oprescu, 1996). To this end, the investigator deliberately manipulates one or more independent variables and controls the conditions to observe their effects on the dependent variables.

The experimental method involves the mobilization of a coherent set of complementary capacities, such as the formulation and testing of scientific hypotheses, the elaboration of operational definitions and the organized application of scientific knowledge in various didactic contexts (frontal, individual, group); thus contributing to the development of scientific thinking and investigative skills (Bybee, 2010; Karplus & Thier, 1967).

The typology of experiments can be carried out depending on the proposed objectives, the way of realization, the materials, the level of student involvement, the moment of integration into the lesson or the specificity of the object of study (Bouzit et al., 2018; Bouzit et al., 2020; Cerghit, 2006; Ciascai, 2010; May et al., 2023; Oliveira & Bonito, 2023; Tomkova, 2024).

1.2.3 Learning in the Classroom and Outside the Classroom through Experimental Activities

The role of the primary school teacher in these activities is being redefined. Thus, the role of the teacher is transformed from that of knowledge provider to that of learning facilitator, having the function of mediating the relationship between the student and knowledge, of organizing relevant experimental situations and of guiding the student's investigative approach (Bruner, 1966). The teacher creates stimulating learning contexts, formulates open-ended problems, guides students in planning and conducting experiments and encourages reflection on the results obtained.

The stages of an experimental activity carried out in the classroom generally follow the specific structure of scientific research as follows: (1) *The objective* is to understand a scientific concept under controlled conditions; to verify hypotheses (Ciascai, 2000); (2) *The learning environment* that is controlled by the teacher, dependent on available equipment, simulated (selected traits and artificially reproduced conditions) (Bybee, 2010); (3) *The problem/question to be investigated*, it is recommended that the phenomenon, process, physical object to be studied be from the student's familiar context or his life experience. Whenever possible, the object of study is concretely brought to the classroom. If this is not possible, models, photographs or films presenting the object, deed, phenomenon or process investigated will be brought (Karplus & Thier, 1967); (4) *Issuing predictions/assumptions* – anticipating results based on previous knowledge and experience. The teacher explains his way of thinking with reference to the formulation of hypotheses and supports the students to reason logically if they have the main role in formulating the hypotheses (Bybee, 1997); (5) *Design of the controlled experimental observation* or experiment and its organization. The project includes the object of observation, the purpose/hypothesis, the experimental equipment, the way of working (experimental tasks), the way of retaining experimental data (tables, lists). The teaching materials are standardized (test tubes, thermometers, water, candles, etc.). Emphasis is placed on precision and repeatability (Kolb, 1984); (6) *Conducting the experiment*, observing and directly manipulating the variables related to objects or phenomena; (7) *Data collection and processing*. The data are retained in tables and processed in order to make findings (Cañal, 2007); (8) *Analysis of the results*, then comparison of the experimental findings with the hypotheses; (9) *Formulation of findings and conclusions* – generalization of acquired knowledge (Lai, 1999); (10) *Application of knowledge* in new contexts; (11) *Process evaluation* (worksheets, observation of experimental performance and results (knowledge) Șuteu & Ciascai, 2024).

1.3. STEM/STEAM/STREAM ACTIVITIES

1.3.1. Integrated STEM approach

The concept of STEM has been developed since the 1990s as a reaction to the need to train a workforce capable of adapting to the needs of today's society. The acronym was coined by Dr. Judith Ramaley in 2001, then deputy director of human resources at the U.S. National Science Foundation (Tytler, 2020).

STEM can effectively respond to the challenges of today, but also to those of the future. Industry 4.0 requires new types of professionals. It is estimated that by 2030, 186 professions will emerge and 57 will disappear, according to the New Atlas of Professions. A large part of the work techniques used in the labor market are starting to be replaced by machines/robots, and in the not too distant future more and more professions will be automated (Shatunova et al., 2019). However, in school practice, mathematics and science are priority subjects, and engineering is a secondary subject.

1.3.2. STEM Education, Foundations and Developments

STEAM education can be conceptualized according to the degree and type of integration of disciplines, with several distinct forms being identified. Thus, transdisciplinary STEAM education involves a complete fusion of disciplines, with problem-solving as a central element (Kazakoff et al., 2013). In the case of interdisciplinary STEAM education, integration is carried out around a common theme, while maintaining the specificity of each discipline (Makrakis & Kostoulas-Makrakis, 2015). Multidisciplinary STEAM education involves collaboration between several disciplines, but without leading to their deep integration (De la Garza, 2019; Shatunova et al., 2019). Finally, transversal STEAM education is characterized by analyzing one discipline from the perspective of another discipline, fostering conceptual connections between different fields (Harris & Bruin, 2018).

At the international level, STEM education policies do not currently specify an adequate framework for the development of well-trained and technologically competent individuals (Zeidler, 2016). Most stakeholders say that STEM skills need to develop in a formal setting, i.e.

at school (Falk et al., 2016). Promoting STEM education in schools supports equal opportunities, also attracting girls to scientific and technological fields, traditionally dominated by men.

1.3.3. Experimental Activities in the STEM/STEAM/STREAM Context

Activities in the context of STEM/STEAM/STREAM offer a framework conducive to experiential learning, due to their complex, integrated and applicative nature. This framework can be authentic, reflecting real situations, or built in the classroom, through practical activities. In both cases, students have the opportunity to explore scientific and technological concepts through direct practice and collaboration. Within these activities, the following characteristics are found: the experimental component that includes the observation of natural phenomena, the formulation of hypotheses and their testing through experiments prevails. In this context, students explore facts and phenomena, establish variables that represent causes and effects, measure, compare and draw conclusions (Newmann et al., 2007); includes engineering in primary education through activities of designing and building simple devices or devices, which represents the first stage of practical/hands-on activity in the use of the necessary tools (Rickinson & Tanner, 2001); technology involves the practical application of the project carried out. Technology identifies and uses the materials necessary for the implementation of the engineer's project (Schoenfeld, 2016); It ensures precision and rigor to the experimental activities, the engineer's design, the use of materials by the technologist. Mathematics is the one that provides tools, calculation models in these activities.

In terms of experimental activities, the STEM/STEAM/STREAM approach develops scientific skills such as: logical, critical and analytical thinking; the ability to develop and test hypotheses, process and interpret data to formulate conclusions; the ability to make decisions taking into account the outcome of the explorations; the ability to argue by reference to evidence (Ciascai, 2023).

CHAPTER 2. ORIGINAL RESEARCH CONTRIBUTIONS

2.1 OBJECTIVES AND GENERAL RESEARCH METHODOLOGY

2.1.1. Research objectives

Although STEM has become a topic of interest both nationally and internationally, studies that test the effectiveness of training programs aimed at developing STEM skills are few, at least in Romania. Although a simple search on the internet indicates the existence of a very large number of STEM educational resources, there are few studies that offer a training program proven to have empirical validity.

In this thesis we aim to investigate the experimental activities in the context of STEM/STEAM/STREAM within the "Natural Sciences" classes using a scientific methodology and from a practical educational perspective.

The general objectives of the proposed studies are the following:

O1. To investigate the perceptions, experiences and practices of primary school teachers regarding the implementation of integrated STEM/STEAM/STREAM approaches, in order to analyze the ways of curricular integration, the frequency of their use, the educational benefits, as well as the difficulties and constraints that influence their application in teaching practice.

O2. To analyze the conceptual structure and epistemological coherence of the integrated STREAM approaches developed by the students of the specialization Pedagogy of Primary and Preschool Education, from the "Babeș-Bolyai" University, in order to highlight the operationalization of disciplinary integration, the consistency of the integrative concepts and the way of operationalization of interdisciplinary competences.

O3. To assess the formative potential of STREAM workshops and summer schools in developing the key competences of primary school students, by analysing how interdisciplinary and inquirive learning experiences contribute to strengthening critical thinking, creativity, problem-solving and shaping interest in STEM careers.

O4. To assess the formative potential of summer schools and STREAM workshops in developing teachers' professional competences for the design and implementation of innovative educational practices, by analysing how these interventions contribute to strengthening STEM skills, critical thinking, creativity, collaboration and problem-solving, both at the level of teachers and in relation to the perceived impact on students' learning.

O5. Determining the impact of experimental activities in the STEM context on the quality of cognitive processes of primary school students.

Specific objectives

The general objective no. 1 was carried out during study 1, which collects data from primary school teachers on the use of STEM/STEAM/STREAM activities in the classroom and the integrated approaches chosen for these subjects.

The general objective no. 2 was carried out during the course of study 2, in which data are collected from the students of the Pedagogy of Primary and Preschool Education within the "Babeș-Bolyai" University on the realization and structuring of the content of the integrated STREAM approaches.

The general objective no. 3 was carried out during the course of study 3, which collects data on the analysis of the impact of STREAM workshops and summer schools on the development of key competences of primary school students, in particular critical thinking, creativity and problem-solving capacity, in experiential and interdisciplinary learning contexts.

The general objective no. 4 was carried out during study 4, which collects data on the training and strengthening of teaching skills necessary for the effective integration of the STREAM approach into educational practice, by promoting innovative strategies and examples of good practice.

The general objective no. 5 was carried out during the course of study 5, which collects data on determining the impact of experimental activities in the STEM context on the quality of cognitive processes of primary school students.

2.1.2. General methodology

The thesis includes 5 empirical researches, structured in 5 studies, namely: a quantitative study conducted through an online questionnaire-based survey among primary school teachers, a mixed study (quantitative and qualitative) on the analysis of the structure and content of the integrated STREAM approach proposed by PIPP students from "Babeș-Bolyai" University, two quantitative studies with interventional design on the impact analysis of schools and STREAM summer workshops conducted with students and teachers and a quasi-experimental study with pretest-intervention-posttest design on the impact of experimental activities in the STEM context on the quality of cognitive processes of primary school students.

In the following, we will present general methodological aspects regarding the research population, the general research designs, the measurement instruments used, the data analysis procedures.

Population Selected for Research

In study 1, the selection of survey participants is carried out on a voluntary basis. 103 teachers participated.

In study 2, the selection of participants is made among 72 students from the PIPP specialization of the "Babeș-Bolyai" University and 20 master's students.

In study 3, the selection of participants was carried out among the students participating voluntarily in the STREAM summer schools and workshops. 273 students participated in this research.

In study 4, the selection of participants was carried out among the teachers participating voluntarily in the STREAM summer schools and workshops. A number of 218 teachers participated in this research.

In study 5, the selection of participants was made among the students involved in the research of the application of the STREAM experimental activities within the classes of "Mathematics and Environmental Exploration" and "Natural Sciences". 430 students from grades II-IV participated in this research.

Teachers who meet five criteria were involved in research 1 and 4: they teach "Mathematics and environmental exploration", respectively "Natural Sciences" in these classes; they are tenured teachers in the school; some of them have a professional certificate: they have obtained professional certification (finalised, / teaching degree II/ teaching degree); participation was voluntary; informed consent. In the research, the requirements and ethics of the research were respected, as well as the protection of the participants' personal data according to [GDPR].

General Research Designs

Study 1 is a quantitative research in which data collection was carried out through a questionnaire of its own design. The questionnaire was validated by 2 experts in educational sciences.

Study 2 is a mixed type research (quantitative and qualitative) on the analysis of the implementation of the STREAM integrated activity projects. 72 students from the Pedagogy of

Primary and Preschool Education specialization at the "Babeș-Bolyai" University participated in the research. However, in the second stage of the research, 20 teachers, master's students were interviewed on the clarification of the results on the Theory of Multiple Intelligences (TIM) and how it is used in the classroom.

Study 3 is a quantitative research, with an interventional design, in which the data collection was done through the survey method based on a questionnaire and an evaluation sheet of the knowledge and skills developed among the students participating in the STREAM schools and summer workshops.

Study 4 is a quantitative research, with an interventional design, in which the data collection was done through the survey method based on a questionnaire and an evaluation sheet of the knowledge and skills developed among the teachers participating in the STREAM schools and summer workshops.

Study 5 is a quasi-experimental research that has a pre-test-intervention-post-test design in two groups: a control group (CG) and an experimental group (EG). The research was carried out with the participation of 14 professors (including the doctoral student).

Tools used

In study 1, research data is collected through the questionnaire "Research on perceptions of STEM/STEAM/STREAM education" (Annex A1). The tool is designed by the researcher based on her own experience in teaching and some information from the literature. It is structured on two parts. The first part includes 7 items to identify the demographic characteristics of the respondents, and the second part has 41 items on STREAM education, the integration of TIM in teaching activities and the relationship between them.

In study 2, research data collection is done in two stages. In the first stage, the implementation of integrated activity projects is analyzed, based on 18 pre-established criteria. In the second stage, an interview is organized investigating the clarification of the subjects' knowledge about TIM and if/how they use it in class.

In study 3, the research data collection is carried out through a survey based on a short questionnaire on the information that students have on the integrated STEM approach, accompanied by an evaluation sheet of the knowledge and skills developed during the summer schools and workshops in which they participated.

In study 4, the research data collection is carried out through a short questionnaire on teachers' perceptions of the integrated STEM/STEAM/STREAM activities and an evaluation sheet of the knowledge and skills developed through the activities carried out within the STREAM summer schools and workshops.

In study 5, the research data collection is carried out through 2 tests, of own design (a pre-test, a post-test). The tests contain 8 objective, multiple-choice items. For solving each test, 8 points are awarded. Scores are calculated for each student, on each test.

Data Analysis Procedures

In study 1, the data analysis involved the use of descriptive statistics, by processing the responses to the items on the Linkert scale by aggregating the categories of agreement and disagreement and reporting the results in the form of percentages, means and standard deviations, appropriate to the exploratory nature of the study.

In study 2, the data analysis was carried out in two stages, through descriptive evaluation based on a scale with 18 criteria assessed on a 5-point Likert scale, with the reporting of the results by aggregating the minimum and maximum levels, completed in the second stage by qualitative data obtained through group interviews to deepen and clarify the results.

In study 3, the data analysis was carried out by triangulating information from systematic observation, questionnaires and analysis of the products of the students' activity, in order to obtain an integrated perspective on the impact of STEM/STEAM/STREAM activities on the development of their skills.

In study 4, the data processing was carried out by corroborating the information from the systematic observation, the questionnaires applied and the evaluation sheets completed by the teachers, in order to analyze the impact of STEM/STEAM/STREAM activities on the development of the targeted competences.

In study 5, the data analysis involved the quantification of the scores obtained in the initial and final tests, the comparative correlation of the results to assess the students' progress and their processing through descriptive statistical methods (averages, minimum and maximum scores, performance distributions), in order to highlight the impact of the formative intervention on school performance and cognitive development.

2.2 STUDY 1: ANALYSIS OF TEACHERS' VIEWS ON THE INTEGRATION OF STEM-BASED ACTIVITIES IN PRIMARY EDUCATION

2.2.1 Introduction

The aim of this study is to investigate the opinion of primary school teachers on the use of STEM/STEAM/STREAM subjects in the classroom and the integrated approaches chosen for these subjects. In addition, the aim was to investigate the respondents' experiences in teaching STREAM subjects, the preferred methods to integrate this type of content, as well as to identify the difficulties they face in teaching based on this type of activities.

The research questions are as follows:

IC1. What is the importance given by teachers to integrated STREAM subjects and approaches in primary education?

IC2. What are teachers' perceptions of the impact of STREAM activities on students' development and their orientation towards the study of STREAM subjects?

IC3. What is the teachers' experience in designing and implementing integrated STREAM activities in the teaching process?

IC4. What are the difficulties faced by teachers in implementing STREAM activities and what strategies do they use to overcome them?

2.2.2 Method

Participants

The research included 103 primary school teachers, mostly female (94.17%), who voluntarily participated in the study. Regarding the level of education of the participants, 52.43% of the respondents have a bachelor's degree, 43.69% a master's degree, and 3 respondents have a doctorate in Educational Sciences. The respondents' teaching experience is distributed as follows: up to 5 years (9.7%); between 6 and 10 years old (11.65%); between 11-20 years old (34.95%), between 21-30 years old (33.98%) and over 30 years old (9.71%). Regarding the teaching certification, 62.14% of the respondents hold the level 1 qualification ("grade I"), 25.24% obtained the level 2 qualification ("grade II"), 7.77% obtained tenure, and 4.85% did not have a teaching certificate. The distribution of respondents according to the teaching area is as follows: 73.79% of respondents teach in urban areas, 25.24% teach in rural areas, and 1 respondent teaches in both types of areas.

Data Collection

Data collection was carried out between 20.01.2020 and 26.01.2020 through a questionnaire on perceptions of STEM/STEAM/STREAM education. Respondents voluntarily and anonymously participated in filling in the questionnaire. They were selected through the groups of teachers for primary education in the online environment.

Instrument

The tool used in the research was an online questionnaire, called in the present research "Questionnaire on perceptions of STEM/STEAM/STREAM education" (Annex A1), applied through the Google Drive platform and adapted from the tool used by Zsoldos-Marchis and Ciascai (2019), respectively processed in the study conducted by Baboș Ioana-Aurelia and Ciascai Liliana (2020). The questionnaire is structured in two parts. The first part includes 7 items to identify the demographic characteristics of the participants, and the second part has 41 items related to STREAM education, the integration of the Theory of Multiple Intelligences (TIM) in teaching activities and the relationship between STREAM and TIM. For most items, the questionnaire uses the 5-point Likert scale (from 1 - *disagree at all* to 5 - *strongly agree*). For 12 items included in the questionnaire, the answers consisted of writing statements/denials, developing answers or establishing the hierarchy of several given statements. In order to achieve the purpose of this study, 27 items that addressed the issue of STREAM education were extracted for data analysis.

Data Analysis

In order to be able to make the statistical interpretation of the collected answers, a descriptive statistic was previously made. The data analysis of the items evaluated on the Likert scale was based on the calculation of the percentages of respondents who either *disagree* or *agree* with the evaluated statements. Thus, the responses strongly *disagree* and *disagree were summed* under the Disagree label, and the responses *total agreement* and *agreement* were labeled as *Agreement*. Being an exploratory study, the results are reported in the form of percentages, averages and standard deviations.

2.2.3 Results and Discussions

Respondents' importance of STEM/STEAM/STREAM integrated disciplines and approaches

The results show a high level of agreement among respondents regarding the role of teachers in stimulating students' interest in STEM/STEAM/STREAM areas, with 81.55% of them expressing a favorable opinion (m = 4.23, SD = 0.88). A similar level of consensus can be observed in relation to the importance of integrated STEM-based approaches, for which the same percentage of 81.55% of respondents agree (m = 4.30, SD = 0.91).

Also, 75.73% of the participants (m = 4.09, SD = 1.02) consider it important to carry out the integrated STEM/STEAM/STREAM activities in the context of the class. However, a significantly lower percentage of 45.63% (m = 3.17, SD = 1.19) consider that the design of such activities is easy, which suggests the existence of perceived difficulties in the practical implementation of these teaching approaches.

Respondents' opinion on the impact that STEM/STEAM/STREAM activities have on the development of students and on the profile of students interested in studying STREAM disciplines

A percentage of 71.84% (M = 3.92, SD = 1) of respondents agree with the statement "The school performance of students who systematically participate in integrated STEM/STEAM/STREAM activities is higher than that obtained if they did not participate" and 85.44% (M = 4.40, SD = 0.86) agree that "It is good for teachers to develop an integrative vision for the STEM/STEAM/STREAM fields". A possible explanation for these results is that students' knowledge, skills, and interests are valued through integrated approaches.

2.2.4 Conclusions

The results obtained from the analysis of the data collected through the questionnaire indicate a predominantly favorable attitude of teachers towards the integration of STEM/STEAM/STREAM approaches in educational work. The high percentages of agreement recorded for the items related to stimulating students' interest in STEM fields (81.55%) and for the implementation of integrated approaches based on these areas (81.55%) suggest that the majority of respondents recognize the relevance and importance of this educational approach for the learning process. Also, a significant percentage of the participants consider it important to carry out integrated activities in the classroom (75.73%), which indicates a general openness to the use of these interdisciplinary approaches in teaching practice.

Regarding the perception of the impact of integrated activities on student development, the results highlight the conviction of the majority of respondents that systematic participation in STEM/STEAM/STREAM activities contributes to increasing school performance (71.84%) and to the formation of relevant skills for contemporary society. In particular, respondents associate success in STEM fields with a number of cognitive and attitudinal characteristics, such as curiosity (87.38%), logical thinking (85.44%), critical thinking (83.50%) and a high level of general knowledge (83.50%). At the same time, they believe that students with performance in these fields have higher chances of integration into modern society (83.50%), which reflects the perception of the relevance of STEM skills for adapting to the current demands of the labor market and the knowledge-based society.

The data analysis also highlighted the existence of significant differences between respondents depending on their teaching experience. Thus, teachers with 21–30 years of experience seem to use integrated activities more frequently, considering them particularly relevant for current generations of students. On the other hand, teachers with 11–20 years of experience admit their use to a lesser extent, citing constraints such as lack of time for training, busy schedules or insufficient teaching and technological resources. Also, two categories of respondents, teachers with less than 10 years of experience and those with more than 30 years of teaching activity, signaled more pronounced barriers in the implementation of these approaches. In the case of beginner teachers, difficulties seem to be associated with a lack of methodological training and institutional support, while in the case of highly experienced teachers, there is a certain resistance to change, determined by trust in traditional teaching methods.

Regarding the concrete experience in implementing integrated activities, most respondents (70.87%) say that they have carried out such activities before the time of the study, although their frequency varies considerably. The results also show that these activities are not perceived as limited to certain specific educational contexts, most teachers considering that they can be carried out in a formal setting, but also in other educational environments, which suggests a flexible perspective on the organization of the learning process.

The results of this first preliminary study show that primary school teachers want to implement the integrated STEM/STEAM/STREAM approach, considering that it is associated with a number of benefits for students. Therefore, opening up teachers to this type of approach should encourage those responsible for teacher training and training in the design and implementation of STEM/STEAM/STREAM courses and materials for primary education. These results show us that primary school teachers are prepared to carry out such programs, even if they will need support in order to overcome certain difficulties. Therefore, the training program proposed in this paper aims to be a guide for teachers who want to implement STEM education in primary school students.

As a follow-up to this first study, we present the results of the second study, focused on identifying the structure and content of the integrated STREAM approaches proposed by future primary and preschool teachers. As the first study shows us that primary school teachers have a positive attitude towards the implementation of STEM education and associate it with a number of advantages for students, it is important to identify the extent to which they are prepared to design integrated STEM activities for primary school students. Therefore, Study 2, presented below, highlights the main area on which the integrated STREAM approaches proposed by future primary and preschool teachers are based, the superficially integrated areas within this approach, the integrative concepts that are intended to be developed through this integrated approach and the interdisciplinary skills valued by future teachers.

2.3 STUDY 2: ANALYSIS OF ACTIVITY PROJECTS IN THE CONTEXT OF STREAM EDUCATION AND THE THEORY OF MULTIPLE INTELLIGENCES

2.3.1 Introduction

Purpose of the research was to investigate structure and content of the integrated STREAM approaches proposed by students of the primary and preschool education specialization.

The research questions are as follows:

IC1. To what extent do students own and understand the concepts specific to the STREAM domains in the design of teaching activities?

IC2. To what extent do students correctly integrate the STREAM domains and adequately formulate concepts, behaviors and questions in the design of activities?

IC3. To what extent do students capitalize on interdisciplinary skills and pedagogical principles such as student-centeredness, creativity and multiple intelligences in STREAM activities?

The quality of the formulation of the work tasks, the creativity shown by the subjects in the elaboration of the project and the predominant types of intelligence valued by the students through their projects were also appreciated. The creativity targeted both the content and the structure of the activities specific to each field as well as the interdisciplinary connections proposed by the project. The types of intelligence were identified in the lesson projects based on their defining characteristics.

2.3.2 Method

The participants were asked to individually carry out the project of an integrative theme of their choice, pointing out the following aspects of interest with reference to each integrated field (science, mathematics, technologies, engineering, arts, reading/reading of scientific texts): scientific content; questions and assignments addressed to students (these are related to the levels of the revised Bloom taxonomy); skills specific to each field, necessary to be developed for students; interdisciplinary concepts and skills, respectively behaviors to the development of which the study of the proposed theme contributes; explaining the integrated activity through a concept map (for the overview of the theme).

Participants

72 students of the specialization "Pedagogy of Primary and Preschool Education" from the "Babeș-Bolyai" University participated in this study. The majority of participants are women (97.22%), aged between 18 and 24 years.

Data Collection

The data were collected during the second semester of the 2019/2020 academic year.

Research Tool & Data Analytics

The research was carried out in two stages. In the first stage, the integrated activity projects proposed by the 72 participants were analyzed. The rating scale was conducted by the researchers based on the tasks given to the subjects and contains 18 criteria. The evaluation of the projects was carried out by the researchers individually, then discussed and finalized. The level of fulfillment of each criterion was assessed on a 5-point scale, where 1 signifies *to a very small extent* and 5 *to a very large* extent. For the presentation and discussion of the results, the percentages corresponding to levels 1 and 2, respectively 4 and 5 were summed, these being the minimum and maximum standards, respectively.

The second phase of the research aimed to clarify the results on the Theory of Multiple Intelligences (TIM). To this end, a group interview with teachers was organized, in which 20 teachers, master's students, participated. The subjects' knowledge of TIM and if/how they use TIM in class were investigated.

2.3.3 Results and Discussions

The interview conducted with the students highlighted several relevant aspects. Teachers do not frequently use differentiated teaching according to the predominant type of intelligence at the classroom level, as it is difficult to identify and quantify it. Also, the school curriculum is perceived as uniform and insufficiently adapted to the development of the students' multiple intelligence profile, which makes it difficult to implement integrated activities.

At the same time, the students interviewed said that they are not familiar with the concept of "TIM class", in the absence of knowledge of the students' intelligence profile. In the educational context in Romania, there is insufficient evidence on the effective functioning of the model based on multiple intelligences, which leads to a more reserved approach to the implementation of STREAM education.

However, the participation of future teachers in continuous training programs, focused on STREAM education and on capitalizing on multiple intelligences, can contribute to the adaptation and diversification of teaching strategies, ensuring a better correlation of the teaching process with the needs of students.

2.3.4 Conclusions

The analysis of the data highlights that although students demonstrate a moderate level of mastery of knowledge specific to integrated areas in the STREAM sphere, there are significant gaps in terms of deep conceptual understanding and coherent application of them. In particular, the major difficulties are associated with the delimitation of engineering and technology concepts, as well as with the correct identification of disciplinary skills and the formulation of appropriate introductory questions, essential aspects for effective didactic design.

Regarding the integrated approach, the results indicate a limited capacity of students to operationalize the integrative concepts and formulate the targeted behaviors in learning, which suggests an insufficient internalization of the principles of interdisciplinarity. However, a strong point is the correct identification of interdisciplinary skills, most students being able to recognize higher cognitive processes such as analysis, synthesis or problem solving.

From the perspective of the pedagogical dimensions, there is a positive orientation towards the student-centered and the manifestation of creativity in the design of the activities, but these aspects are overshadowed by the difficulties in the clear and correct formulation of the work tasks, which affects the coherence of the teaching approach. Also, the integration of the principles of the Theory of Multiple Intelligences in teaching activities is reduced, which reflects both the students' lack of familiarity with this theoretical framework and the difficulties of practical application.

The opinions of students and teachers confirm these results, highlighting a discrepancy between the recognition of the importance of the TIM profile and its effective application in educational practice. The lack of clear benchmarks in the curriculum, insufficient teacher training and the absence of functional models at national level contribute to the limited and reluctant implementation of STREAM education.

In conclusion, the results suggest the need to strengthen the initial training of teachers, with a focus on clarifying fundamental concepts, developing integrated design skills and capitalizing on students' potential through the prism of multiple intelligences. These directions are essential for increasing the quality of the educational act and for an authentic and efficient implementation of modern educational approaches.

2.4 STUDY 3: ANALYSIS OF THE IMPACT OF STREAM WORKSHOPS AND SUMMER SCHOOLS FOR STUDENTS

2.4.1 Introduction

STREAM workshops and summer schools are non-formal and informal educational contexts that extend the learning experience beyond the formal classroom setting, providing students with the opportunity to explore, experiment, and apply knowledge in authentic situations (Dewey, 1938). These activities capitalize on learning through experience and investigation, facilitating the active involvement of students in the process of knowledge and contributing to the development of critical thinking, creativity and problem-solving capacity (Kolb, 1984). The analysis of the impact of these educational activities aims to identify the effects they have on the development of students' skills, as well as on their attitudes and interest towards learning (Bybee, 2010).

The aim of these workshops was to analyse the impact of STREAM workshops and summer schools on the development of key competences of primary school pupils, in particular critical thinking, creativity and problem-solving skills, in experiential and interdisciplinary learning contexts.

The research questions were:

IC1. What knowledge do the participating students have in the field of experiential learning and STEM/ STEAM/STREAM?

IC2. What is the students' interest in STREAM activities?

IC3. What are the students' perception and interest in the jobs of the future?

IC4. What is the impact of STREAM activities on critical thinking and problem-solving?

2.4.2 Method

Participants

Throughout the duration of these workshops and STREAM summer schools, a total number of 273 primary school students were registered who had their parents' consent to participate in the activities (Annex B1). The students participated 15-20 in a workshop.

Data Collection

The study was conducted between August 2022 and October 2025 through students participating in the STREAM workshops and summer schools. 7 workshops were held, one workshop being allocated 2 days of 2 hours each. The students have participated in thematically structured STREAM activities (e.g. construction, sustainable energy, wind measurement, solar system, STEM careers), using recyclable materials and digital technology.

Instrument

The students participating in the workshops were subjected to a survey based on a questionnaire developed by the doctoral student, applied with the support of the activity partner. The questionnaire was applied at the beginning of the activity and at the end of it (Annex B2). Also, the students filled in evaluation sheets of the knowledge and skills developed (Annex B3).

Data Analysis

The data analysis was carried out based on the systematic observation made by the doctoral student, the data collected from the completion of the questionnaires and the analysis of the products of the students' activity, in order to obtain a complex perspective on the impact of STEM/STEAM/STREAM activities on the development of their skills.

2.4.3 Results and Discussions

Prior to the formative intervention, workshops 1, 2 and 3 carried out with the students aimed, on the one hand, to investigate the valences of the STEAM activities and to orient the students towards STEM careers and on the other hand to select the theme and prefigure the structure of the activities proposed to the students in the experimental groups in the context of the formative intervention. These workshops included 135 students.

The PhD student also conducted workshops in parallel with the formative intervention, workshops 4 and 5, which allowed her to identify solutions to the malfunctions noticed and to make small adjustments at the level of the activities carried out at the experimental groups in the formative intervention. These workshops included 50 students. It should be noted that, based on the results of the training intervention, the doctoral student optimized the activities proposed to the students through workshops 6 and 7, which followed the intervention and which included 88 students.

The percentage of students who recognize the role of STREAM knowledge in solving real-life problems increased from 22% to 33%. At the same time, 53% of students expressed interest in future careers in STEM fields (e.g.: researcher, IT engineer, construction engineer, astronaut).

2.4.4 Conclusions

The analysis of the data collected during the workshops carried out with the students highlights a number of relevant aspects regarding the impact of STREAM activities on their cognitive, motivational and behavioral development. Firstly, there is a relatively low level of previous exposure to such activities, with only 36% of students stating that they have participated in similar experiences before. This suggests that integrated education is not yet sufficiently capitalised in current educational practice, which limits students' opportunities to develop interdisciplinary competences in a systematic way.

However, the results obtained from participating in the workshops indicate a significant progress in terms of motivation for studying the STEM/STEAM/STREAM fields. The increase in the percentage of motivated students, from 23% to 40%, reflects the effectiveness of these activities in stimulating interest in learning through interactive and applied methods. At the same time, the fact that more than half of the students (53%) express interest in a career in STEM fields highlights the important role of these experiences in early vocational guidance and in shaping professional aspirations.

Another significant aspect is the improvement of the level of understanding of the integrated nature of knowledge. If initially only 22% of students were aware of the need to use knowledge from multiple fields to solve real-life problems, at the end of the workshops the percentage increases to 33%. Although progress is visible, it also indicates the need to continue educational approaches to strengthen interdisciplinary thinking.

In conclusion, the STREAM workshops had a positive impact on the students, favoring the increase of motivation, the development of interdisciplinary skills and the orientation towards STEM fields. In this regard, in order to increase the efficiency of these approaches, it is considered necessary to extend and systematically integrate them into the curriculum, as well as to develop students' skills of investigation and critical reflection.

2.5 STUDY 4: ANALYSIS OF THE IMPACT OF STREAM WORKSHOPS FOR TEACHERS

2.5.1 Introduction

The effective implementation of STREAM approaches obviously depends on the training of teachers, their openness to innovation and interdisciplinarity (Ciascai & Zsoldos-Marchis, 2019). Thus, the continuous training of teachers through workshops is a fundamental approach for the development of the pedagogical competences necessary to integrate these approaches into teaching practice (Margot & Kettler, 2019; Kotsis, 2024). These workshops provide opportunities for experiential learning, exchange of best practices and reflection on their own teaching strategies, contributing to the continuous professional development of teachers.

Therefore, analysing the impact of STREAM workshops for teachers becomes essential for understanding how they influence teachers' educational practices, attitudes and competences (Ciascai & Zsoldos-Marchis, 2019).

The aim of these workshops was to train and strengthen the teaching skills necessary for the effective integration of the STREAM approach into educational practice, by promoting innovative strategies and examples of good practice.

The research questions were as follows:

IC1. To what extent do teachers have knowledge of experiential learning and STREAM approaches?

IC2. What is the teachers' perception of students' interest in STREAM activities and in the jobs of the future?

IC3. Are there significant differences between teachers' perceptions before and after participating in STREAM activities on professional development?

IC4. What is the teachers' perception of the impact of STREAM activities on the development of critical thinking, creativity, collaboration and problem-solving, both in students and for them personally?

2.5.2 Method

A sample of teachers participating in the workshops were subjected to a survey based on a short questionnaire developed by the doctoral student, applied with the support of the colleague and their activity was observed by the doctoral student. The questionnaire was applied at the beginning of the activity and at the end of a workshop. Also, the participants filled in evaluation sheets of the knowledge and skills developed through the activity.

Participants

At the workshops, 218 teachers were selected who voluntarily participated in these activities and completed both questionnaires/evaluations.

Data Collection

The study was conducted between September 2021 and September 2025 through teachers participating in the STREAM workshops. 15 workshops were held, one workshop being allocated a day of 4-5 hours each. The teachers participated, like the students, in thematically structured STREAM activities (e.g.: construction, sustainable energy, wind measurement, solar system, STEM careers), using laboratory tools, recyclable materials and digital technology.

Instrument

The teachers participating in the workshops were answered to a questionnaire-based survey (Annex C1) and filled in an evaluation sheet (Annex C2) developed by the doctoral student, applied with/without the support of the activity partner. The investigation was carried out before and after the activity, within a maximum period of 3 days.

Data Analysis

The data analysis was carried out based on the systematic observation made by the doctoral student, the data collected from the completion of questionnaires and evaluation sheets, in order to obtain a complex perspective on the impact of STEM/STEAM/STREAM activities on the development of their skills.

2.5.3 Results and Discussions

Prior to the formative intervention, presented in Study 5, workshops from 1 to 10 were carried out with the teachers. These workshops with the theme "STREAM Education in Primary Education" aimed, on the one hand, to investigate the teachers' opinion with reference to (i) the valences of STEAM activities and (ii) the theme to be addressed in the activities of the formative intervention, respectively (iii) the prefiguration of the structure of the activities proposed to the students in the experimental groups in the context of the formative intervention. The previous workshops included 1049 teachers.

The PhD student conducted workshops 11, 12, 13 and 14 together with the teaching staff, in parallel with the formative intervention. This approach facilitated the identification of solutions for the dysfunctions found and the making of adjustments at the level of the activities carried out in the experimental groups within the training intervention. These workshops were attended by 5986 teachers in online activities and 60 face-to-face.

Following the questionnaire applied, a data analysis was carried out which indicated that 22% of teachers say they have heard of STEM, but only 18.45% of teachers know the meaning of the abbreviation STEM. The examples given reveal that teachers fail to distinguish between technology and engineering at the beginning of a STEM activity. The percentage of teachers who encounter difficulties remains relatively constant (38.75%).

28.56% of respondents appreciate STREAM activities as interesting at the beginning of the workshop and 72.59% at the end of it. 54.64% of teachers believe that students will also find these activities interesting, with the reservation that in the preparatory classes, the first and second grades, they are more difficult to put into practice.

2.5.4 Conclusions

The results obtained from the application of the initial and final questionnaires, as well as the observations made during the STREAM workshops, highlight a positive impact of these activities on the professional development of teachers, but also the existence of significant conceptual gaps. At the beginning of the workshops, the level of familiarity with the STREAM field is low, with only a limited proportion of teachers demonstrating a correct understanding of the meaning of the concept and its components. In particular, there are persistent difficulties in delimiting the concepts of technology and engineering, as well as a constant percentage of teachers who have difficulties in approaching these activities.

During the workshops, there is a significant increase in teachers' interest in STREAM activities, which suggests their effectiveness in stimulating motivation and openness to innovative approaches. Also, teachers' perceptions of students' interest are generally positive, although reservations are expressed about the applicability of these activities to lower levels of education.

The comparative analysis of the initial and final responses indicates an increase in the level of agreement regarding the role of STREAM activities in the development of professional competences. The most significant progress is made in terms of creativity, collaboration, problem-solving and interdisciplinary knowledge, which confirms the formative value of the workshops. However, critical thinking is showing less growth, suggesting the need for more sustained teaching interventions and longer exposure to STREAM activities. The slight decreases observed in some items can be interpreted as the effect of a recalibration of teachers' perceptions, who, following direct experience, more realistically assess their skills and the impact of their activities.

2.6 STUDY 5: INVESTIGATING THE EFFECTIVENESS OF EXPERIMENTAL ACTIVITIES IN STEM CONTEXTS ON CRITICAL THINKING AND SCHOOL PERFORMANCE OF PRIMARY SCHOOL STUDENTS

2.6.1 Introduction

Based on the results obtained in previous studies, we developed a quasi-experimental investigative approach, focused on the analysis of the impact of experimental activities in STEM contexts on the development of cognitive processes of primary school students. This approach led to the formulation of the research question, the objectives, the hypotheses and the design of the formative intervention. Through its methodological structure, the research provides a rigorous framework for analyzing the relationship between the didactic intervention of the experimental activity in the STEM context and the development of students' cognitive processes, providing solid premises for the interpretation of the results obtained.

In the present study, a quasi-experimental design with the control group is used, based on pretest-posttest measurements, which allows the comparative analysis of the effects of the formative intervention on cognitive processing and school performance of students.

2.6.2 Theoretical framework of the research

The importance of critical thinking skills is reflected both in the quality of reasoning and in the ability to formulate correct answers, these two dimensions being complementary (Halama & Strizenec, 2004). In this sense, the systematic integration of critical thinking in the learning process contributes to the organization and structuring of students' knowledge, facilitating its transfer in problematic contexts and supporting the identification of effective solutions for solving learning tasks.

2.6.3 Purpose, variables and assumptions

In the present study, a quasi-experimental design with the control group is used, based on pretest-posttest measurements, which allows the comparative analysis of the effects of the formative intervention on cognitive processing and school performance of students.

The aim of this study is to investigate to what extent experimental activities in the STEM context contribute to the development of critical thinking and school performance of primary school students, by stimulating the capacity for analysis, interpretation, argumentation and problem solving in application-interdisciplinary learning contexts.

At the same time, this study aims to highlight the impact of these activities on the active application of students in the learning process, on cognitive autonomy and on the formation of key competences.

The general objective of the research is to determine the impact of experimental activities in the STEM context on the quality of cognitive processes of primary school students. The achievement of this objective was possible through the implementation of a formative intervention program, based on integrated STEM teaching, which aims to stimulate students' cognitive processing, in accordance with the levels of Bloom's taxonomy (recall, understanding, application, analysis, evaluation and creation). The intervention was centered on learning through discovery, experiment and reflection, promoting the active involvement of students in the construction of knowledge.

The research question was the following: "To what extent do experimental activities in the STEM context influence reflection, critical thinking and school performance in the discipline of Natural Sciences among primary school students?"

This question concerns not only lower-level cognitive acquisitions (recall, understanding, application), but especially the development of higher cognitive processes (analysis, evaluation, creation), in accordance with the revised Bloom taxonomy.

The general hypothesis from which we started the study was the following: "The implementation of an intervention program based on integrated experimental activities in the STEM context determines a significant improvement in the level of critical thinking and school performance in the Natural Sciences discipline, compared to conventional teaching methods".

The following specific assumptions emerge from the general hypothesis:

Specific hypothesis 1. Students in the experimental group will perform higher in science compared to students in the control group.

Specific hypothesis 2. Experimental activities in a STEM context increase students' critical thinking skills.

As a result, the study had the following variables:

The independent variable of the research is represented by the formative intervention program, based on experimental activities in the STEM context and applied to the experimental group, while the dependent variable is represented by the level of school performance and cognitive processing of the students, evaluated by the scores obtained at the tests applied during the research.

The dependent variable is represented by the level of school performance, on the one hand, and critical thinking, on the other hand.

The control variables of the research are represented by the age of the students, the class level, the school curriculum and the conditions of application of the tests, kept constant to ensure the validity of the results.

Through its methodological structure, the research provides a rigorous framework for analyzing the relationship between the didactic intervention of the experimental activity in the STEM context and the development of students' cognitive processes, providing solid premises for the interpretation of the results obtained.

2.6.4 Method

Participants

The experimental research was carried out during the 2024-2025 school year, involving students from the second, third and fourth grades, from two schools in the urban area of Sălaj County: the "Gheorghe Lazăr" Secondary School Zalău and the "Mihai Eminescu" Secondary School Zalău. The choice of these school units allowed the study to be carried out in educational contexts comparable from a curricular and organizational point of view.

The total sample consisted of 430 students from the second, third and fourth grades, divided into two groups: an experimental group (GE = 209 students) and a control group (CG = 221 students). The groups included classes with close numbers (between 26 and 32 students), which contributed to the methodological balance of the study. The students' participation in this experiment was done with the consent of the parents .

14 teachers (including the doctoral student) were involved in the research, each responsible for a class. The distribution of students aimed to maintain the natural character of the collectives, while ensuring comparability between groups. The structure of the groups was carried out at the class level, without reorganizing the students, which gives the research a quasi-experimental character. In this context, the GE benefited from the formative intervention based on experimental activities in the STEM context, and the CG went through the teaching activities through traditional methods.

Data Collection

The experimental design (Table 2.6.4) included two evaluation moments, namely pre-test and post-test, applied to both the experimental group and the control group, under similar conditions. Within the GE, between the evaluation moments, experimental activities were implemented in the STEM context, while in the CG the instructional-educational process was carried out through the use of traditional teaching methods, without the introduction of the formative intervention.

Table 2.6.4

Experimental design

Timing evaluation / Group	Pretest	Formative intervention	Posttest
Experimental group	Interdisciplinary assessment test	Experimental activities in the STEM context	Interdisciplinary assessment test
Control group	Interdisciplinary assessment test	The traditional method	Interdisciplinary assessment test

The evaluation of the students was carried out by applying standardized tests, developed unitarily for all class levels involved in the research and built in accordance with the provisions of the school curriculum.

Within the formative intervention, the didactic strategies used integrated various active-participatory methods, such as experimentation, brainstorming, problem solving and investigation, contributing to stimulating the cognitive involvement of students. The organization of the activities was flexible, alternating in forms of group work, in team, frontal and individual, depending on the specifics of the learning tasks and the objectives pursued.

Instrument

The assessment tools consisted of two tests: an initial test (Pretest) applied at the beginning of the experiment and a final test (Posttest) applied at the end of the experiment (Annexes D1, D2). The tests were adapted to the level of cognitive development of primary school students, were previously piloted on a similar sample and subsequently revised to ensure the clarity, relevance and validity of the items.

The items included in the assessment tests targeted different levels of cognitive processing (Table 2.6.5), from recall and comprehension, to application, analysis and critical thinking, according to Bloom's taxonomy. The scoring of the tests was carried out objectively, by awarding one point for each correct answer, the total score being eight points for each assessment tool. The calculation of the scores was carried out on the basis of a matrix of specifications and performance descriptors, presented in Annexes D1, D2, which allowed for a rigorous and comparable evaluation of the results.

Table 2.6.5

Classify test items based on the cognitive processing they require to solve

Type of cognitive processing	Pretest	Posttest
Reminder	Item 1	Item 1
Reflection	Items 2, 3, 5	Items 2, 3, 5
Analysis	Item 4	Item 4
Application	Item 6	Item 6
Critical thinking	Items 7, 8	Items 7, 8

Teaching activity (Formative intervention)

In the initial stage of the research, the Pretest was applied to both groups of students, at the beginning of October. The tests were applied in physical format, under controlled conditions, identical for all the groups investigated, in order to ensure the comparability of the results. The tests were administered during the course hours, under unitary conditions for all participating classes. The duration of the application was approximately 30-40 minutes, being adapted to the age particularities of the students.

Subsequently, within GE, the formative intervention program was implemented, consisting of weekly experimental activities in the STEM context. In parallel, in the CG, the instructional-educational process was carried out through the use of traditional teaching methods, without the introduction of intervention.

The formative intervention program consisted of the implementation at GE of a set of 10 experimental activities in the STEM context, over a period of 20 weeks carried out weekly (one activity was carried out during two hours, therefore over 2 weeks), within the classes of "Mathematics and environmental exploration" (second grades) and "Natural Sciences" (third and fourth grades). The activities were designed in an interdisciplinary manner, integrating experimental activities in the STEM context, adapted to the age level of primary school students (second, third and fourth grades). The activities were designed in accordance with the contents provided by the national curriculum and aimed at the progressive development of students' cognitive processing, according to the levels of Bloom's taxonomy. The topics addressed aimed at exploring physical and chemical phenomena, investigating biological processes, as well as developing the skills of observation, analysis, interpretation and scientific argumentation.

The activities were designed to encourage the active participation of students in the learning process, to encourage the formulation of hypotheses, the investigation of phenomena and the reflection on the results obtained. The activities had an interdisciplinary character, integrating elements from the fields of science, technology, engineering and mathematics, being methodically structured in stages: identifying the problem, formulating hypotheses, conducting the experiment, observing and interpreting the results, as well as formulating conclusions. The general structure of the experimental activities in the STEM context was a unitary one and included the following stages: presentation of a supporting material (text, audio-video resource or contextualized situation); formulation and analysis of the problem situation; conducting preliminary discussions based on the students' previous knowledge; identifying and presenting the necessary materials; conducting the experiment, according to clear and well-structured steps; formulating the conclusions and extending learning to new situations; reflection on the learning process and the difficulties encountered; the acquisition and use of a specific scientific vocabulary; analysis of the activity from the perspective of STREAM, by highlighting interdisciplinary connections.

Data Analysis

The correlation of the items from the initial and final tests allowed the comparative evaluation of the students' progress and the identification of the impact of the formative intervention on cognitive development.

The data obtained from the application of the assessment tools were subjected to a rigorous process of processing and analysis, in order to highlight the impact of the formative intervention on the students' school performance and cognitive processing.

In the first stage, the students' answers were quantified by awarding one point for each correctly solved item, the total score for each test being 8 points. The results obtained were centralized in separate data tables for Pretest and Posttest, for both EG and GC.

2.6.4 Results and Discussions

Since the data distribution does not deviate significantly from the normal one and the t-test is not significantly influenced by a slightly atypical distribution, the effectiveness of the intervention was tested by means of the student t-test. We present below the results obtained from the statistical analysis. Thus, in Table 2.6.6. The differences between the initial and final tests in the two groups, experimental and control, are presented.

Except for the *Interpretation* dimension, the differences identified between the experimental group and the control group are statistically significant, suggesting the impact of the educational intervention.

Regarding the total score, it is observed that at the time of pre-testing there are no significant differences between the two groups ($t = 0.295$, $p = 0.768$), which indicates the initial equivalence of the groups, an essential condition for the internal validity of the study. On the other hand, in the post-test, the experimental group registers a significant increase ($M = 7.47$, $SD = 0.528$, $p < 0.001$), compared to the control group ($M = 5.06$), which suggests a strong effect of the intervention.

On the *Understanding* dimension, there are no significant initial differences ($p = 0.493$), but at post-test there is a statistically significant difference ($t = 15.113$, $p < 0.001$), in favor of the experimental group. This result indicates that the intervention contributed to the development of medium-level cognitive processes, associated with the understanding of concepts.

For the *Reminder size*, the differences are smaller. Although a statistical significance is observed at post-test ($p = 0.045$), it is borderline, suggesting that the intervention had a moderate impact on reproductive memory, compared to other cognitive dimensions.

In the case of the *Application size*, no significant differences are identified even in the pre-test ($p = 0.092$), nor at post-test ($p = 0.245$). This result may indicate that the transfer of knowledge in new situations is more difficult to achieve and requires longer interventions or additional teaching strategies.

The *Critical Thinking* dimension highlights the most consistent results: from the absence of significant initial differences ($p = 0.138$), to a strongly significant increase at post-test ($t = 23.257$, $p < 0.001$). This suggests that the intervention was effective in developing higher cognitive skills, such as analysis, evaluation, and reflection.

Table 2.6.6

GE-GC pre-test-post-test differences

Size	**Group**	**Pretest**				**Posttest**				
		M	***SD***	***t***	***p***	***M***	***SD***	***t***	***p***	***d***
Total	GE	5,41	1,217	0,295	0,768	7,47	0,528	28,236	0,000	2.703
	GC	5,38	1,128	–	–	5,06	1,145	–	–	
Understanding	GE	0,95	0,214	0,687	0,493	0,98	0,352	15,113	0,000	1.448
	GC	0,94	0,244	–	–	0,53	0,263	–	–	
Reminder	GE	0,85	0,231	0,907	0,365	1,00	0,000	2,014	0,045	0.211
	GC	0,83	0,248	–	–	0,98	0,134	–	–	
Application	GE	0,56	0,345	-1,687	0,092	0,90	0,199	1,164	0,245	-
	GC	0,62	0,353	–	–	0,87	0,220	–	–	
Critical thinking	GE	0,53	0,240	1,485	0,138	0,92	0,190	23,257	0,000	2.217
	GC	0,49	0,239	–	–	0,41	0,264	–	–	

Table 2.6.14 analyzes the results of the t-test for paired samples shows statistically significant differences between pretest and posttest for most of the sizes analyzed in the experimental group. For the total score, the difference is strongly significant ($t = -16.345$; $p = 0.000$), indicating a substantial increase in student performance on the posttest.

The analysis of the differences between pre-test and post-test for EG shows significant changes in most of the dimensions assessed, which indicates the effect of the teaching intervention (Table 2.6.14).

Regarding the *Recall dimension*, there are no statistically significant differences between the two evaluation moments, the scores remaining relatively constant ($M\_pre = 0.84$; $M\_post = 0.83$; $t(62) = 0.241$; $p = 0.811$). This result suggests that the intervention did not influence the ability to reproduce the information. On the other hand, for the *Understanding dimension*, a statistically significant increase is observed, with students achieving maximum post-test scores ($M\_pre = 0.87$; $M\_post = 1.00$; $t(62) = -4.252$; $p < 0.001$). This result indicates a clear improvement in the capacity for conceptual understanding. The *Critical Thinking* dimension also registers a strong and significant increase, with scores increasing considerably in post-test ($M\_pre = 0.44$; $M\_post = 0.92$; $t(62) = -12.915$; $p < 0.001$). This development highlights the development of capacities for analysis, evaluation and reflection. Similarly, the *Application* size shows a statistically significant increase, with students achieving much higher post-test scores (*M_pre* = 0.45; *M_post* = 0.95; $t(62) = -10.718$; $p < .001$), which indicates an improvement in the capacity to transfer and use knowledge in practical contexts.

Table 2.6.14

Intragroup t-test in GE class II

Size	**Pair**	**Differences (Pre-Test and Post-Test)**	***SD***	**SEM**	**95% CI inf.**	**95% CI sup.**	***t***	***DF***	***p* (bilat.)**
Total	P1	-2,603	1,264	0,159	-2,922	-2,285	-16,345	62	0,000
Understanding	P2	-0,040	0,363	0,046	-0,131	0,052	-0,869	62	0,388
Reminder	P3	-0,198	0,262	0,033	-0,265	-0,132	-6,001	62	0,000
Application	P4	-0,500	0,370	0,047	-0,593	-0,407	-10,718	62	0,000
Critical thinking	P5	-0,480	0,295	0,037	-0,554	-0,406	-12,915	62	0,000

The data presented in Tables 2.6.15 and 2.6.16 show that there are no significant differences between girls and boys, gender not influencing the results. The comparison of the two tables highlights that, although descriptive statistics indicate a clear increase in performance from pretest to posttest for both genders (with a slight advantage of girls in the posttest), the t-test for independent samples confirms that these differences are not statistically significant ($p > 0.05$ in both pretest and posttest).

Table 2.6.15

Gender Differences at GE Class II

Variable	**Gen**	***N***	***M***	***SD***	***SEM***
Total Score (Pretest)	M	32	4,84	1,247	0,220
	F	31	4,84	1,293	0,232
Total Score (Post-Test)	M	32	7,38	0,609	0,108
	F	31	7,52	0,508	0,091

Table 2.6.16

T-test for independent samples by gender in GE Class II

Variable	**Var. equals**	***F***	***p***	***t***	***DF***	***p* (See.)**	***D***	**SEM diff.**
Total Score (Pretest)	Yes	0,053	0,818	0,016	61	0,987	0,005	0,320
	No	–	–	0,016	60,714	0,987	0,005	0,320
Total Score (Post-Test)	Yes	1,113	0,295	-0,997	61	0,323	-0,141	0,142
	No	–	–	-1,000	59,698	0,321	-0,141	0,141

Comparative analysis of data from descriptive statistics and the t-test for independent samples shows a clear concordance between the trends observed at the level of the means and their statistical validation within the control group (CG). The differences between the environments are generally small for all the variables analyzed, both in the pretest and in the posttest, which suggests a relatively uniform distribution of student performance. These minor variations are confirmed by the insignificant t-test values ($p > 0.05$), indicating that the observed differences have no statistical relevance. For some variables, such as recall and pretest, there are more noticeable descriptive differences and materiality threshold values close to the accepted limit, but these do not reach the level necessary to be considered significant, suggesting rather a natural variability of the data. In other situations, such as final score, comprehension and critical thinking, both the average values and the results of the inferential test indicate a marked stability and the absence of real differences between subgroups.

Overall, the results confirm the homogeneous nature of the control group and support the idea that any differences identified in subsequent analyses can be attributed to the teaching intervention, and not to initial discrepancies between participants.

First, the analysis of the final score indicates a statistically significant increase in the overall performance of the students, from an average score of 5.90 in the pre-test to 7.52 in the post-test, the difference being supported by the result of the t-test ($t(62)= -17.139$; $p < 0.001$). This evolution confirms the effectiveness of the teaching intervention as a whole, reflecting a consistent combination of school results.

At the level of size *Understanding*, the very high average values recorded both in the pretest ($M = 0.992$), and at the post-test ($M = 1.00$) indicates the existence of an almost maximum initial level. In that context, the lack of a statistically significant difference ($t(62)= -1,000$; $p = 0.321$) can be explained by the ceiling effect, which limits the possibility of measurable progress.

As regards the size of the *Reminder*, there is a statistically significant decrease in performance, from an average of 1.00 at the pre-test to 0.84 at the post-test ($t(62)= 3.420$; $p= 0.001$). This decrease can be interpreted in relation to the specificity of the intervention, which favored the processes of deep understanding and application, to the detriment of the mechanical memorization of information.

Size *Application* shows a statistically significant increase, from an average of 0.714 in the pre-test to 1.015 in the post-test ($t(62)= -4.294$; $p = < 0.001$), which indicates a clear development of students' ability to use knowledge in new contexts. This result is a relevant indicator of the effectiveness of the STEM approach focused on the transfer and functional use of knowledge.

The most pronounced evolution is recorded at the level of *Critical thinking*, where the average increases from 0.497 to 0.972, the difference being statistically significant ($t(62) = -10.133$; $p < 0.001$). This result indicates the development of analysis, argumentation and evaluation skills, central objectives of STEM/STREAM educational interventions.

Overall, the comparison of descriptive results with infervenal results highlights a methodological coherence: variations in means are statistically confirmed in the case of consistent differences (application, critical thinking, final score, recall), while in the case of minimal differences (understanding), the t-test indicates the absence of statistical significance. This fact reinforces the validity of the conclusions regarding the impact of the formative intervention on the cognitive development of the students in the experimental group.

In the case of the final score, the descriptive data indicate a decrease in the average from 5.25 to 4.79, suggesting a decrease in post-test performance. This trend is confirmed by the t-test, where the difference is statistically significant ($p = 0.000$) and the confidence interval does not include the value 0. Thus, the observed regression is not accidental, but reflects a real change in performance.

For the *Understanding dimension* , there is a statistically significant increase. Students reach the maximum score, which indicates improvement in basic comprehension (possible and ceiling effect) ($M\_pre = 0.96 \rightarrow M\_post = 1.00$; $t(94) = -2.734$; $p = 0.007$).

For the *Recall dimension* , a very strong and statistically significant decrease is highlighted. Students lose the ability to reproduce information, which is a clear signal of a lack of reinforcement of learning ($M\_pre = 0.99 \rightarrow M\_post = 0.33$; $t(94) = 13.604$; $p < 0.001$).

For the *Application size*, there are no statistically significant differences. The application capacity remains practically unchanged, there is no knowledge transfer ($M\_pre = 0.56 \rightarrow$ M_post $= 0.58$; $t(94) = -0.445$; $p = 0.657$).

For the *Critical Thinking dimension*, a statistically significant increase is observed and thus students moderately improve their ability to analyze and evaluate ($M\_pre = 0.42 \rightarrow M\_post = 0.58$; $t(94) = -6.829$; $p < 0.001$).

Overall, the comparative analysis reveals a high concordance between descriptive and inferential data, in the sense that all trends observed at the level of the means are statistically confirmed where the differences are consistent. The profile of evolution within the GOC is uneven, characterized by progress in understanding and critical thinking, stability in application and regression in final score and recall, which suggests the influence of unsystematic factors and the absence of a coherent teaching intervention that supports the balanced development of all competences.

2.6.5 Conclusions

The comparative analysis of the results obtained by the students in the experimental group and those in the control group highlights the significant impact of the teaching intervention based on the integrated STREAM approach on the development of students' competences.

In the case of the experimental group, there is a consistent progress between the pre-test and post-test stages, reflected both in the improvement of the quantitative results and in the quality of the answers provided by the students. This progress is associated with the use of student-centered teaching strategies, based on exploration, experimentation and interdisciplinary integration of contents, in accordance with the 5E model and the one developed by the doctoral student. The students highlighted a superior ability to understand concepts, apply knowledge in new contexts and formulate reasoned explanations, which indicates progress in the development of critical thinking and problem-solving skills.

Comparatively, in the control group, where the teaching process was mainly carried out by traditional methods, the progress made was lower and limited especially at the level of reproductive acquisitions. Students in this group showed difficulties in transferring knowledge and tackling open tasks, suggesting insufficient development of higher-level skills.

Another relevant aspect is related to the motivational dimension. The students in the experimental group showed an increased interest in the activities carried out, active involvement in tasks and openness to collaboration, which confirms the positive role of STREAM activities in stimulating the intrinsic motivation for learning. In contrast, in the control group, student involvement was lower and dependent on the external requirements of the tasks.

The results also suggest that experimental activities in the STEM context facilitate the development of interdisciplinary skills, with students being able to make connections between fields such as science, technology, engineering and mathematics, as well as its developments

(Reading and the Arts). This capacity for knowledge integration is essential for the formation of relevant competences in the context of contemporary society and represents a clear advantage over traditional fragmented approaches.

In addition, the didactic intervention favored the development of socio-emotional skills, such as collaboration, communication and confidence in one's own abilities, aspects predominantly observed within the experimental group. These results support the idea that activities based on investigation and experimentation create an authentic and stimulating learning environment.

In conclusion, the results of the research confirm the hypothesis that the use of experimental activities in the STEM context, in correlation with the 5E model, leads to a significant improvement in student performance, both cognitively and motivationally and behaviorally, compared to the traditional methods used in the control group. Thus, the proposed intervention proves to be efficient and relevant for optimizing the instructional-educational process in primary education.

CHAPTER 3. CONCLUSIONS AND GENERAL DISCUSSIONS

3.1 General conclusions

The cumulative results of the 5 studies configure a coherent picture of the relevance and effectiveness of STEM/STEAM/STREAM approaches in primary education, both from the perspective of the educational actors involved and from the perspective of the impact on students' learning and development processes. Overall, the research confirms that the integration of STREAM approaches is not only an innovative methodological alternative, but an educational framework with significant potential for developing the skills needed for the 21st century.

A first general conclusion highlights the existence of a favorable climate for the implementation of integrated education reflected in the positive attitudes of teachers towards STEM/STEAM/STREAM approaches. Study 1 reveals teachers' openness to the use of interdisciplinary strategies and the recognition of their value in stimulating students' interest, in developing critical thinking and in forming relevant skills for the knowledge-based society. At the same time, the results indicate that this openness is accompanied by awareness of real challenges regarding implementation, which underlines the need for systemic support for these approaches.

A second major conclusion derives from the analysis of the initial training of future teachers and highlights the fact that interest and availability for integrated approaches are not sufficient in the absence of a solid conceptual foundation and interdisciplinary design skills. Study 2 shows that although students value the STREAM principles, there are difficulties in operationalizing them into coherent teaching projects. This result suggests that the authentic implementation of integrated education depends not only on favourable attitudes, but also on the quality of initial and continuing training.

Another important conclusion concerns the formative impact of STREAM activities on students. Studies 3, 4 and 5 converge in demonstrating that learning experiences based on investigation, experimentation and interdisciplinary integration contribute to the development of motivation for learning, higher cognitive skills, creativity, collaboration and critical thinking. Moreover, the experimental data confirm the superiority of formative interventions based on the 5 E model and experimental activities in relation to traditional practices both at the level of school performance and knowledge transfer and application.

The results also highlight that the development of critical thinking and interdisciplinary competences does not arise spontaneously, but requires deliberate pedagogical contexts, structured around authentic problems, investigation and reflection. In this perspective, the research supports the idea that experimental activities in STREAM contexts can function as privileged training environments for the development of complex skills, difficult to cultivate through fragmented disciplinary approaches.

At the same time, the general conclusions of the research highlight the existence of persistent challenges: insufficient preparation for the integration of the engineering and technological dimension, the difficulties of students in formulating hypotheses and research questions, as well as the gaps between the theoretical valorization of integrated approaches and their effective implementation. These aspects indicate that the effectiveness of STREAM education is conditional on the existence of enabling educational ecosystems, which include flexible curriculum, adequate resources, vocational training and validated pedagogical models.

Overall, the research confirms the general hypothesis that integrated STEM/STEAM/STREAM approaches, supported by experimental activities and structured formative interventions, have the potential to optimize the instructional-educational process in primary education, while contributing to the development of school performance, critical thinking and existential transversal competences.

3.2 Theoretical implications

The results of the research make relevant contributions to the development of the theoretical teaching framework on STEM/STEAM/STREAM education in primary education by consolidating and expanding the constructivist, socioconstructivist and inquiry-based learning perspectives on learning. A first theoretical implication consists in validating the idea that integrated approaches represent privileged contexts for articulating the relationship between disciplinary knowledge and the development of higher level competences.

The data obtained support the theoretical premises formulated in the constructivist paradigm, according to which learning is the result of the active interaction between the student and the investigative environment, and knowledge is built through exploration, problematization and reflection. In this regard, the results provide empirical support for the learning-cycle and 5 E models, demonstrating their relevance for the development of critical thinking and cognitive transfer in integrated contexts.

An important contribution of the research aims to clarify the relationship between disciplinary integration and the development of interdisciplinary competences. The results suggest that the mere juxtaposition of content from several domains does not guarantee the authentically integrated character of an activity, but requires the existence of integrative concepts, authentic problems and complex cognitive processes that support the coherence of the approach. This finding contributes to the conceptual refinement of STREAM education by delimiting the authentic integration of superficial or additive forms of interdisciplinarity.

At the same time, the research brings contributions regarding the conceptualization of the role of the experienced dimension within integrated education. The results support the idea that experimental activities are not only teaching methods, but also epitemic contexts through which students develop practices specific to scientific thinking: formulation of hypotheses, evidence-based argumentation, modeling and problem solving. In this perspective, the research contributes to strengthening the relationship between STEM education and the development of scientific literacy.

Another theoretical implication derives from the emphasis on critical thinking as a cross-cutting dimension of STREAM approaches. The results support the treatment of critical thinking not only as a result of training, but as a central mechanism of integrated learning mediated through investigation, reflection and argumentation. This perspective contributes to articulating a theoretical framework as coherent as possible regarding the relationship between STEM and the development of higher cognitive skills.

The studies also highlight the relevance of articulating the STREAM framework with differentiated perspectives on learning, including in relation to the Theory of Multiple Intelligences and student-centered pedagogies. Thus, the research supports the extension of the theoretical discourse on integrated education beyond the personalization of educational experiences.

Through all these results, the research contributes to strengthening the theoretical foundations of STREAM education in primary education and provides conceptual benchmarks for the development of explanatory models regarding the relationship between curricular integration, experimentation, critical thinking and school performance

3.3 Practical implications

From an applicative perspective, the research results generate relevant implications for teaching practice, teacher training and educational policies. A first practical implication concerns the need for the systematic integration of STEM/STEAM/STREAM approaches in the curricular activities in primary education, not as punctual or extracurricular experiences, but as a constructive part of the instructive-educational approach.

The results suggest that designing activities based on investigation, experimentation and authentic problem-solving can become an effective strategy for increasing student motivation, developing school performance and stimulating interdisciplinary skills. In this regard, the research offers arguments for capitalizing on the 5 E didactic models and the integrated experimental sequences as methodological landmarks for classroom practice.

A major practical implication concerns the initial and continuous training of teachers. The results highlight the need to develop training programs explicitly oriented towards the design of STREAM activities, the integration of the engineering and technological dimension, the use of the didactic experiment and the development of skills to facilitate investigation. In this sense, the training program proposed within the research can function as a transferable intervention model in similar contexts.

The research also indicates the importance of developing concrete pedagogical resources: methodological guides, examples of good practices, integrated scenarios, experimental kits and digital resources, which reduce the barriers perceived by teachers in the implementation of integrated approaches. This direction is especially essential in the context of the difficulties identified regarding the design time, resources and engineering size of the activities.

At the level of evaluation practices, the results suggest the need to extend evaluation beyond reproductive acquisitions, to tools capable of capturing progress in critical thinking, collaboration, creativity, and problem-solving. Thus, the research supports the use of authentic assessments, investigative tasks and training tools as appropriate ways of assessment in STREAM contexts.

Another practical implication is the design of the curriculum. The results argue the need for a more flexible curriculum, which allows for authentic interdisciplinary approaches, connections between disciplines and systematic integration of investigation and experimentation into school activities. At the same time, they suggest the opportunity to include STREAM education and investigative practices in institutional development programs and curricular innovation policies.

Last but not least, the research has implications for the school's organizational culture, suggesting the need to build communities of practice and collaborative contexts in which teachers can design, implement and reflect on integrated activities. Such a perspective transforms STREAM education from an individual initiative into a sustainable institutional approach.

Therefore, the practical implications of the research go beyond the level of punctual intervention and support the development of an educational model in which experimental activities in the STEM/STEAM/STREAM context become tools for transforming teaching practice and optimizing primary education.

3.4 Limits of research

This paper, although it provides relevant results on the efficiency of approaching experimental activities in an integrated STEM/STEAM/STREAM context in primary education, presents a series of limits that must be taken into account in the interpretation and generalization of the conclusions.

Firstly, the size and structure of the samples is a limit, as the studies were carried out on a relatively small number of participants, coming from specific educational contexts. This aspect can influence the degree of generalization of results at the level of the entire school population.

Secondly, the duration of the formative interventions was limited, which does not allow us to fully capture the long-term effects of the experimental activities in the STEM/STEAM/STREAM context on the development of students' skills. Some benefits may only become more apparent after prolonged application.

Another limitation is related to uncontrolled external variables, such as individual differences between students, teachers' teaching styles or their level of involvement, which can influence the results obtained.

The assessment tools used can also be a limitation, as although they have been designed to capture the competences targeted, the assessment of dimensions such as critical thinking or creativity remains complex and difficult to quantify exhaustively.

Another aspect is the possible influence of the novelty effect, the students in the experimental group being able to show a higher level of interest and involvement due to the innovative nature of the activities, which can temporarily amplify the results.

In addition, the reliance on teacher skills and preparation in the implementation of experimental activities in the STEM/STEAM/STREAM context can influence the effectiveness of the intervention, making it difficult to accurately replicate the results in other educational contexts without adequate teacher training.

Last but not least, the research did not look in detail at individual student differences (e.g., multiple intelligences profile), which could provide a more nuanced perspective on how different students respond to this type of teaching approach.

Consequently, the results must be interpreted with caution and their validation requires further studies, carried out on larger samples and in various educational contexts.

3.3 Future research directions

The results obtained in the present research open a series of relevant perspectives for further developments in the field of STEM/STEAM/STREAM education.

A first direction aims to extend the study to larger and more diverse samples, including students from different educational backgrounds (urban/rural), in order to verify the generalizability of the results and to highlight possible contextual differences in the effectiveness of the STEM/STEAM/STREAM approach.

Another important direction is the realization of longitudinal studies, which would follow the long-term impact of experimental activities in the context of STEM/STEAM/STREAM on the development of students' skills, especially on critical thinking, creativity and orientation towards STEM careers.

It is also necessary to investigate the role of teacher training in the effective implementation of the STEM/STEAM/STREAM approach, by analyzing the relationship between the level of teacher training and the quality of the activities carried out in the classroom. In this regard, dedicated continuing education programs can be developed and evaluated.

A complementary direction is represented by the integration of emerging digital technologies (augmented reality, artificial intelligence, interactive platforms) in STEM/STEAM/STREAM activities, in order to analyze how they can amplify student engagement and the efficiency of the learning process.

At the same time, future research could explore the relationship between the STEM/STEAM/STREAM approach and the theory of multiple intelligences, looking at the extent to which integrated activities contribute to the development of different types of intelligence and to the personalization of learning.

Another relevant direction is the analysis of the impact on socio-emotional skills, such as collaboration, communication and self-regulation, essential aspects for adapting students to the requirements of today's society.

In addition, it is recommended to investigate the ways of assessing the competences developed through experimental activities in the STEM/STEAM/STREAM context, by developing authentic assessment tools, capable of capturing not only the results, but also the learning processes.

Finally, a direction of interest is the analysis of the integration of experimental activities in the STEM context into the national curriculum, identifying the existing barriers and opportunities at the level of educational policies and proposing sustainable implementation models.

APPENDICES

Annex A1

Questionnaire on teachers' perceptions of STEM/STEAM/STREAM education

A. General information

Please answer every question

A1. Genre :

- Female
- Male

A2. Age:

- 20-24 years old
- 25-29 years old
- 30 -35 years old
- 35-39 years old
- 40-49 years old
- 50-59 years
- Over 60 years old

A3. Graduated studies

- High School
- License
- Master's degree
- PhD

A4. Teaching experience

- Less than 5 years
- Between 6 and 10 years old
- Between 11 and 20 years old
- Between 21 and 30 years old
- Over 31 years old

A5. Teaching degree

- No teaching degree
- Finalized
- Grade II

- Grade I

A6. The school(s) you teach at are located in the area

- rural
- urban
- rural and urban

B. Questions regarding the relationship of TIM with school practice

B1	Item	Yes	No	I don't know
1	Do you think that the current school curriculum supports the capitalization of TIM (Theory of Multiple Intelligences) in school practice?			
2	Do you know the TIM (Theory of Multiple Intelligences) profile of the students in your class?			
3	Do you think that if you knew the type of intelligence prevalent in your class, you would be able to make lessons more attractive to students?			
4	Do you think that if you knew the type of intelligence prevalent in your classroom, you would be able to make lessons more effective?			
5	Have you noticed in the school textbooks or other curricular documents concerns for the capitalization of TIM in the proposed teaching activities?			
6	Does capitalizing on TIM in teaching activities lead to better school results?			

B2. How would you improve the quality of the educational act if you knew the predominant type of intelligence of your class?

....

C. *Questions regarding the integration of STEM/STEAM/STREAM activities into educational practice*

C1. Have you carried out integrated STEM (Science, Technology, Engineering, Mathematics)/ STEAM (Science, Technology, Engineering, Arts and Mathematics)/ STREAM (Science, Technology, Reading, Engineering, Arts and Mathematics) integrated activities so far?

- Yes
- No

C2. What is in your opinion regarding STEM/STEAM/STREAM education? Please rate, on a scale of 1 to 5, your degree of agreement with reference to each item (1 - strongly disagree; 2 -

partial disagreement; 3 - neither agreement nor disagreement; 4 - partial agreement; 5 - total agreement) *

Item		1	2	3	4	5
1	Teachers must promote students' interest in STEM/STEAM/STREAM subjects					
2	Teachers should take training courses on the application of the STEM curriculum					
3	In order to carry out integrated STEM/STREAM activities, teachers should have a very broad general culture					
4	Teachers should stimulate students' interest in integrated STEM/ STEAM / STREAM approaches					
5	It is good for teachers to develop an integrative vision of the STEM/ STEAM / STREAM fields					
6	Students capable of outstanding performance in the STEM/STEAM/STREAM fields are interested in these areas					
7	Students with superior performance in the STEM/ STEAM / STREAM fields think logically					
8	Students with superior performance in the STEM/ STEAM / STREAM fields think critically					
9	Students with superior performance in the STEM/ STEAM / STREAM fields are curious					
10	Students with superior performance in the STEM/STEAM/STREAM fields have a broad general culture					
11	Students with higher performance in the STEM/ STEAM / STREAM fields will integrate more easily into modern society					

D. Questions regarding how to carry out the integrated STEM/STEAM/STREAM activities.

D1. Do you believe that the current school curriculum encourages the realization of integrated STEM (Science, Technology, Engineering, Math) / STEAM (Science, Technology, Engineering, Arts and Math) / STREAM (Science, Technology, Reading, Engineering, Arts and Math) activities

- Yes
- No
- I don't know

D2. What is in your opinion regarding STEM/STEAM/STREAM education? Please assess, on a scale of 1 to 5, your degree of agreement with reference to each item (1 - totally disagree; 2 - partial disagreement; - neither agreement nor disagreement; 4 - partial agreement; 5 - total agreement) *

Item	1	2	3	4	5

1	STEM/STEAM/STREAM approaches are difficult to achieve in the primary cycle					
2	Primary school textbooks do not have integrated STEM/ STEAM / STREAM activities					
3	Primary school students are not prepared (cognitively or attitudinally) to engage in integrated STEM/STEAM/STREAM activities					
4	Integrated STEM/STEAM/STREAM activities should only take place in laboratories					
5	Integrated STEM/STEAM/STREAM activities should only take place outdoors					
6	Integrated STEM/STEAM/STREAM activities can also be done in the classroom					

D3. I do STEAM/ STREAM /STREAM activities

- o Daily
- o Several times a week
- o A few times a month
- o Once a month
- o Other answer

Detail how often you do STEM/STEAM/STREAM activities if you chose the "Other Response" option, otherwise put line.

....

E. Please rate, on a scale of 1 to 5, your degree of agreement with respect to each item (1 - strongly disagree; 2 - partial disagreement; 3 - neither agreement nor disagreement; 4 - partial agreement; 5 - total agreement) *

	Item	**1**	**2**	**3**	**4**	**5**
1	The most difficult thing is to teach knowledge of: Science					
2	The most difficult thing is to teach knowledge of: Technology					
3	The most difficult thing is to teach knowledge of: Engineering					
4	The most difficult thing is to teach knowledge of: Arts					
5	The most difficult thing is to teach knowledge of: Mathematics					
6	The most difficult thing is to teach knowledge of: Reading					
7	I find it easy to design integrated STEM/ STEAM /STREAM activities					
8	I think it is important to carry out integrated STEM/ STEAM /STREAM activities in the classroom					
9	The systematic integration of students in integrated STEM/STEAM/STREAM activities leads to an increase in their school performance					

10	Designing STEM/STEAM/STREAM activities with the TIM profile of the classroom in mind is an easy activity for the teacher					
11	The school performance of students who systematically participate in integrated STEM/STAM/STREAM activities is higher than those obtained if they did not participate					

F. The highest school performance is achieved when students are involved in (assign a place to each situation, 1st place being the most important)

	Item	**I**	**II**	**III**
1	In teaching activities that take into account the TIM profile of the class			
2	In integrated STEM/STEAM/STREAM activities that take into account the TIM profile of the class			
3	In integrated STEM/STEAM/STREAM activities			

Indicate your email address if you want to receive the results of the survey

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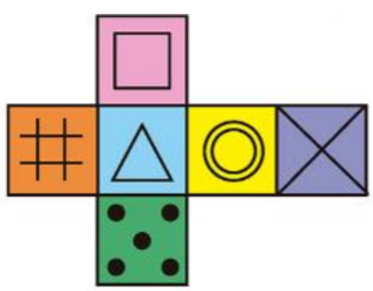
Annex D1

Initial tests for students (pretest) grades II-IV

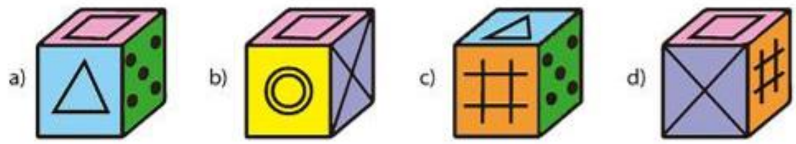
Third grade pre-test

Student's First Name Class Date

1. In order to maintain our health, we must take care:
   a) Let's eat healthy and exercise.
   b) Let's be clean and drink plenty of fluids.
   c) To have a healthy diet, to exercise and to keep our things clean.
2. The Earth's air envelope is called:
   a) Ozone;
   b) Atmosphere;
   c) Air.
3. Which of the 3 students are right:
   a) Ana says: "Land occupies the largest surface of the Earth".
   b) Andrei says: "The hills have rounded peaks".
   c) Mihai says: "The chamois lives in the plain area".
4. Geometric shapes were drawn on the faces of a cube. In the drawing below is the unfolding of the cube.



Which of the following cubes cannot be built based on the given unfolding?



5. The animals in the picture live:

a) At the South Pole.

b) In Europe.

c) At the North Pole.

6. Why does the Moon appear to us differently in the sky: sometimes full, sometimes half?

a) Due to the position of the Moon in relation to the Sun.

b) Due to the position of the Moon in relation to the Earth and the Sun.

c) Due to the position of the Moon in relation to the Earth.

7. You have 2 potted plants. One of them will be placed in a room near the wall, the other will be placed on the windowsill. Which of the two plants do you think will grow and develop?

a) Both plants will grow and develop.

b) The plant on the windowsill because it has light, heat, water and air.

c) The plant in the room, because, even if it has less light, it has heat, air and is watered daily.

8. You have 3 parallelepipeds made of wood, iron and copper. Which ones are attracted to a magnet?

a) The parallelepiped made of copper.

b) The parallelepiped made of wood.

c) The parallelepiped made of iron.

Answer options:

1-c

2-b

3-b

4-C

5-C

6-b

7-b

8-C

For each item with the correct answer, 1 point is awarded. Final score 8.

Annex D2

Final tests for students (post-test) grades II-IV

Third grade post-test

Student Name Class Date

1. You have a lit candle, a jar and a timer. Cover the candle with the jar. What do you notice?
    a) The flame gets bigger.
    b) The flame will go out after a while.
    c) The flame continues to burn for a long time.

2. You have two identical plants. You put one by the window in the light, and the other in a dark closet. You wet them the same for a week. After this time, the plants look different. Choose the answer that most correctly explains the phenomenon.
    a) Plants have grown differently because the temperature of the environment does not affect their growth at all.
    b) The plants grew differently because it is warmer at the window and the potted soil dries out.
    c) The plants grew differently because light is essential for photosynthesis, and the plant in the closet doesn't get enough light.

3. You have two glasses: one with cold water, the other with hot water. Put a teaspoon of salt in each. Which one dissolves faster?
    a) The salt will dissolve faster in the glass of cold water.
    b) The salt will dissolve in the glass of warm water.
    c) The salt will dissolve at the same time in both glasses.

4. What happens if you put the flame of a candle under a plastic cup containing water?
    a) The heat of the flame melts the glass and the water flows.
    b) The water in the glass heats up because it takes heat from the flame, and the glass does not melt because the water protects it and does not let it heat up too much.
    c) The glass does not melt even if the water completely evaporates from it.

5. In a cardboard plate put 2-3 drops of watercolors of different colors and 2 paper clips. Put a magnet under the plate. Explain why the paper clips moved and the watercolor didn't.

a) The clips moved because they are made of metal, and the magnet attracts the metal; Watercolor doesn't move because it's not magnetized.
b) If the clips moved, it was by chance; Watercolor doesn't move because it's sticky.
c) The paper clips and watercolor moved by mixing the colors because watercolor also magnetizes.

6. What happens if you rub a balloon against a sweater and bring it close to your hair?

a) Nothing happens.
b) The hairs are attracted to the balloon.
c) The hairs are frizzing.

7. You have two plates: on one you put a piece of fresh apple and on the other a piece of apple sprinkled with lemon juice. You leave them outside for an hour. Which piece oxidizes (blackens) faster?

a) The piece of fresh apple will oxidize faster.
b) Both blacken the same.
c) The apple piece with lemon juice will oxidize faster.

8. Add a drop of ink to three glasses: one with cold water, one with hot water and one with water at room temperature. Which glass does ink spread the fastest?

a) In the glass of cold water.
b) In the glass of water at room temperature.
c) In the glass of hot water.
d)

Answer options:

1-b

2-c

3-b

4-b

5-A

6-b

7-A

8-C

For each item with the correct answer, 1 point is awarded. Final score 8.

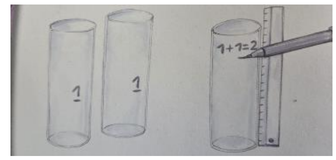
Annex D4

Experimental activities in the context of STREAM class III

Sheet 1

The test of the two identical glasses

1. Presentation of the text from the "Natural Sciences" textbook, Intuitext Publishing House, page 55:



"Every day you observe and use the objects around you. You already know that all objects are not the same. Some of them are hard (balls for the game of billiards), others are soft (plasticine). These bodies are in a solid state. Solid bodies have their own shape and volume.

They are bodies that flow faster (water, milk, ink) or heavier (honey). These bodies are in a liquid state. The liquid bodies flow and take the shape of the vessel into which they are poured. Liquids have their own volume, but they do not have their own shape.

The water vapor that forms above the pot in which the water boils are gaseous bodies. They do not have their own shapes or their own volume, occupying all the space in which they are. ”

2. Problem: What happens to liquid bodies when they are transferred from one vessel to another?

3. What I know: Bodies that are in a liquid state take the shape of the vessel in which they are cast, they do not have their own volume or shape.

4. Materials Needed:

- 3 small glasses (500 ml each)
- water (500 ml)
- a bottle of medicinal spirit (500 ml)
- a ruler (minimum 15 cm)
-a permanent marker

5. Steps to follow:

a) Measure the height of the glass into which you will pour the water with a ruler. When you reach a height of 6 cm, draw a line with the marker.
b) Do the same with the other glass, in which you will pour the alcohol (medicinal spirit). When you have marked the lines on both glasses, write on them the number 1.

c) On the third glass, measure 12 cm from the bottom of the glass and write down 1+1=2 in that place. This means that you measured 6 cm from the other glasses and the same as 6+6=12 and 1+1=2

d) Pour some alcohol into one of the glasses so that you reach the 6 cm mark. It is best to bend down a little to see the mark in your eyes.

e) Pour lukewarm water up to the mark marked on the other glass numbered 1. The water does not have to be boiled, hot tap water can be used.

f) Then pour both liquids from each glass one at a time (the one with water, then the one with alcohol) into the glass on which it is written 1+1=2.

6. What happens?

What do you notice? Did the accumulation of the 2 liquids reach the line marked on the third glass? Does it have anything to do with the bubbles you see in the mixture of the two liquids or is it the fault of the lukewarm water?

7. Student answer

....

....

8. Render through drawing what you experienced and the result obtained from the experiment

9. Conclusions and development directions

Provide answers to the following questions:

- How can you build a water filtration system? What kind of materials would you need?

....

10. Reflection

- List three actions you've taken in this activity.
- Describe the difficulties encountered and how you managed to overcome them?
- Specify two new aspects that you have learned.
- Develop a question related to this activity.

....

Apply stickers to your drawing that indicate what knowledge you have acquired today:

S-Science, M- Mathematics, T-Technology, A-Arts, R-Scientific Language, E- Engineering

New scientific terms: miscible, state of aggregation, solid, liquid, gaseous

STREAM Procurement Analysis

Formulation of new scientific concepts: miscible, state of aggregation, solid, liquid and gas. Formulation of hypotheses. Taking measurements: the amount

Glasses, water, linear and marker.

Formulating explanations using scientific, technical or mathematical language.

Experiment design: identical glasses test.

Decorating glasses.

Calculation of the value of some quantities: the amount of water used. Creating graphical representations on glasses used to illustrate and communicate data.

Interdisciplinary skills

Presentation of the experimental approach (STEM)

Data Analysis and Processing (STEM)

Interpretation of the results obtained (STREM)

Transdisciplinary competences

Selective communication of important and valuable information

Reflection on one's own learning process

Exploring and investigating the real world

Generating possible solutions and anticipating their consequences

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