ION CREANGĂ STATE PEDAGOGICAL UNIVERSITY OF CHIȘINĂU

Manuscript title
CZU: 37.091(043.2)=111

SANDULEAC SERGIU

THEORY AND METHODOLOGY OF DEVELOPMENT AND EFFECTIVENESS OF SCIENTIFIC THINKING IN PEDAGOGUES (INITIAL AND CONTINUING TRAINING)

SPECIALTY 531.01. – GENERAL THEORY OF EDUCATION

Abstract of the Habilitation Thesis in Educational Sciences

CHISINAU, 2024

The thesis is elaborated within the Department of Educational Sciences and Management, "Ion Creanga" State Pedagogical University of Chisinau

Composition of the Public Defense Committee for the Habilitation Thesis
(Approved by the UPSC Senate Decision, Minutes No. 3, dated 31.10.2024)

1. COJOCARU Victoria, Doctor Habilitated in Pedagogy, Professor, "Ion Creanga" State Pedagogical University, Chisinau - **Chair**;
2. ȘEVCIUC Maia, Ph.D. in Pedagogy, Associate Professor, "Ion Creanga" State Pedagogical University from Chisinau – **scientific secretary**;
3. CUZNEȚOV Larisa, Doctor Habilitated, Professor, "Ion Creanga" State Pedagogical University, Chisinau;
4. COJOCARU Vasile, Doctor Habilitated in Pedagogy, Professor, "Ion Creanga" State Pedagogical University Chisinau;
5. GUȚU Vladimir, Doctor Habilitated in Pedagogy, Professor, State University of Moldova;
6. GORAȘ-POSTICĂ Viorica, Doctor Habilitated in Pedagogical Sciences, Professor, State University of Moldova;
7. PAVALACHE Mariela, PhD in Psychology, Professor, "Transilvania" University of Brasov, Romania;
8. ȘLEAHTIȚCHI Mihai, Doctor Habilitated in Psychology, Ph.D. in Pedagogy, Professor, State University of Moldova;

The public defense of the habilitation thesis will take place on December 20, 2024, at 13:00, in the session of the Habilitation Thesis Defense Committee at "Ion Creangă" State Pedagogical University of Chișinău, address 1, I. Creangă Street, Bl. 2, Senate Hall.

The habilitation thesis and its abstract can be consulted at the Scientific Library of "Ion Creangă" State Pedagogical University of Chișinău and on the ANACEC website (www.anacec.md).

The abstract was submitted on _____ 2024

Scientific Secretary:
of the Habilitation Thesis Defense Committee,
Ph.D. in Pedagogy, Professor **_____ ȘEVCIUC Maia**

Scientific consultant:
Doctor Habilitated, Professor **_____ CUZNEȚOV Larisa**

Author
Ph.D. in Psychology, Associate Professor **_____ SANDULEAC Sergiu**

CONTENTS

LIST OF ABBREVIATIONS

ST – Scientific thinking

DEST – Developing and efficiency of scientific thinking

TMDEST – Theory and methodology for developing and efficiency of scientific thinking

OECD – Organisation for Economic Co-operation and Development

STEAM – Science, technology, engineering, arts, maths

STREAM – Science, technology, reading and writing, engineering, arts, maths

RCH- – Right cerebral hemisphere

LCH – Left cerebral hemisphere

CONCEPTUAL FRAMEWORK OF THE RESEARCH

The Relevance and Importance of the Topic.

Science has led to significant changes in our lifestyle and profound transformations in our way of thinking, generating new attitudes and perspectives. Today, science is an integral part of our daily lives, playing a crucial role in the modern era in meeting the needs and desires of society and becoming one of the fundamental human activities interlinked with numerous fields of study. The study of science enhances our ability to generate questions, select and collect useful information, develop and verify knowledge, organize and test various hypotheses and ideas, solve problems, and ultimately apply what we have learned effectively. Consequently, the development of scientific thinking within the *context of continuing education/ lifelong learning* and from a holistic approach has become a highly relevant and debated issue in post-modern pedagogy across all educational systems.

The study of science prompts meaningful behavioral shifts not only among students and young adults but also within the broader professional landscape, including among educators, who play a vital role as catalysts in developing scientific thinking within the upcoming generation. The cultivation of scientific thinking contributes significantly to the enhancement of an individual's intellectual potential, offering a foundation for creativity, imagination, and both general and specialized skills. It also enables more efficient and innovative engagement with work-related activities. Furthermore, science, both as a field of inquiry and as a structured subject of study, encompasses valuable priorities that grant the educational process not only epistemological and ethical rigor but also encourage reflective engagement, critical thinking, and deepened knowledge acquisition through research and discovery. It promotes the formation of reasoned judgments, logical thinking, and the unification of awareness and conduct, while nurturing the capacity to generate insightful conclusions on the existential challenges facing the modern world [57].

International policy documents emphasize the need for a profound shift in the approach to professional training for educators, which is reflected in several critical frameworks. Among these are the European Commission's 2030 *Strategy for the Joint Research Centre* [96]; European strategic priorities to promote research culture and create a scientifically literate citizen [87; 96]; the 2018 European Council recommendations aimed at strengthening the European Union's innovation capacity [51]; Review of the *Organization for Economic Cooperation and Development* (OECD) concept on scientific literacy, 2015 [82]; *the U.S. National Research Council's 2007 report on science education* [54]; Proceedings of the 46th session of the *International Conference on Education in Geneva* (September 5-8, 2001) [88], etc. Additionally, the 1993 Recommendations of the American Association for the Advancement of Science underscore key benchmarks for scientific literacy across populations [53]. Within this global context, state and educational policies in the Republic of Moldova align with similar objectives. Thus, Article 3 of the Education Code of the Republic of Moldova emphasizes the development of scientific literacy from the perspective of continuing adult education as a component of lifelong learning, which ensures permanent access to science, information, culture, in order to flexibly adapt the individual to the new socio-economic realities in constant change and in order to develop the skills necessary for professional and social activity [5, p. 2]. Two other foundational documents, *the EU-Moldova Action Plan for Research, Development, and Innovation* [30, p. 36]

and *the European Strategy of the Republic of Moldova*, alignment with EU practices-articulate short- and medium-term strategies prioritizing science as a national development focus [37, p. 504].

In this context, the examination of scientific attitudes and interests, as well as the potential for fostering the development of scientific thinking among pre-university students, emerges as a fundamental priority in reshaping the approach to the prospective cultivation of the younger generation [72]. This objective, undoubtedly, can be effectively realized only through the professionalization of educators, who are positioned as key agents in promoting scientific values, with a particular emphasis on the development and optimization of students' scientific thinking.

The analysis of specialized literature [3; 44; 45; 72 etc.] eloquently demonstrates with the development of neuroscience promoting *metacognition* [49] and the emergence of global information networks, the role of the teacher is evolving, aligning with the direction of constructing the learning process from the perspective of developing scientific thinking and research technologies accessible to those engaged in daily investigative practices. By analyzing and synthesizing the concerns related to the holistic development of the child's personality and the provision of quality education, we highlight that one of the key priorities for ensuring the quality of pre-university education is the development of students' scientific thinking at all educational levels. This, in turn, necessitates the professional development of teachers focused on enhancing scientific thinking throughout both initial and ongoing professional training.

Thus, in light of current conditions, the motivation for selecting this research topic stems from the critical need to foster scientific thinking, positioning the cultivation of research skills as an educational priority. This priority highlights why both theorists and practitioners in the field of educational sciences are increasingly interested in advancing this area of study.

Simultaneously, fostering scientific thinking among teachers has become a pressing issue, especially as the education system navigates formidable challenges arising both from the Covid-19 pandemic and from the evolving landscape of online learning, information technologies, and advancements in cognitive neurosciences—particularly in the field of *neurodidactics.* [29]. Low levels of student engagement and motivation, the transition from traditional to online education, challenges in classroom management amid the democratization of social relations, and numerous other issues faced by educators today—particularly the evolving mindset of the younger generation—are among the critical problems urgently requiring solutions. [33]. Thus, in today's educational landscape, teachers are encountering a series of complex challenges that reflect an inadequate development of students' cognitive systems, including their difficulty in making inferences, forming judgments, and reasoning effectively. Consequently, a central issue arises from *digitization and the often uncritical reliance on online information*. Students are inundated with digital content, and their excessive use of gadgets and the internet – as primary sources of information and entertainment-reduces teachers' capacity to sustain students' interest in educational activities. educators find themselves in direct competition with the vast offerings of digital technologies and media.

Another challenge is *undermining the development of analytical and critical thinking* (important components of ST), which are under the strong influence of the development of *clip/ momentary thinking*. The phenomenon of *clip thinking* is

becoming more pronounced as young people become accustomed to perceiving quick, fragmented, superficial information provided by video clips and other online resources. The threats of the uncontrolled promotion of the development of *artificial intelligence* may also contribute to a stagnation in the development of critical and analytical thinking, which is essential for the process of cognition and authentic learning, but also for access to a higher level of development of human intellectual potential. Unlimited access to information through digital content not only provides a range of images, perceptions and visions, but also contributes to a heterogenization of learner groups. *The superficial and varying levels of student preparation and development* place teachers in the situation of dealing with individuals whose cognitive system *(knowledge, processing level, algorithmic-representational level, implementation level)* and metacognition are underdeveloped. Significant differences in students' preparation, cognitive abilities and low motivation can make *it difficult to adapt to a program that would correspond to the individual needs of the students. Therefore, the integration of information technologies into the educational process* creates new difficulties and contradictions for the scientific literacy and scientific literacy development of pupils in the contemporary school.

For these reasons, our focus is directed towards enhancing and optimizing the scientific thinking skills of teachers, both in their initial education and ongoing professional development. Evidence from advanced educational practices demonstrates that a teacher equipped with scientific thinking capabilities can effectively guide and monitor students' knowledge-building processes, thereby supporting the development of students' intellectual potential, metacognitive abilities, and the continuous expansion of their cognitive capacities. This approach integrates cognitive growth with social interactions, reflective practice, and the cultivation of lifelong learning skills.

In this context, we view the cultivation of scientific thinking as a pivotal element that enables students to surmount the challenges posed by digital learning environments and the proliferation of information technologies. While these technologies offer convenience and certain advantages, they also carry the risk of impairing human reasoning, cognition, and metacognitive skills when used without careful consideration. Therefore, the education system itself must undergo reconceptualization and restructuring to become more flexible, while maintaining an unwavering commitment to developing highly competent specialists across fields, whether in education, psychology, economics, mathematics, industry, or beyond. At the core of all disciplines is the need to cultivate individuals who are both competent and efficient, with the capacity to innovate, research, and revolutionize their respective fields by actively engaging with scientific thinking. Achieving this goal requires that university-level education prioritize the preparation of teachers who are oriented towards self-awareness and self-efficacy and dedicated to fostering scientific thinking.

The current state of research and the relevance of this topic to both international and national agendas underscore the need for more complex and in-depth studies on the development of scientific thinking. A review of the literature [9; 10; 13; 16; 20; 23; 29 etc.] reveals that social and practical issues pose challenges that require nuanced approaches to understand and enhance scientific thinking. This review has also helped clarify the key areas that merit investigation, including the essence, specificity, and ontogenesis of scientific thinking, as well as the con-

ditions that promote its development and effectiveness. Establishing and elaborating on the core components of scientific thinking (ST) serves as the foundation of our research. Historically, significant aspects of scientific thinking were first introduced within the learning model developed by J. Dewey [61; 62] and have since been expanded upon by scholars such as W. R. Torbert [97], B. L. Hall, R. Tandon [67], W. F. White [98], among others.

We find the essence of the concept and some related definitions of scientific thinking in the research of J. S. Woolley and A. M. Deal [100], who have identified and characterized scientific analysis skills, procedural skills, experimental and investigative skills, thinking skills, scientific research skills, scientific thinking skills; directed knowledge seeking and assimilation behaviours through the development of ST, etc.

The correlation and in-depth study of the concepts of *science, science education and scientific thinking* were elucidated in the works of С. И. Гессен [45]; K. Hoover, T. Donovan [70]; A. Moles [79]; C. Magno [78], etc. A number of important aspects of *investigative/research behavior, scientific thinking and reasoning skills* are reflected in the research of А. Н. Поддьяков [47]; R. S. Mansfield, T. V. Busse, D. W. MacKinnon [95] etc. Valuable is the research on personality traits and scientific creativity by D. N. Jackson and J. P. Rushton [71], G. J. Feist [65] etc.

In addressing important aspects of the development of scientific thinking (ST) within our field, several key studies provide foundational insights. Notably, I. Neacșu's research [29] examines the neurocognitive mediation of adaptation to new learning situations, exploring the connections between human cognition and the central structural core of learning logic. Vl. Guțu's work [17; 18 etc] focuses on the teleological approach to competencies within the education system, with an emphasis on adult learning and cognitive development. His studies also investigate the theoretical and applied foundations of the school curriculum, as well as the specification and explanation of key competencies for lifelong learning, particularly transversal competencies aimed at enhancing scientific thinking skills; the research of E. Joița [21], delves into cognitive education, highlighting the development of metacognition based on the constructivist paradigm and emphasizing the formation of students' thinking. Additionally, Larisa Cuznețov's studies [11; 12] offer a socio-psychopedagogical perspective on the professionalization of teachers, focusing on making the development of scientific thinking and lifelong self-actualization more efficient. M. Sleahtițchi's work [38; 39] examines the social representation of scientific thinking through oppositional taxonomies, providing valuable insights into how these frameworks directly influence scientific thinking and its orientations; the research by Victoria Cojocaru [7] contributes significantly to understanding innovative training strategies, viewing them as key priorities in the transfer of innovation, and highlighting their role in the development of scientific thinking. Additionally, D. Pătrașcu's research [Apud 35], addresses critical aspects of psycho-pedagogical methodology and creativity, particularly through the educational technologies employed within these frameworks. Moreover, the work of V. Gh. Cojocaru [6] underscores the importance of professionalizing the teaching career in alignment with the integral components of teacher training, reinforcing the relevance of these studies to the overall development of scientific thinking in educational contexts.

Although, information technologies bring significant opportunities, there are certain contradictions related to the adaptation and effective integration of the learner in the new teaching-learning-assessment process. Hence the need for con-

tinuous training of teachers in order to make effective use of *technological innovations* in an optimal combination with classical elements of teaching. Another challenge in today's schools is the problem of *managing large groups and the insufficient management of emotions, including the addiction to gadgets* that has arisen as a result of digitalization. Thus, pupils bring a wide range of emotions and personal experiences to the classroom. Managing these complex realities and dynamics in a large learning environment can be difficult. This raises the *problem of adapting to the diversity of cognitive and affective stimuli*. Contemporary pedagogues must be prepared to optimally adapt *teaching-learning-assessment methods* to respond to the competition with information technologies [33]. The need to *reconceptualize and resize the educational system* is evident from the essence of **the contradictions** facing contemporary schools. *The given situation orients us towards the realization of scientific education and training of students* and the development-efficiency of scientific thinking in teachers. The development of *scientific thinking and the contextual changes* occurring in the process of educating students require *teachers to re-evaluate and restructure their role and position in relation to their own educational process, but also in relation to the students', teachers being not only transmitters of information, but also guides, facilitators, managers and mentors capable of self-improvement and permanent self-actualization.*

The Research Problem. In contemporary educational science and practice, a contradictory situation has emerged. On one hand, there has been an expansion and deepening of theoretical courses designed to contribute to the development of scientific thinking among both students and educators. On the other hand, the methodological and theoretical-applicative foundations of this targeted development process remain insufficiently explored, often in a fragmented manner, and fail to be effectively correlated with the principles and strategies of scientific education, the principles of pedagogical neuroscience, as well as the frameworks for lifelong learning. Consequently, there is a pressing need to address the following question: ***What constitutes the core and epistemic structure of the theory and methodology behind the development and enhancement of scientific thinking in educators (both in initial and in-service training)?***

The Aim of the Research is to conceptualize, substantiate, and validate the theory and methodology for the development and enhancement of scientific thinking in educators. This will be structured within the framework of the *Pedagogical Model for the development and effectiveness of scientific thinking in pedagogues.*

Research Hypothesis: the scientific foundations for the development and effectiveness of scientific thinking in educators will prove to be a relevant and distinct research direction if they are established as the epistemic core and a coherent theoretical-applicative framework for enhancing scientific thinking.

Research Objectives:

1. Examine the epistemological aspects of the research problem by analyzing theoretical frameworks and defining the specific characteristics of key concepts related to the development and effectiveness of scientific thinking in educators.
2. Determine the significance and essential coordinates of developing effective scientific thinking within the context of teacher professionalization.
3. Synthesize general trends on the relationship between *scientific thinking - critical thinking - metacognition - science education and training*.

4. Identify factors, laws, psycho-pedagogical conditions and principles of the development-effectiveness of scientific thinking in initial and in-service teacher education.
5. Establish the strategic and technological framework of the development-effectiveness of scientific thinking in pedagogues, correlated with the scientific education and training of students.
6. Develop and substantiate of the methodology of the development- effectiveness of scientific thinking in teachers.
7. Design, substantiate and experimentally validate of the *Pedagogical Model of the Development and Effectiveness of Scientific Thinking in Pedagogues* (which includes the theory and methodology of DEST).
8. Demonstrate of the functionality and theoretical-applicative value of the basic constructs of the *Pedagogical Model of Development and Effectiveness of Scientific Thinking in Pedagogues.*

Epistemological landmarks of research. Summary of research methodology. The research is based on ideas, concepts, theories on scientific thinking from pedagogical, psychological, philosophical and sociological perspective; on the requirements and provisions of national and international normative documents; *on some philosophical conceptions on the importance of the development of scientific thinking* (Aristotle, Plato, [32], J. Dewey [61], Im. Kant, K. Popper [85] etc.). *Theories on the development of thinking and the specifics of thinking* (П. И. Гальперин [31], H. Gardner [15], J. P. Guilford [8], J. Piaget [31], R.J. Sternberg [94], С. Л. Руббинштейн [48], А. Н. Леонтьев [46], Л. С. Выготский [43]); *neuropsychological-pedagogical theories and orientations concerning the conception of the development of scientific thinking* (W. R. Torbert [97], B. L. Hall, R. Tandon [67], W. F. White [98], K. Dunbar [63], B. Koslowski [74], D. Kuhn [75], R. Paul, L. Elder [84], S. Schafersman [91], C. Zimmerman [101], L. Schauble [92], C. Magno [78] and others). In our research we also focused on: the *concept and methodology of science education, interest, motivation and attitude to science education* (С. И. Гессен [45], K. Hoover, T. Donovan [70], E. Har [68]); *the views and ideas on the influence and formation of personality traits in education and scientific creativity* (R.S. Mansfield, T. V. Busse, D. W. MacKinnon [95], D. N. Jackson and J. P. Rushton [71], G. J. Feist [65], I. Mânzat [25], D. Pătrașcu [Apud 35]); *principles and strategies of cognitive and metacognitive education* (M. Lebrun, I. Cerghit [4], E. Joița [21]); *coordinates, principles and strategies of neurodidactics* (I. Neacșu [29], A. Britt [41]); *the conception of adult learning, the development of adults' cognition and the teleological approach of competences in education* (Vl. Guțu [17; 18 etc]); *the strategies of development of ST through teachers' self-actualization* (Larisa Cuznețov [11; 12]); *social representation of scientific thinking* (M. Sleahtițchi [39]); *integrality of the components of the teacher training process* (Vasile Cojocaru [6]); training and innovation transfer in pedagogy (Victoria Cojocaru [7]); *international norms on STEAM education* [90]; *learner-centered education* [52]; *UNESCO principles of lifelong learning; the concept of lifelong learning* [88].

Similarly, the research was based on the epistemological values of national and international normative documents such as: *Education Code of the Republic of Moldova* [5]; *European Strategy of the Republic of Moldova* [37]; *Romanian National Education Law no. 1/2011* [24]; *Joint Research Center Strategy 2030 of*

the European Commission [96]; *Report of the Expert Group on Science Education to the European Commission* [64].

The methods applied in scientific research consist of ***theoretical methods***: scientific documentation, analysis of pedagogical phenomena (analysis of meaning, conceptual, hermeneutic, argumentative, structural analysis); synthesis (explanation and conceptualization, systematization, generalization, etc); ***practical methods:*** pedagogical experiment (sampling, observation, conversation, expert/Delphi method, preliminary experiment; observation experiment, formative and control experiment); ***statistical and mathematical methods***: measurement of correlation between variables, one-way ANOVA, exploratory factor analysis, statistical linear regression, structural equation modeling, structural equation modeling, calculation of effect size indices, determination of significance of differences between samples, calculation of percentage ratios, comparison of means/means for independent samples and paired samples.

The novelty and originality of the research resides in the elaboration and scientific substantiation *of the theory and methodology of the development and effectiveness of the development and efficiency of the ST in pedagogues*, objectified in a set of epistemological and applicative tools, which was validated in experimental research.

The scientific results that have led to the argumentation of the new research direction are circumscribed to a *neuropsychopedagogical conception*, based on the result of the theoretical study of its conceptualization; of the consistent research of the experiential and experimental framework. The investigative approach has allowed to demonstrate that the theory and methodology of DEST in pedagogues is a part of the general theory of education and is constituted as a broad inter-, pluri- and transdisciplinary approach of major epistemological, pedagogical, psychoneurobiological and philosophical complexity. The concept is based on the idea postulated in the formula: scientific thinking is a higher cognitive process, which requires a systematic, multilevel and multiaspectual pedagogical exercise of human intellectual potential.

The main new results for science obtained in the research are configured in the following entities:

1. The notional framework of the development and effectiveness of ST in pedagogues is constituted by the specification, delimitation, updating and approach of fundamental and operational concepts from the socio-psychopedagogical perspective. The theoretical instrumentation focused, in particular, on the definition of the basic concepts: *instruction and scientific education; development, training, efficiency and modeling; paradigm, theory, professionalization of teachers*.

2. Cognitive-constructivist, neurobilogical and neurodidactic approaches to the development and effectiveness of the development and effectiveness of the ST in teachers.

3. Determination and formulation of **the general** characteristics **of the ST, structured in eight** essential **tasks**, correlated with the functions of modeling educational activities for different ages of students and with the coordinates of ***education for science and the future*** in relation to the expansion and deepening ***of the cognitive system of the pedagogue***, which ensured the explanation of the phenomena of *educability and cognitive architecture* in a more complex cognitive-constructivist pedagogical vision, centered on *three guidelines* that reside in: *prioritizing the development of mental processes over knowledge outcomes; centering*

on critical and metacognitive analysis; assuming the role of the teacher as mediator in the construction of knowledge and learning.

4. The elaboration of ***the matrix of the definitions of ST***, which offered the possibility of highlighting two axes in the DEST (the first one aims at the individual/particular aspect, and the second one orients us towards the development of ST in the sphere of professionalization of the individual) and *outlining three perspectives of professionalization of the teacher*, which refer to:

- development of higher-order ST, conditioned by the functioning of cognitive mechanisms, focused on scientific literacy and scientific reasoning;
- training transversal teaching competences that will ensure the development of ST in pupils;
- to know and stimulate the formation of personality traits that allow the teacher to persevere in the given process and to maintain the tendency to lifelong learning.

5. **Explaining *the phenomenon of neurodidactic transposition***, oriented towards the translation/transfer of knowledge elements into elements of didactic content.

6. Deduction and formulation of the definition that ST is a higher, purposeful and consistent psychic process, which manifests itself more frequently in complicated/problematic existential situations (social, personal, professional, educational, etc.) that require the use of scientific knowledge, cognitive and metacognitive abilities; the optimal exploration of all operations, forms and types of thinking in which the person develops and tests hypotheses, heuristic strategies, making reflections, inferences/judgments, reasoning, transfer of ideas, conclusions, predictions, arguing relevantly the actions taken and the results obtained.

7. The epistemological milestones of the new research direction have been determined and scientifically grounded in a broad and interconnected configuration, incorporating: *notional framework; the essential coordinates of education for science and for the future; the definition and the set of features of ST; the similarities in pedagogues' ST development and theoretical correlation with the levels of the cognitive system and types of thinkers; the criteria and characteristics of pedagogues' scientific literacy; neurobiological premises, neuropsychological possibilities and laws; modeling pedagogical convergences; psycho-pedagogical research methods; epistemological coordinates of DEST in teachers, which contains three compartments: the coordinate itself, its essential characteristics; research and directions of analysis, including, theoretical-applicative openings*.

8. The nominated theory of the research direction is based on the field-specific normativity (*General Theory of Education*), which in combination with the conceptualization and analytical-synthetic study provided *the foundation and formulation:*

- ***the** following **legalities for the development and effectiveness of ST**: The legitimacy of motivation and preparation for DEST in the context of learning and professionalization of teaching career; the legitimacy of transfer and ensuring the back-connection of content and conceptual elements with direct and multiple impact on DEST; the legitimacy of learning focused on organizing the logical structures of curricular content and building new mind maps; the legitimacy of the valorization of skill structures in the context of learning and development of ST; the legitimacy of the exploration of inter-, pluri- and transdisciplinarity in the framework of cognitive-constructivist learning and*

development-efficiency of ST; the legitimacy of the focus on the multiaspectual practice of the scientific mind/thinking in the lifelong learning process);

- ***the guiding principles of learning development and effectiveness of the ST***, *structured in five general normative theses, the observance of which will guide the actions of student-pedagogues and teachers in DEST (Pr. knowledge of the functioning of the human brain and stimulation of the functioning of the modal brain potential; Pr. stimulation of the activities of both cerebral hemispheres/RCH and LCH; Pr. combining and stimulating in learning all cognitive mental processes with emphasis on the development of memory, language and various types of thinking; Pr. centering the individual on the respect of psycho-emotional balance and healthy lifestyle as a biopsychological basis for stimulating the activity of neurons; Pr. knowledge and effective exploration of the neurodynamics of learning through the development and improvement of the individual's ST*);
- ***the psycho-pedagogical conditions of the DEST***, which are the set of circumstances that need to be created in order to successfully carry out the process. Essentially, the conditions guide the creation of facilitating circumstances for the DEST and contribute to optimizing the functioning of the principles outlined above. Thus, ***conditions***: *approach and valorization of learning in correlation with DEST; compliance with the principles and strategies of cognitive constructivism; optimal valorization of learning styles and development of ST; ensuring the development of multiple intelligences in complex learning and DEST; ensuring the formation of connections between the development- effectiveness of ST, complex learning and the specifics of the profession, which correlates with the* ***Decalogue, the 10 psycho-pedagogical conditions, compliance with which will contribute to the development of metacognition and critical thinking in student-pedagogues***, which reside in: *verification and consolidation of self-knowledge; active and thorough examination of learning and knowledge tasks; guiding the student in developing hypotheses by modeling their formulation; consolidation of knowledge related to the development and application of pedagogical strategies; practicing the development of strategies for the development of metacognitive skills on planning educational activity; organizing the implementation of educational strategies; elaboration and use of strategies for regulating teachers' pedagogical activity; learning and practicing metacognitive conduct of student-pedagogues, organizing activities focused on reflection, elaboration and exploration of academic reports, reports and debates.*

9. The analysis and approach of the psycho-pedagogical and philosophical value of the SDSE in the professional training of teachers led to the configuration of the ***Master Strategy of the development- effectiveness of DEST in teachers*** and to the establishment of the ***Mechanism of the development-effectiveness of DEST in teachers***, consisting of: *the cognitive-constructivist technology, the formation of personality traits facilitating DEST, the conducive educational environment - all, integrated in the Master Strategy of development- effectiveness of DEST*, carried out in the context of scientific education and self-education (in philosophical and paxiological approach), which, working interconnected, contribute to the ***self-actualization of the pedagogue and the formation of transversal competences*** *(those of SDSE and personality cultivation* focused on the enhancement of SDSE in the educational process).

10. ***The pedagogical model of the development and effectiveness of ST in pedagogues*** is the central construct of the process. Essentially, the model contains two main components: epistemological and praxiological milestones, which together embody the theory and methodology of pedagogical DEST. It is perceived and approached as dual and interactional, because the act of development-effectiveness of ST will take place in the correlational context with the same necessary actions to be valorized in the training of students, pedagogues and pupils.

The pedagogical model of the DEST for pedagogues proved to be a functional and open structure, which can be developed and completed, which was confirmed by the fulfillment of multiple functions designed and validated in the experimental research (the functions of: framing the actors involved; informing them; conceptual-theoretical and instrumental-regulatory function; those of activating and exploring intellectual potential in an optimal way, stimulating metacognition, creativity and knowledge transfer in practice - were achieved).

Essentially, the model aims at developing and making fully effective the ST, realized in the context of lifelong learning by involving the guiding directions, coming from educational policy documents, from the decision-making framework and curriculum design, which take place in the pre-university and university education process, in the space of pedagogical professionalization (in initial and continuing training), valorized from the perspective of neuropsychopedagogical, processual, systemic and inter-, pluri-, transdisciplinary approaches in the implementation of theoretical and praxeological landmarks (theory and methodology of the DEST), by explaining the tools developed and scientifically based (*epistemological coordinates, values of scientific training and education; criteria, indicators and descriptors of DEST; Technological map of development and Strategy of development-effectiveness of ST, master and operational strategies; Methodology of action-operational DEST; Professional portrait of the student-pedagogue possessing ST; Conceptual scheme and formative program of DEST; Benchmark of evaluation and assessment of the level of development- Strategy of development- effectiveness of ST*, etc.).

All the above-mentioned components have their origin in the investigation and theoretical approach, being important for understanding and awareness of the process of DEST in pedagogues, both epistemologically, axiologically and praxiologically, which involves the set of concrete actions: professional orientation and guidance on the development and effectiveness of DEST; restructuring and configuration, openness to the implementation of new ideas of learning and comprehensive cognitive development; implementation, monitoring and supervision of educational practices of SDSE (in those educated: adults and children).

If we delimit this vision from the theoretical point of view, we can identify it as the ***Concept of professionalization of pedagogues in the context of DEST***, and if we highlight the praxiological aspect, we specify the scientific foundation of the new research direction – ***Theory and Methodology of DEST in pedagogues***.

The importance and theoretical significance of the research consists in the conceptualization of the perspective of development, training, and efficiency of scientific thinking from the perspective of professionalization of teachers, related to lifelong learning in order to highlight the trends of reconfiguration of the educational process in contemporary school. At the same time, the perspective of the development of scientific thinking in students was emphasized by establishing the

confluence of factors and conditions of its development in teachers. The research proposes to define the concepts of: *scientific thinking, development, effectiveness of scientific thinking in teachers, training, modeling, scientific literacy, scientific education and instruction, cognitive education, neurodidactics, metacognition, professionalization of teaching career in the context of the use of modeling pedagogical convergences and neurodidactic transposition, which consists in the transfer of knowledge into didactic content.* The conceptualization and analytical-hermeneutic synthesis of the current trends and perspectives of the process of initial and continuing professional training allowed to determine the epistemological and axiological foundations of the development and effectiveness of scientific thinking in pedagogues, to elaborate the laws and principles, pedagogical model and to base the research direction of TMDEST.

The applied value of the research.

The theory and methodology of development and effectiveness of scientific thinking in pedagogues and scientific thinking in students ensures modernization and innovation of the technology of educational practices approached from the perspective of scientific instruction and education of students by increasing the professionalization of the teacher and placing it at a new level of awareness of his role as a facilitator of thinking, generating new ideas for learning and development of knowledge and ST. On the basis of this research direction new courses were developed for the second cycle of studies *Theoretical and applied foundations of the development of scientific thinking in teachers*, a methodological guide for teachers: *Development of scientific thinking in teachers: theoretical and applied foundations (revealing the macro-structural perspective).*

Implementation of scientific results.

The research results have been used in initial training within the *Erasmus Plus* international academic mobility programs in Serbia, Romania, as well as in in-service teacher training within the international projects: *pedagogical measures to optimize learning efficiency by promoting scientific thinking during the protracted crisis caused by the pandemic Covid-19* with the number nr. IN 2020-73615; within the Civil Society Scholar Award (CSSA) of the Open Society Foundations. The research results were also integrated into the national project: *Psychosocial aspects of psychological security and its social manifestations in children*, with the number 20.80009.0807.31. Also, the research results in the form of modules of the courses taught were integrated into the didactic process of preparation and training of students, master and doctoral students at the faculties of pedagogy of higher education institutions of the Republic of Moldova. At the same time, the results of the research have been used in in-service training courses organized in pre-school, pre-university and university educational institutions (early childhood education institutions, secondary schools, high schools, vocational schools, colleges and centres of excellence, universities). All pedagogical tools were developed and approved in the pilot experiment in the Republic of Moldova and Romania.

Most of the research results were presented at seminars scientific-methodical seminars with educators and teachers from the following institutions: the State Pedagogical University "Ion Creangă" from Chisinau, the "ProSucces" Theoretical High School, the "Iulia Hașdeu" Theoretical High School, the "Tudor Vladimirescu" Theoretical High School, the "N. H. Costin" Secondary School, "Raisa Pacalo" Center of Excellence in Medicine and Pharmacy, "Raisa Pacalo" Center of

Excellence in Light Industry, College of Veterinary Medicine and Agricultural Economics from Brătușeni, and Early Education Institutions no. 40, 91, 63, 89, 79, "Câmpulung Moldovenesc" Special Vocational School, "Teodor. V. Ștefanelli", Technological High School no. 1 Câmpulung Moldovenesc, etc.

The theoretical-applicative openings and the originality of the results obtained in this research have led to the creation and foundation of a ***new scientific direction***: ***The theory and methodology of the development and efficiency of scientific thinking in pedagogues (initial and in-service training)***.

Approval of scientific results.

The scientific value of the research has been addressed and confirmed at national and international scientific conferences, their plenary sessions, workshops, workshops and trainings for initial and continuing professional training of teachers. At the same time, the investigative results were approved in: the II International Scientific Conference. *Political and Economic Self-Constitution: Migration, Inequalities and Discrimination (PESC)* University of Peloponnese, Corinth, Greece, June 7-8, 2024. *Scientific literacy - an integrative development perspective and efficiency of scientific thinking;* 4th *International Symposium on Scientific Research and Innovative Studies* (ISSRIS 24) Bandırma Onyedi Eylül Eylül University Bandırma Onyedi, Turkey, from March 13-16, 2024. *Epistemological Constants in The Development of Scientific Thinking from The Perspective of The Professionalization of Teaching Staff*; *National Symposium with International Participation. Kreatikon: Creativity-Training-Performance. "Creativity and innovation – prerequisites for excellence in education"*. 19th edition from March 28 to March 30, 2024. "Petre Andrei" University of Iasi. *Critical thinking in the context of developing metacognition and streamlining scientific thinking in initial training (Plenary session);* International Scientific Conference. *Education from the perspective of the future classroom concept,* from November 3-4, 2023 organized within the research project *Initial and Continuous Training of Teaching Staff from the Perspective of the Future Classroom Concept. Project number: 20.80009.0807.37,* in the framework of the workshop *Scientific versus professional thinking*; National Scientific Conference with international participation. *Psychological security in children in times of crisis,* State Pedagogical University "Ion Creangă", May 26, 2023, *Psychological security of students through the exercise of modeling versus scientific thinking training;* National Scientific Conference with international participation. *Psychological assistance at the contemporary stage: realities and perspectives.* 4th edition, Alecu Russo State University of Balti, October 27-28, 2023. *Perspectives of development of scientific thinking in students in contemporary school. (Plenary session);* National Scientific Conference with international participation. *Family – existential factor of promoting eternal-human values 3rd Edition,* State Pedagogical University "Ion Creanga", May 12, 2023. *The role of scientific thinking in maintaining harmonious family. (Plenary session);* National Symposium with international participation. *Kreatikon: Creativity-Training-Performance. "Creativity and innovation - premises of excellence in education"*. 18th edition from March 30 to April 1, 2023. "Petre Andrei" University of Iasi. *Modeling students' scientific thinking in educational activities (Plenary session),* International Scientific Conference. *Science, education, culture* from February 13, 2023, University of Comrat. *The process of developing and making more effective the scientific thinking in teachers in the context of the realities of the XXI century;* International scientific conference. *Pedagogical conditions for optimizing learning in post pandemic crisis through the prism of the development of scientific thinking,* State

Pedagogical University "Ion Creanga" of Chisinau, June 18, 2021, Chisinau, Moldova. *Scientific thinking - fundamental concept in the professionalization of teachers (Plenary session);* National Scientific Conference. *Pedagogical measures to increase learning efficiency by promoting scientific thinking during the prolonged crisis caused by the Covid 19 pandemic*. "Ion Creangă" State Pedagogical University of Chisinau, November 27, 2021, Chisinau, Moldova. *Developing scientific thinking in teachers: theoretical and applied foundations. Book launch: Developing scientific thinking in teachers: theoretical and applied foundations. (Plenary session);* National Conference on Research in Education, 2021, 7th Edition, Educational Research and the Challenges of Today's Society/ *Educational Research and Challenges of the Contemporary Society*, is organized by the University "Alexandru Ioan Cuza" of Iași from 28-29 October, 2021. *Development of scientific thinking in educationalists: approaches and perspectives*. Thematic section: trends in educational policies and strategies in the academic field. Moderators: Nicoleta Rogoz, Oana Dănilă. *https://www.cered.ro/sectiuni_tematice/;* National scientific conference with international participation. *National and international practices of professionalization of teachers in the context of societal challenges,* State Pedagogical University "Ion Creangă" in Chisinau, November 17, 2021. *Factors and conditions in the development of scientific thinking in pedagogues through the priST of streamlining the educational process (Plenary session);* National Scientific Conference with international participation *Problems of socio-humanistic sciences and modernisation of education,* Pedagogical State University "Ion Creangă" of Chisinau, 26 March 2021. *Scientific thinking as a theoretical-applicative foundation in the continuous training of pedagogues in the digital era,* National Scientific Conference with international participation. *Psychosocial aspects of psychological security and its social manifestations in children,* State Pedagogical University "Ion Creangă", from October 29, 2021. *The role of scientific thinking in ensuring teachers' competence of psycho-pedagogical security of pupils (Plenary session);* Webinar within the project (CPOED). *Psychological profile of the teacher who possesses scientific thinking.* State Pedagogical University "Ion Creangă" of Chisinau, September 28, 2020. Webinar within the project (CPOED). *Development of scientific thinking in teachers and students: educational technologies.* State Pedagogical University "Ion Creangă" of Chisinau, October 19, 2020. Webinar within the project (CPOED). *Psychopedagogical bases for optimizing learning through the development of scientific thinking in teachers.* State Pedagogical University "Ion Creangă" of Chisinau, September 28, 2020. Webinar within the project (CPOED). *Personal efficiency, self-improvement and neurobiological factors in the development of scientific thinking in teachers (in the context of enneatypology).* State Pedagogical University "Ion Creangă" of Chisinau, December 15, 2020. Webinar within the project (CPOED). *Psychological profile of the teacher with scientific thinking.* Pedagogical State University "Ion Creangă" of Chisinau, February 01, 2021.

Keywords: thinking, scientific thinking, neurosciences, neuroscience, neurodidactics, critical thinking, pedagogical thinking, development, efficiency, training, modeling, professionalization, scientific literacy, scientific literacy, scientific literacy, scientific literacy, scientific literacy, scientific literacy, teachers, student teachers, initial training, in-service training, cognitive system, cognitive education, metacognition, declarative knowledge, factual knowledge, conceptual knowledge, procedural knowledge.

THESIS CONTENT

The **Introduction** argues the topicality and importance of the research, outlines the problem, aim, hypothesis and objectives. The scientific novelty and originality, theoretical significance, applicative importance and the main scientific results obtained in the research are presented.

In **Chapter 1,** ***Theoretical approaches to the development and effectiveness of scientific thinking in the context of teacher professionalization,*** the complexity of definitions of scientific thinking from the perspective of D. Klahr, K. Dunbar, C. Zimmerman [63; 73; 77], D. Kuhn [75], R. Lehrer, L. Schauble [76], B. Koslowski [74], Larisa Cuznețov [10; 36]. Scientific thinking is presented as a higher-order psychological process, which constitutes a form of scientific knowledge based on deep systematic knowledge. The notional framework is clarified from the perspective of the definition of the concept of *development* in relation to the concepts of *training, efficiency and modeling, which are* analyzed from several perspectives: psychological, social and pedagogical. The relationship between the concepts of *development, training, efficiency and shaping* emphasizes a progressive process of moving to a higher level, either of matter or of natural and social phenomena. Human development involves a gradual evolution and a significant expansion of individual capacities, influenced by hereditary factors as well as environmental and educational factors.

The concept of ***effectiveness***, in the context of scientific thinking is presented as a characteristic of people with a certain developed potential (teachers, scientific researchers, other professionals), but, which requires permanent optimization with the aim of increasing the depth of cognitive processes, deepening and expanding the cognitive system; strengthening the functioning of interconnections: *thinking - scientific thinking - professional thinking - everyday thinking - lateral thinking - creativity - efficiency - professional and existential performance* [36].

The concept of ***modeling*** scientific thinking, approached as a method of intervention, is one of the means of cognition of reality on the basis of which the potential for the development of mental abilities can be harnessed [35]. Modeling, in a didactic context, contributes to directing and orienting the pupil's thinking, guiding it towards discovering the truth on the basis of judgments and reasoning carried out by analogy, and the model used determines the assimilation and understanding of information in a more concrete, explicit and effective way for learning [14].

This has provided the possibility to concretize, but also to make theoretical generalizations about *scientific knowledge* in relation to the development of ST, *professional thinking* in connection with the *professional scientific thinking of* the teacher and his/her *methodical thinking.* It has been established that methodical thinking consists of three important components: *scientific thinking within a distinct science* (mathematics, history, etc.); *scientific-pedagogical thinking and applied pedagogical thinking*.

Literature review [68; 81 etc.] has allowed us to see that the analysis of the epistemological landmarks of scientific thinking is also approached through the prism of science as *part of a culture*. Despite the fact that one of the criteria of scientific character is *the independence of science from the socio-cultural environment*, in practice this independence cannot be totally ensured, since science is a component of culture and is a social phenomenon.

Also, through the interpretative analysis of the ideas formulated by scholars A. Moles, K. Popper, C. Zimmerman, E. M. Теплов, C. И. Гессен, C. Ю. Пискаревская, I. Neacșu, etc., it was established that the development of ST presupposes the ways of intervention at the ontogenesis level with a continuation in *training* (educational plan) and *streamlining,* if we consider adult lifelong learning and/or professionalization. At the same time, a determinant aspect has been outlined, which is one of the main functions of *shaping* responsible for fixing and following the path of the person's own cognitive movement, materialized in the form of scientific thinking, which occurs under the influence of *literacy, scientific training/education* through deepening and expanding the cognitive system and the development of metacognitive abilities [Apud 35].

Therefore, as the scholar C. И. Гессен, the development of scientific thinking is a fundamental goal of education, which is a special condition for the professionalization of any specialist, regardless of his field of activity, and even more so of the teacher.

On the basis of the analysis of epistemological categories we have to point out ***that scientific thinking, the process of scientific instruction and education*** are, in fact, the fundamentals of cognition and point to the higher level of cognition, which is ***metacognition***. Reflecting on these aspects, we deduce that only an educator endowed with *scientific thinking* can successfully approach *metacognition, scientific education and instruction of students* [45]. Another concept, an important epistemological category elucidated in the chapter is known in the formula of ***professionalization of teachers*** (or teaching career). As the local researcher Vasile Gh. Cojocaru, the professionalization of teachers is *one of the significant dimensions of contemporary social developments, which today is manifested with increasing intensity* [6, p. 31], delimiting the specifics of professionalization in initial training, emphasizing that it goes through *three interdependent stages: self-centeredness,* which for the individual is a confrontation with the representation he has about the chosen profession and his expectations; *task-centeredness, on the quality of its accomplishment and result-centeredness* [6].

We point out that in our research we approach the DEST both within the framework of specialized training/ professionalization and within the framework of the formation of the general culture of the student-pedagogue.

In this context, the utilization of hypothetico-deductive, hermeneutic and analytical-synthetic study in approaching theories, orientations and scientific conceptions; the analysis of the researchers' conceptions: J. Piaget; Л.С. Выготский; J. Dewey; M. Zlate; M. Miclea; E. Joița, etc., has contributed to the clarification, completion and expansion of the contents of the four levels of the human cognitive system, as follows:

The first level of the *human cognitive system*, that of ***knowledge***, includes all the information and knowledge that a person has assimilated. This level also involves studying sources of information, analyzing previous experience, evaluating tasks and problems in real contexts; reviewing and updating skills and ways of approaching new knowledge. Likewise, the level of self-awareness, the individual's abilities and competences in the domain, influence on one's own cognitive behavior, metacognitive skills and others are explored. For pedagogues, this level is summarized as general, fundamental and specialized knowledge.

The second level, called the ***knowledge processing*** level, refers to the processes involved in the relationship between *inputs* and *outputs*, starting from the analysis of the tasks to be solved, their components and the *input-output* data. This level covers the processes of processing knowledge, information and ensures that knowledge processing skills are practiced to achieve the desired outcome or performance.

The third level, known as ***algorithmic-representational***, aims at establishing and specifying the algorithm for processing information in terms of *inputs* and *outputs*, as well as the ways of representing them. At this level, representations and knowledge about the objectives and data of the task being addressed are processed by specific algorithms or a combination of them, which ensures the use of various types of judgment, reasoning, strategies and methods of solving depending on the person's style and type of thinking.

The fourth level, called ***implementation level***, is concerned with how psychological, neurobiological and pedagogical processes unfold when solving the task. This level examines the implications of cognitive neurosciences and integrates them into the educational context, focusing on the organization and unfolding of the whole teaching-learning-assessment process and, obviously, the implementation process either in real life or in education. Also included in this level are: knowledge and skills related to the protection of the individual's health; respect for the hygiene of intellectual work; ensuring optimal pedagogical conditions and use of teaching technologies [Apud 10, p. 112-113]. Obviously, these four levels of the cognitive system will interact and complement each other, thus configuring the phenomenon called ***cognitive architecture*** [10]. In this frame of reference, the researcher Larisa Cuznețov mentions that *cognitive architecture is influenced not only by the above-mentioned aspects, but also* by the *culture of the individual, the quality of the didactic technologies applied in the educational process and obviously it also depends on the experience, skill and skill of the teacher, including his level of development and the level of utilization of scientific thinking in his work* [Ibid, p. 113].

In anticipation of the description and elucidation of the experimental research (Chapters 4 and 5), we mention that the epistemological study allowed us to demonstrate that the interaction of the methods applied in instruction, which are consciously and skillfully explored by pedagogues, through ***neurodidactic trans-position***, can ensure the development and exploration of *cognitive architecture*, focused on cultivating *the cognitive educability* of students, will lead to the development of scientific thinking in the context of the complex valorization of the essential directions, which are related to: *assuming the role of mediator on the part of the teacher in the construction of knowledge; prioritizing the development of mental mechanisms and processes; focusing on metacognition* and the *development of types of thinking according to the nine criteria* (by orientation; by type of mental operations; by purpose; by the sense of evolution; by logical approaches; by the way of unfolding; by value; by correspondence with reality and by efficiency) [29].

Also, in the first chapter, after analyzing the multiple works [2; 8; 16; 26; 101 etc.], which elucidate the essence and particularities of scientific thinking, we outline the definitions and the **set of its characteristics,** as **summarized** in Table 1.1, by indicating their basic content and the researchers who have contributed to the explanation of scientific thinking.

Table 1.1. Matrix of definitions of scientific thinking

Authors	Some definitions of scientific thinking
D. Kuhn	***Scientific thinking*** is a purposeful, consistent, goal-directed way of thinking, i.e. to increase new and original knowledge, using the skills of generating, testing and revising theories, and the ability to reflect on how knowledge can be acquired and changed [75].
A. Moles	***Scientific thinking*** operates with heuristic problem-solving strategies [79, p.130].
S. Schafersman	***Scientific thinking*** is based on the scientific method, the importance of which is to promote scientific knowledge. Scientific thinking can be confused with other types of thinking such as *logical, analytical, critical, heuristic, divergent*, etc. Scientific thinking involves cognitive operations that are also used in everyday life, such as: induction, deduction, problem solving, argumentation, etc. [Apud 32, p.13]. The scientist considers critical thinking as an operational component of scientific thinking.
C. Zimmerman	***Scientific thinking*** is a complex set of cognitive and metacognitive skills, the formation or development of which is made possible through exercises and practice. The researcher emphasizes that scientific thinking is based on critical thinking as an essential element of its structure. He emphasizes the operational character of scientific thinking [101, p.13].
J. Dewey	At the basis of ***scientific thinking*** is the scientific method that links cognitive/knowledge acquisition to practical work, which must be adapted to all types of investigation [Apud 99].
B. Koslowski	***Scientific thinking*** is a process of applying scientific methods and principles to argue or facilitate a variety of problem-solving situations in research and social settings [74, p.14].
R. Raul L. Elder	***Scientific thinking*** is the type of thinking that refers to a particular scientific object or scientific problem in which the thinker makes inferences, evaluates scientific research, developing its quality [Apud 84, p.15].
K. Dunbar	***Scientific thinking*** is a higher psychological process, used when synthesizing and drawing conclusions; making judgments, arguments about scientific content involved in various activities [Apud 32, p.16].
K. Popper	***Scientific thinking*** manifests itself in the organization of real forms of cognitive activity through the testing of scientific hypotheses, which presuppose the orientation of the researcher in a certain existing paradigm and the ability to reach another paradigm in case the previous strategy does not ensure the comparison of explanations of the reality under study [Apud 85, p.16].
R. Lehrer L. Schauble	***Scientific thinking*** is a process characterized by the capacity for scientific argumentation [76, p.16].
I. Mânzat	***Scientific thinking*** is distinguished by a person's tendency to infer the general on the basis of syntheses and comparisons, to formulate hypotheses and projects in discovery activities; to carry out structural analysis and systematic research as a basic method; to combine causal and probabilistic explanation, its multiphasic and multidimensional unfolding; to combine observation with forecasting or succession with simultaneity; to use the transfer of strategies or mechanisms, to operate with sets of information and procedures, to make use of all abstract mechanisms of information processing [Apud 21, pp. 68-69].
M. Zlate	***Scientific thinking*** correlates with *reproductive* and *productive-creative thinking*, which ensure the elaboration of new solutions, the discovery of new strategies and principles for dealing with the phenomena under investigation (an essential aspect of scientific thinking). [Apud 35].
E. Joița	***Scientific thinking*** at different ages demonstrates that its structure incorporates several types of thinking, each individual having new explanations and methodologies for solving problems [Apud 21, pp. 44-45].
Larisa Cuznețov	***Scientific thinking*** includes the values of knowledge, the values of intellectual and moral intelligence, self-improvement oriented towards self-knowledge and knowledge of others, towards the development of intellectual potential, towards the management of learning, research, self-study and self-image in the human community in general and the family and professional community in particular [Apud 35].

Certainly, the definitions of scientific thinking could be continued, but what is relevant is that ***researchers mention a specific characteristic, according to which the cognitive process concerned is of a higher rank, involving all operations and forms of thinking; it involves the ability to make judgments and reasoning, to conduct scientific research and arguments***.

The conceptualization and theoretical-analytical investigation carried out on the definitions and views on the concept of scientific thinking by researchers in the field of educational sciences (D. Kuhn; A. Moles; S. Schafersman; C. Zimmerman; J. Dewey; B. Koslowski; R. Raul; L. Elder; M. Zlate; K. Popper, etc.) has allowed us to outline its specifics and characteristics, including the delimitation of types of thinkers [Apud 35, pp. 31-32].

The specificity and characteristics of the ST outlined above, correlated by us with the classifications of the types of thinkers, selected from the literature [84, p.25] has been associated with varying levels of preparation and manifestation of teacher thinking.

Schematically represented, the types of thinkers have been placed in a cognitive ladder proposed by R. Paul and L. Elder in accordance with the objectives of the revised taxonomy by L. Anderson and D. Krathwohl, which we have developed and completed, correlating them with the four levels of the cognitive system (Figure 1.1).

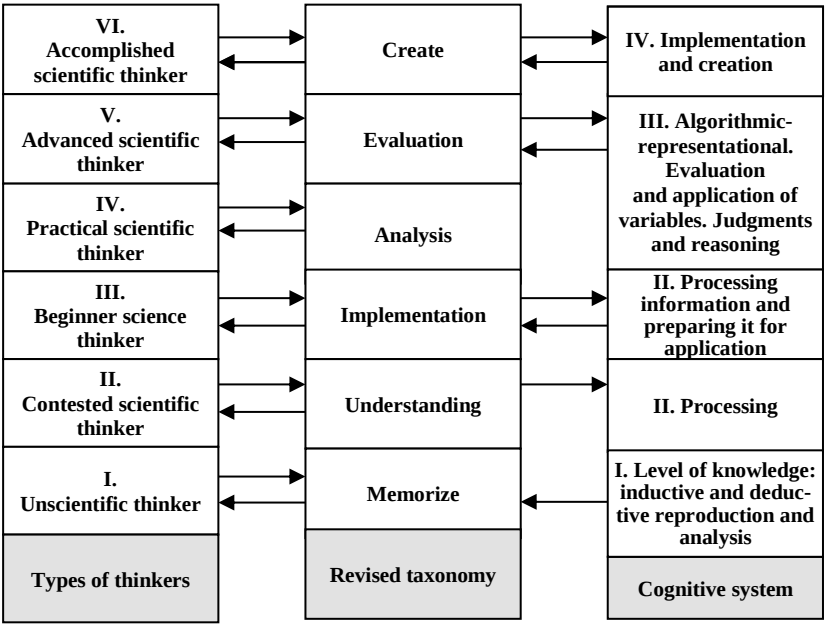

Figure 1.1. Similarities in the development of scientific thinking of pedagogues; theoretical correlation with levels of the cognitive system and types of thinkers

The analysis of the specifics of the six types of thinkers, their correlation with the six operations of thinking, highlighted by L. Anderson and D. Krathwohl, combined with the basic elements of the content of the four levels of the human cognitive system, allowed us to establish that certain actions of memorizing, under-

standing, applying, analyzing, analyzing, evaluating and creating can be overcome, in essence, by each type of thinker and, of course, can be extended and deepened within each level of the cognitive system. The determined similarities and possibilities instill confidence in the enhancement of lifelong learning-improvement activity from the perspective of the development-effectiveness of scientific thinking of pedagogues. Another important aspect related to the process of DEGSD is related to the perspective of scientific education and implies *scientific literacy and continuous development of scientific reasoning, including professional reasoning as a fundamental benchmark in the formation of scientific thinking, which would ensure the completion of cognitive and metacognitive processes, making analytical, critical, argumentative and prognostic pedagogical skills more efficient.*

Thus, in specialized literature the concept of *scientific literacy* is often used with different connotations, as an **end of the educational process** [1; 89 etc.] and as a **continuous process of development** [59; 93 etc]. Note that scientific literacy gradually increases over time. So, in this context, we can outline two directions in the process of formation of scientific thinking, the *first one is based on scientific literacy centered more on the development of the informational side, considered as a bottom-up, dynamic and continuous process* and *the second one, which analyzes and considers ST as a measurable product, centered on the development of the operational side that includes the understanding and application of the main scientific concepts* [Apud 93, p. 10].

The essence of this idea is outlined in the work of several scholars: A. Britt [41], С. И. Гессен [45], M. Miclea [26], S. Angheluta [1], etc. Therefore, the aspects included in the concept of *scientific literacy* and the competences possessed by a professional, scientifically literate person occur in the context of STEM. Scientific literacy and ST enable the individual to understand life, the world around them, to be engaged in discourses about science, to be curious and question the acceptances made by others on various issues; to develop hypotheses, formulate questions, investigate and develop prognoses, evidence-based conclusions; to make informed decisions about human existence, environment, profession, society, one's own health and well-being [Ibid].

On the basis of the epistemological analysis carried out and the criteria of scientific literacy exposed, we outline the definition elaborated by us, by which we note that ***scientific thinking*** *is a higher, purposeful and consistent psychic process, which is more frequently manifested in complicated/problematic existential situations (social, personal, educational, professional, etc.), which requires the valorization of scientific knowledge, cognitive and metacognitive abilities; the optimal exploration of all operations, forms and types of thinking in which the person develops and tests hypotheses, heuristic strategies, making reflections, inferences, judgments, reasoning; transfers of ideas, conclusions, predictions, arguing relevantly the actions taken and the results obtained.*

In current educational science and instructional practice a contradictory situation has arisen. On the one hand, there is a broadening and deepening of the study of theoretical courses, which formally contribute to the development of scientific thinking of students and pedagogues, while on the other hand, the methodology and theoretical-applicative foundations of the targeted process remain insufficiently and fragmentarily researched, not being correlated with the principles and strategies of scientific education, the laws of pedagogical neurosciences, including the coordinates of lifelong learning. **Thus, it is necessary to find an answer to the question: *what is the core and epis-***

temic structure of the theory and methodology of the development and effectiveness of scientific thinking in pedagogues (initial and in-service training)?

Chapter 2, ***Conceptual Configurations of the Development and Effectiveness of Scientific Thinking***, includes epistemological analysis and interpretation of concepts, visions and understandings in the field of neuroscience, especially neurobiology and neurodidactics, approached in the context of teacher education.

The conceptualization has allowed us to realize that if we intend to develop and make scientific thinking in pedagogues more efficient, we need to know and respect the *neurobiological premises of human brain functioning* from a ***genetic-evolutionary perspective***, which is the basis of the understanding and explanation of the psychic-brain, founded by J. H. Jackson and И. П. Павлов. It has served as a methodological tool that demonstrated that the neural mechanism of a psychic function is not innate and predetermined, but is constituted in the course of phylogenetic and ontogenetic evolution in the process of appearance and development of the function itself, so our idea is based on a solid biological foundation. *From this point of view, the genetic-evolutionary perspective indicates that no psychic function should be approached as a given and referred to a particular structure, because it can be successfully developed in the course of human life, which means that the brain requires permanent training*. In essence, function is integrated into structure, both function and structure forming an evolving dynamic unit, important and decisive in the learning process, a phenomenon demonstrated by the application of special cortical imaging techniques [58, p. 6-7].

We note that the study and analysis of the contribution of П. К. Анохин, the founder of *the functional system theory*, it has been demonstrated that the *psychic function is a tool of adaptation of man to the environment*. Hence, persons engaged in training and education, development of human thinking, should be acquainted with the *fundamental brain-psychic* and *secondary brain-psychic relationship*, which ensures the functioning of the mechanism by which the psychic processes are realized and the anatomical level at which a certain psychic function is integrated is determined. In this regard, we would like to *emphasize the crucial role of neuromediators/ neurotransmitters* [58, pp. 9-12] through which nerve impulses are transmitted. Each neuron releases one or more neuromediator substances (to date, there are about 70 neuromediators whose action is known and about 200 whose action has not yet been identified). Neuromediators fulfill vital functions in the activity of the nervous system and in regulating the activity of the whole human organism, maintaining homeostasis. Thus, the optimal knowledge and exploration, by pedagogues, of the neurobiological premises can ensure the identification of neuropsychological possibilities that unfold at the level of *cognitive mind maps* and the behavior of students and adults, materialized in emotions, affective states, volitional and motivational acts. In this context, were determined, analyzed and described ***the investigative psycho-pedagogical methods*** *(method of analysis of activity products, method of tests, experimental and laboratory method, genetic and comparative method, logical-mathematical method, etc.).* At the same time, were determined, analyzed and described ***the fundamental laws of mental organization***.

- ***The Law of Development and Becoming*** argues with scientific arguments that the psyche is formed over time, possesses an ascending sense of transformations, which represents the possibility of becoming and development of the ST and points to the optimizable aspect.

- ***The law of dialectical interaction between causes, external factors and internal conditions*** postulates the interdependence of the above aspects and indicates that the process of becoming and development of the human psychic system is determined by external influences and of course by internal factors. Throughout life, man progresses from biological/physiological interactions between the person and the environment to formative ones, which incorporate educational actions and existential experience.

Anticipating the analysis and interpretation of ***the impact of the modeling pedagogical models*** and ***convergences***, we would like to emphasize ***the key moment: namely, the knowledge and respect of the essence of these laws by pedagogues provides awareness of the value of the neuropsychological possibilities to design and build optimal educational process, the path and process of lifelong learning, including the process of development and effectiveness of the ST***.

- ***The law of stadiality, which*** captures and renders the gradual and gradual character of the development and formation of all psychic functions and processes, has been formulated and demonstrated by several famous researchers: **J. Piaget**; **H. Wallon**; **E. Erikson** etc [Apud 31]. In this context, it is important to note that the transition from one stage to another in the plan of psycho-behavioral development is supported and, implicitly, correlated with the transition from a lower to a higher level in the structural-functional organization of the brain [58, p. 61-62] and the development of human thought.
- *The* ***law of heterochrony*** indicates that all mental functions, processes and structures are constituted and consolidated at different time intervals (e.g. perceptual mechanism develop before thinking). J. Piaget showed that developmental stages do not omit and do not intersect, because there are genetic interactions between them, i.e. the current stage prepares the emergence of the next, ensuring the necessary conditions for certain transformations to occur further on.
- ***The law of heteronomy*** reflects the heterogeneous and contradictory nature of psychic development at intra-individual and inter-individual levels, which denotes that within the psychic system different levels of development are observed and, at the same time, a psychic function or structure may have different levels of development in two or more individuals [Ibid, p. 62]. Starting from these laws, we note that nowadays *technology in educational sciences lends itself to a systemic approach (to instruction, education, teaching), characterized by the clarity of the proposed objectives, it is becoming increasingly topical to use optimal strategies, methods, procedures, which would contribute to the design and implementation of teaching-learning-assessment appropriate to certain styles, levels and goals of the development of transversal competences,* [18, p. 185] which, in fact, presuppose the development of ST. We obviously support and associate ourselves with this pertinent observation by the local researcher Vl. Guțu. On the basis of the above-mentioned understanding and the extensive theoretical study, we confirm that ST can be developed and made more effective only through a systemic epistemological and praxeological approach.

This made it possible to define what ***quality learning*** means and to establish that at the basis of the development- effectiveness of ST are two major scientific orientations with a decisive impact on education: *cognitive neurofunctionalist and metacognitivist*, associated with M. Minder under the aegis of *modern operant cognitivism* [27, p. 20-22].

This idea reflects the author's functional, participatory and interdisciplinary conception, which offers *concrete recommendations on how to* ***didactize knowledge****, because the knowledge produced is scientific knowledge*, it cannot be automatically taught. In order to be learned, it must be reconstructed: selected, organized, linked to the subjects of study; adapted to the individual-typological and age characteristics of the students, assimilated, evaluated, certified and transferred [Ibid, pp. 20-27], which leads us directly to respect the neurobiopsychological and *neuropedagogical* laws of *the development of the mind* [41, pp. 17-25], including in the context of transversal skills training.

Also, through the interpretative analysis, the following general ***pedagogical modeling convergences*** on the development-effectiveness of the ST ***were established and argued***: *the approach of cognitive education theory in pedagogical sciences from the perspective of education for science and for the future*, which supports knowledge as a product of cognitive activity and as a mental process of relationship between cortical mechanisms, between them and the environment [29, pp 71-73]. It is obvious that we cannot neglect the process of receiving and processing information, the person's reactions to it, changes in human behaviour, which forms the accumulated culture in the sociological sense, in the development and effectiveness of ST, but the focus will shift to the construction of knowledge, to the effectiveness of internal processes of cognition, namely: memorizing, representing, understanding, categorizing, conceptualizing, developing and verifying judgments, reasoning, problem solving, decision making, etc. In line with the above, we mention the acceptance of and adherence to the ***cognitive constructivism paradigm***, which incorporates learner-centered practices, learning through discovery, working with tasks that require the exploration of concepts, judgments, reasoning, the application of reflection, the use of multiple intelligences, etc. [22].

One of the modeling convergent axes of the development-effectiveness of ST *is the provision of qualitative learning, subsumed to constructivist learning,* which emphasizes the development of cognitive initiative, the cultivation of activism, creativity, the ability to build and apply their own tools of knowledge, to use metaanalysis, metacognitive strategies, those of elaboration and monitoring of the path and process of knowledge and learning; of processing and integrating information, solving problems, arguing and explaining the results obtained; *systematic exploration in the process of instruction* (in basic and specialist subjects) *of all types of structured and systematized thinking according to nine criteria formulated by M. Zlate.*

Starting from the identification and analysis of the neurobiological premises and neuropsychological possibilities, the determination and formulation of *modeling pedagogical convergences of a general type*, the set of ***modeling pedagogical convergences of an applicative/operational nature*** (ten in number) was established, which imply guiding constructs of pedagogical activities and actions focused on the organization-development-monitoring of the development and development and effectiveness of the ST in the learning process.

The investigative and explanatory epistemological excursions allowed us to state that *the axioms of pedagogy* (philosophical, sociological, psychological), *pedagogical laws, principles and rules* within the development-effectiveness of ST in pedagogues remain the same/ constant, at the same time their study and critical analysis have ensured the deduction and formulation of the laws, which, in essence, configure the normativity of actions undertaken in the process of development-effectiveness of ST. These are:

1. ***The legitimacy of the motivation and preparation for the development-effectiveness of the ST in the context of learning and professionalization of the teaching career*** aims at the conditionality of its specific actions, aiming at the formation of regulatory competences, which can be ensured by the systematic exploration of the following factors: *the ability of self-evaluation* and *determination of intention, conscious and free expression of personality*; *the level of aspirations, needs and establishing the area of interest* (cognitive and professional), including *inventory and awareness of* intellectual *abilities* and skills; self-assessment of the level of maturity and cognitive development.

2. ***The legality of transfer and ensuring the inverse connection of* content, conceptual elements with *direct and multiple impact on the development-effectiveness of the development of the ST*** ensures the interrelation of the basic aspects of *cognitive psychology* with *the theory of cognitive education, neurodidactics of learning* and *competence-based pedagogy*, guiding teachers towards valuable transfers of conceptual, content, methodological, procedural-organizational, including axiological-attitudinal, methodological, procedural-organizational elements.

3. ***The legitimacy of learning focused on the organization of logical structures of curricular content and the construction of new mind maps*** aims to ensure the processuality of learning through the exploration of the framework schema, addressed by several researchers (Vl. Guțu [17]; E. Joița [22]; I. Neacșu [29, pp.128-129]. We agree with the thesis of I. Neacșu [Ibidem, p. 127] according to which learning, both scholastic and academic, is an activity and a state, a phenomenon and a process, a necessary existential mode, which has a certain structure and relations, it knows movement/dynamics and evolutionary states and/or states of involution. In this frame of reference, we specify **the classical structural components of learning by correlating them with the development of ST**. **These include: the *subject/*** who learns and develops their ST; ***the conception/*** rationale (purpose, decision, plan, actions, etc.); the ***content*** (what learners learn in order to assimilate knowledge, skills, values and develop their ST); the ***goals*** (synthetically these are the competences, which have been formed on the basis of the realization of clear, conscious, proposed goals, objectives, tasks, proposed for application and integration); the ***motivation*** (why and for what they learn - interests, desires, aspirations, expectations, personal, professional life projects, etc.); *methodology/how to learn and develop ST* (strategies, forms, methods, procedures, techniques, etc.); ***resources*** (material, informational, energetic, temporal, etc.); ***time; conditions*** (external and internal); ***context*** (social, cultural, academic, school, etc.); ***pedagogical normativity*** (rules, laws, legalities, principles, etc.); ***evaluation*** (criteria and indicators for objectivity of assessment; ***results*** (concrete products, concrete performances; visible values that can be measured). To remain in the key of the research, we consider it very important to mention that the *structure of the framework scheme from the perspective of development-effectiveness of the ST in the context of teacher professionalization* will not be complete if it does not include such components as: *original, creative implications and applications in the learning process, realized through connections, transfers, derivations, extensions, deepening, etc. in the study of fundamental and specialized disciplines*, explored in the initial training of student-teachers and in the design-organization-development of formal and non-formal pedagogical activities, the development of professional practice placements.

4. ***The legitimacy of valuing aptitudinal structures in the context of learning and development of ST.*** The respect of this law requires from the teacher not only

knowledge in the field of personality psychology, but also abilities, skills of diagnosing, appreciating and stimulating general and special aptitudes in his/her students.

5. ***The legitimacy of exploring the principle of inter-, pluri- and transdisciplinarity within cognitive-constructivist learning and developmental-effectiveness of ST***. This legitimacy is not something radically new, at the same time it draws attention to the systematic valorization of the principle in cognitive-constructivist learning, which implicitly includes the development-efficiency of ST through the application of various metacognitive strategies and techniques.

6. ***The legitimacy of focusing on the multi-aspectual exercise of the scientific mind/thinking in the lifelong learning process*** requires ongoing adherence, whether in professional, personal and social settings. Of course, the development-efficiency of ST in the three environments will strengthen the intellectual capacities of the specialist, being also an early prophylaxis of human dementia. Thus, the conceptualization and the analytical reflection on the research issue allowed us to ***determine the neurobiological premises, to outline the neuropsychological possibilities, to formulate and explain the pedagogical modeling convergences and the development and efficiency of the development and effectiveness of*** *the ST*, to be exploited in the teaching activity with students and in the professionalization of teachers.

Synthesizing the general ideas in the field of neuropsychopedagogy and transferable practices in neuropedagogical [29, pp. 67-69], we have outlined the respective coordinate, the content of which made it possible to establish and formulate the set of ***principles of learning development and effectiveness of ST***. Essentially, every educator should be aware of and respect the following principles of learning and development of scientific thinking:

- **The principle of knowing how the human brain works and stimulating the functioning of modal brain potential**. The human brain is a highly complex unit with differentiating structures, functions and specializations, a relatively coherent set of subunits in equilibrium and capable of progressively changing its modal potential in response to external influences;
- **The** cortical region involved in neurodynamics is divided into two hemispheres, which are not absolutely symmetrical, each having relatively distinct but complementary functions with functionally integrated effects. Thus, *the neurons of the left cerebral hemisphere* (*LCH*) are able to process information especially quantitatively, while *the neurons of the right cerebral hemisphere* (*RCH*) are able to process qualitative, vaguer, more global, more general concepts.
- **The principle of combining and stimulating all cognitive mental processes in learning, with emphasis on the development of memory, language and various types of thinking.** In learning, each hemisphere plays its specific role, e.g. information is processed by the LCH, expressed in words and contextualized, i.e. set in motion by the complementary function of the RCH. This also occurs in the process of memorization, where facts will be retained to the extent that their understanding and processing through thought operations and types occurs.
- **The principle of centering the individual on the respect of psycho-emotional balance and healthy lifestyle as a biopsychological basis for stimulating the activity of neurons.** This principle ensures the updating of the teacher's knowledge of how to systematically orient students towards the knowledge and use of behavioral conditions and actions that will ensure the body's homeostasis, the balance of the flow of chemicals produced by certain components of the

human brain (hypothalamus and pituitary) and other endocrine glands (thyroid, parathyroid, adrenal glands, etc.), which have a direct impact on the activity of neurons and the emotional sphere (and therefore on learning, memory, development of thinking, skills, etc.) [29, p. 55] and directly on human thinking.

The last principle, in our view, must be systematically and systematically harnessed in the process of studying all school subjects (for pupils) and all university subjects, in order to form transversal competences, skills and intellectual habits.

- **The principle of effective knowledge and exploration of the neurodynamics of learning through the development and effectiveness of the individual's ST.** It has been formulated to ensure the teacher's understanding of the complexity of the human brain, composed of a set of structures, possessing constant and differentiating functions and specializations, which function efficiently if the neurodynamics of learning are monitored [29, p. 21], organizing the creation of optimal conditions facilitating the development-effectiveness of the ST (effective teaching technologies, stable psychological climate in the classroom, collaboration and cooperation among learners; original and accessible thinking and structuring of curricular content, but also focused on metacognition and the *development of the proximal area of cognition* from the perspective of *the cognitive development theory* of **Л. С. Выготский**, by which we emphasize the importance of developing and exploring effective teaching technologies.

Establishing and defining *the epistemological coordinates of the development and effectiveness of STEM* and outlining the guiding principles of developing, learning and optimizing scientific thinking in teachers, we have developed a pedagogical synthesis tool, called ***Epistemological coordinates of the development and operationalization of STEM in teachers*** (Table 2.1).

Table 2.1. The epistemological coordinates of the development and effectiveness of ST in teachers

Order no.	Epistemological coordination: essential features	Researchers and lines of inquiry	Application openings
1	2	3	4
1.	**The cognitive-constructivist paradigm** • learner-centeredness; • learning approached as an active and social process; • provides mental representations of reality in the complexity of the world; • provides learning environments based on concrete / real cases; • it orients towards critical reflection on one's own experience; • ensures the construction of knowledge as content and context; • is oriented towards collaborative knowledge building;	**J. Piaget** Theory of cognitive constructivism; **Л. С. Выготский** Social constructivist theory; **C. Rogers** **A. Maslow** Humanistic theories of learning; **A. Bandura** Social Modeling and Learning Theory;	• Active involvement in knowledge/cognition; • Stimulating knowledge activity as a basis for the development of intellect, including scientific thinking; • Capitalizing on *J. P. Guilford's Three-Dimensional Interpretive Model*, which ensures the involvement of three important components: - ***contents***: figurative, symbolic, semantic, behavioral; - ***operations***: evaluations, convergent and divergent thinking, memorization, cognition;

Continuation of table 2.1

1	2	3	4
	• focusing on building knowledge tools, meanings, meaning systems, activating old knowledge structures; • focus on metacognition (designing goals, actions, strategies for solving tasks, problems; hypothesizing; activity monitoring, self-evaluation, etc.); • valuing interpretation by drawing syntheses, conclusions and arguments.	**E. Joița** Cognitive education theory; **Vl. Guțu** The conceptual, methodological and teleological framework of adult education and learning/ andragogy.	- ***products***: units, classes, systems, transformations, implications. • Orienting the educational process on the axis of *cognition-metacognition-intellectual development* by streamlining and strengthening the ST; • The transformation of the individual learner into an active and creative subject, oriented towards self-regulated learning.
2.	**Stages of cognitive development** • Sensorimotor stage (0-2 years); • Pre-operational stage (2-7/8 years); • Stage of concrete operations (7/8-11/12 years); • Stage of formal operations (11/12-15/16 years).	**J. Piaget** The theory of staged cognitive development; Piagetian model of the development of human intelligence; **U. Neisser** Foundations of cognitive psychology (1967) **J. Bartllet** The constructivist approach to knowledge.	• Awareness of the child's possibilities at each age stage, bearing in mind that the built structures become part of the next structure; • Making the most of the possibilities of each stage through appropriate educational influences, focusing on the individual pace of development.
3.	**Levels of the human cognitive system** I. Level of knowledge; II. The computational level of information processing; III. Algorithmic-representational level; IV. Implementation level.	**A. Newell** Information processing and cognitive development; **M. Zlate** Information processing layers model; **Mr. Miclea** The human cognitive system; **E. Joița** Cognitive models and strategies of learning.	• Stimulating the development of the four levels of the individual's cognitive system; • Studying *cognitive architecture* to determine cognitive behavior; • Centering on training that focuses on neural, physiological/biological activity (latest research, neuroscience).
4.	**The principle and condition of scientificity of pedagogical knowledge** • Scientific criteria: - universality - incompleteness - openness to other phenomena as potential objects of study - looking for interdisciplinary connections	**K. Jaspers** Scientific characteristics of pedagogical disciplines; **K. Popper** Criteria of significance of knowledge/ testability of theory; **E. Nagel; Th. Kuhn** scientific criteria;	• The realization of *science education* in close connection with science *education* by respecting the condition and principles of scientificity in the process of studying pedagogical disciplines; • Explaining and objectivizing the principle of scientificity in teacher professionalization activities.

Continuation of table 2.1

1	2	3	4
5.	- the courage to question - working with categories and methods of universal knowledge - reflection/ shaping the scientific attitude of the researcher	**Marin C. Călin** scientific and pedagogical knowledge.	
6.	**Science Learning Theory and *Education for Science and the Future***	**J. Dewey** Training and intellectual development based on experience and knowledge building; **C. И. Гессен** Learning theory and science education (its stages).	• Determining the specificity of science learning in the context of developing SSE; • Creating optimal conditions for student-teachers to build their own knowledge and learning; • Focus on the promotion of lifelong learning as part of teacher professionalization.
7.	**Neurodidactic principles optimizing learning and development of the learning and development of the ST** • Neurodidactics component of neuropedagogy; • Neuropedagogy is the study of educational theories and technologies, centered on data from neurobiology, neurophysiology and neuropsychology.	**E. Durkheim** *Theory of evolutionary development of* society; founder of sociology *Social theory* and the inclusion in the scientific circuit of the concept of anomie (the perceived lack of moral and ethical norms in times of crisis); **I. Neacșu** Cognitive neurosciences and educational sciences; Modeling convergences in neuropsychology and neuropedagogy; Neurodynamics of learning and the formation of learning competence; Human thinking: the central structural core of the logic of learning.	• Stimulating reflection and exploring educational exercises to develop ST; • Focus on neurocognitive mediation of adaptation to new learning situations and professionalization of teachers; • Differentiating the quality of learning through interactive teaching methodologies; • Development of valued intellectual capabilities; • The efficacy of ST in the context of exploring the self-teaching styles of pupils and student teachers.

In this context, the psycho-pedagogical and philosophical value of the development-effectiveness of the ST in the professional training of pedagogues was specified, their essence and basic aspects were focused in the elaboration of another pedagogical tool ***The mechanism of the development-effectiveness of the ST in pedagogues***, which contains several operational methodological elements: ***master strategy of*** the targeted process, **composed of *cognitive-constructivist technology, facilitating personality traits, conducive educational environment***, the interconnection of which will contribute to the formation of the framework of *scientific education and self-education*, ensuring *the self-actualization of the pedagogue*,

including the formation of a personality focused on the enhancement of the EST in the educational process.

As we can see, the targeted mechanism reflects the aspects of the psycho-pedagogical value of the development-effectiveness of the development of ST in pedagogues. We return to the definition of the educational environment, which constitutes a psycho-pedagogical reality, which contains specially organized conditions for the formation of the pupil's personality, but also includes opportunities for development and integration into the social and spatial-objective environment. The pedagogical and psychological essence of the educational environment is the functioning of the set of actions and relations that would facilitate cognition and learning of the participants of the educational process. The ideas of **A. Maslow** about the self-perfection of the person, who considered that the *good environment is one of the main factors of self-actualization and human health, enabling him to adapt effectively to reality,* through self-awareness, self-evaluation and self-improvement behaviors, a decisive aspect for teachers and students who value ST [Apud 35].

Thus, in the process and the expected outcome of adult learning there is a clear tendency towards creativity, a focus on metacognitive skills, critical analysis, rational, inventive, reality-enhancing or reconstructing approaches, etc., which are characteristic elements of ST. At the same time, a ***key aspect*** is quite clear: ***the psycho-pedagogical and philosophical values in the development and effectiveness of ST are interconnected and complement each other, creating an optimal support for the professionalization of teachers, including in the learning of students***.

In this conceptual context, we note that **E. R. Hilgard** [69] has identified twenty principles within three different strands of theory, *behaviorist theory*, *cognitive theory*, and *personality motivation theory*, that are potentially useful for awareness and exploration of the psycho-pedagogical and philosophical value of developing scientific thinking in students. In our research we focused on them, developed and complemented them pedagogically.

In conclusion, the *psycho-pedagogical value of the development-effectiveness of ST in vocational training* is related to the learning activity of students, which, being supported by knowledge and focusing on personality traits, building and maintaining a positive educational environment, making use of pedagogical creativity and metacognitive learning strategies; designing and realizing an efficient and diversified educational process, orients us towards humanistic and axiological understandings of the philosophy of education. Concomitantly with this dual process of development-effectiveness of ST in both actors of the educational process, the pedagogue, who is an adult, must take into account the principles, many conditions, but also the specifics of the andragogical model of learning, as they will help them in their professional self-improvement.

The philosophical value of the development-effectiveness of the development of the ST in pedagogues is manifested both at the attitudinal level and in the enhancement of career professionalization based on the deepening of the study of epistemological, axiological and ontological foundations of self-actualization, learning and permanent becoming of the personality throughout the whole life.

Through the analytical-hermeneutic study, the essence and specifics of metacognition and critical thinking were highlighted; **the psycho-pedagogical conditions of their development were deduced and explained**, approached as theoretical-applicative determining motives in the development and effectiveness of the

development of critical thinking in pedagogues. Parallel to this, metacognitive knowledge and skills were analyzed, with emphasis on the four components of metacognition related to the cognitive and critical capacity of the person (meta-memory, meta-cognition, meta-understanding and meta-thinking), which gives depth, flexibility and flexibility to the pedagogue's thinking.

Several authors [4; 21; 66 etc.] note that metacognition correlates with the learning style, approached from the perspective of cognition and cognitive constructivism with an impact on the search and argument of the meaning of one's own actions, the valorization of the experience accumulated and explored as an active-participative and self-regulating dimension of the process of knowing and learning. Metacognition is important in cognition, learning and realization of various tasks with emphasis on the process of their creative performance. As mentioned above, ***in the initial training we do not advocate overloading the curricula with special subjects that would have as their object of study the development of ST, meta-cognition, critical thinking, etc., Instead, we are focusing on the reconsideration of the contents of the disciplinary curricula and the optimal exploration of teaching technologies, centered on active learning, learning through research, through the construction of knowledge of the subject, the development of its tools; on the development of the ability to formulate questions, hypotheses; the development and use of maps/ mind maps/ conceptual maps; the development, presentation and argumentation of ideas (with emphasis on the specifics of the subject, module), the content studied, etc.; information processing, decision making; creating conditions for optimizing one's own knowledge and learning, searching for new ways of solving educational problems and situations; systematizing information by applying analysis and synthesis of judgments and reasoning; developing the ability to structure and present the studied subject matter, pedagogical modeling, etc.***

Along with metacognition, **another important component of** constructivist pedagogy, emphasized by several researchers in educational sciences [22; 27; 33 etc.], is the ***development of critical thinking***. Representatives of the neurosciences [29; 41 etc.] regard **critical thinking as a central element of scientific thinking**. If we emphasize the essence of critical thinking by emphasizing the mental process of analyzing and evaluating information, then we observe that it is critical thinking that leads the subject to reflection by examining and elaborating arguments, evidence, judgments and reasoning. ***Critical thinking ensures the understanding of the logical connection between phenomena and ideas; it determines the relevance of evidence and conclusions, the ability to construct and evaluate arguments; it ensures the identification of inconsistencies and errors in reasoning; it is the pillar of approaching problems in a consistent, relevant and systematic way; it shapes reflection on the justification of assumptions, ways of thinking, behaving and/or constructing strategies for knowing and learning***.

Thus, starting from the theoretical analysis made, **for the development of metacognition and critical thinking in student-pedagogues**, we start from the specification of the simplest actions, configured in compliance with ***the following psycho-pedagogical conditions:***

- *Checking and reinforcing self-knowledge*;
- *Active and thorough examination of learning and knowledge tasks*;
- *Guiding the student in developing hypotheses by modeling their formulation*;

- *Strengthening the knowledge of developing and applying pedagogical strategies*;
- *Practice developing strategies for developing metacognitive skills on planning educational activity* (for a theme, module and non-formal educational actions);
- *Organizing the implementation of educational strategies* (didactic and educational), followed by analysis, evaluation, collective debates in the context of developing metacognitive skills and critical thinking (by applying observations, comparisons, explanations, argumentation of actions, interpretation, generalization, etc.);
- *Monitoring and control of the implementation of educational strategies* by developing and applying criteria, indicators, agendas for monitoring academic progress (for various study subjects);
- *Developing and capitalizing on strategies for regulating the pedagogical activity of teachers* in general and in particular for various school subjects;
- *Teaching and practicing metacognitive behavior of student-teachers* by exploring critical thinking;
- *Organizing reflective activities; drafting and exploring academic reports, papers and debates in order to* acquire and strengthen metacognitive and critical thinking skills, etc.

The nominated psycho-pedagogical conditions were formulated with an emphasis on cognitive-constructivist actions of valuing metacognition and critical thinking being explored in the formative experiment.

Chapter 3, *Praxiological underpinning of the development and effectiveness of scientific thinking in teachers*.

Starting from the epistemological milestones determined and exposed above, from the results of research in neuroscience [13; 41; 42 etc], we try to demonstrate that the **development of scientific thinking** in students is a priority of present and future learning perspectives and strategies addressed at national and international level, which is observed in many educational policy documents. To begin with we will clarify and explain some aspects related to the **School of the Future** and its conception. The first author who described the Future School concept was **Torson Husén** [72]. Its concept is based on the application of long-term strategies. Nowadays, the new concept of the School of the Future is elucidated in the **STEAM education** approach, where students can study any subject area through concrete strategies, applying scientific skills in *technologies, arts, mathematics and engineering* through various projects, which have a social purpose with practical application in everyday life. Thus, we observe that STEAM education integrates science, technology, engineering, arts and mathematics, underpinning the development of STEM. The study of the targeted orientations indicates that the proposed transdisciplinary methodology is integrated in a *learner-centered design and the use of the cognitive-constructivist paradigm*. STEAM education has evolved from the STEM educational conceptualization, which emerged as a movement advocating a move away from segmented content areas, emphasizing technology to connect and research subjects and realizing the wholeness and connectedness of teaching in accordance with the needs of everyday life. We point out that STEAM education is centered on the acquisition of skills so that subjects acquire necessary skills of collaboration, cooperation, problem solving and application of critical thinking, with emphasis on teamwork and enhancing their research potential in the process of instruction [24].

At the same time, the concepts of *Reading and Writing* were also included in the model. We reiterate that this addition and update has developed the important and necessary **STREAM** type of education, as educators have found that this consistently followed concept in education actively promotes 21st century skills in students: *collaboration, communication, creativity and critical thinking which are found in the* ***STREAM Curriculum*** [60]. It is obvious that the full functionality of STREAM education cannot be ensured without the component of scientific thinking, which is often specified as a process of development of *higher order thinking*. In this context, we note that *collaboration, communication, creativity, critical thinking and other concepts characteristic of functionality in the system of student's cognitive development are found both in the* **Key Competences according to the approaches of the *Organization for Economic Cooperation and Development/ OECD.***

Annually analytically, *the predictors of the ST* were deduced and explained, correlating the *values-functions present in the cerebral hemispheres* with the *key competences of the highly developed ST*, highlighting the specificity of holistic/ complex thinking, the development of which denotes the interconnected and complementary functioning of the two hemispheres, which ensures the ability to focus the individual's attention, causal determination/ attribution; analytical differentiation/ tolerant attitude towards contradictions; perception of change and understanding.

From the above, we deduce that the development of scientific thinking at different age stages is based on at least two elements: cognitive orientation, personality directivity and the problem situation that leads the subject to engage in scientific educational activity. In relation to science education, it provides space for pupils to learn about themselves and others, about the environment, to learn how to apply and develop the acquired skills in learning and everyday life. *The process of science education* provides the individual with a direct experience that would allow for the development of cognitive skills and the development of effective ST skills through the exploration of a range of predictors. ***The predictors of scientific thinking*** are: *formal and informal learning and knowledge experience; cultural context; personality traits and creative attitude cultivated since childhood by awakening interest and forming aspirations towards science-related activities, forming motivation and cultivating the habit of scientific thinking* [86].

In configuring the competences for the development and effectiveness of the ST in pedagogues, we started from the *neurobiological premises*; from the *neuropsychological possibilities, laws, neuropsychological legalities*, from *the modeling pedagogical convergences*; from the *epistemological coordinates* determined and described above.

In the area of these interpretations, we reiterate that the *neurodidactic approach* involves the inventory of a desirable number of *skills and associated behaviors* that are likely to highlight the expected educational progress [Apud 29, p. 14], which come from the context of *cognitive learning* and refer to all the activities involved in the acquisition, processing, organization and use of knowledge, in other words, all those skills associated with *thinking and knowing*. In order to understand how we make the most of *cognitive and constructivist learning* from the *neuropsychological and neurodidactic approach,* we focus further on the *structure of the functioning of the cognitive system through the synthesis of values-functions at the level of personality present in the activity of the two cerebral hemispheres,*

systematized **by I. Neacșu**. The synthesis of the knowledge on the values-functions provides clarity in the elaboration and application of the educational approach of the teacher, so that he/she can efficiently use various strategies for the development of scientific thinking and experiment multiple evaluations at the level of formative/educational interventions. Thus, we can observe a complementarity at the problem solving level, when the subject of thinking uses systematization and communication, the left hemisphere is activated, and when the problem calls for spatial creation and authenticity, the right hemisphere is activated. Likewise, when we elaborate ideas and approach investigation systematically, make logical calculations, analyze quantitatively and perceive, the left hemisphere is called upon. At the same time, neuroscientists have shown that both hemispheres are involved in the process of ST [29; 41].

In the pedagogical aspect, it was established the perspective of development of ST in educators, which is to be oriented, in particular, towards the foundation and promotion of ***neuroeducation***, ***which would organically combine cognitive development sciences, psychology and pedagogy.*** In our view, this fusion creates a *functional interdisciplinary methodological interdisciplinary support*, because, known and applied, it can ensure the development and effective application of educational technologies focused on the development and effectiveness of students' ST.

Another important aspect is the specification of pedagogical competences and their re-dimensioning in the context of ***professional self-actualization*** and the determination of the link between the personality traits of the teacher in the initial training process, which allowed us to develop and base the ***Professional Portrait of the student-teacher who possesses ST***. The proposed tool is methodologically oriented and contains 12 essential traits, such as: *active involvement in learning and research actions; focus on creative, constructive and metacognitive learning; manifestation of intellectual curiosity, principled orientation and motivation; tolerance, understanding, independence and self-criticism; inclination towards reflection and experimentation; inventiveness; ability to get to the essence of the problem; comprehensive acting; preference for diversity and novelty, self-directed learning; focus on moral and professional self-actualization; perseverance, self-confidence, optimism; energetic action and moral consistency; prompt/fast action and risk-taking; ability to develop and argue new and original ideas; ability to generalize, to draw conclusions, predictions and perspectives.* As can be seen, the described qualities are defining elements of the professionalization of the teacher from the perspective of promoting genuine scientific values in the educational system. It is obvious that the features listed must also be characteristic of experienced teachers. In both cases, the important common element is ***openness to the new and innovation***, which creates conditions for different perspectives, *ideas, people, situations and predisposition to a wide range of thoughts, feelings and new scientific problem-solving strategies.* Openness primarily involves an effective response style in approaching or avoiding new ideas, people or situations [65, p. 300].

It should be noted that this portrait also includes pedagogues already working in the field of education. Based on the epistemological coordinates and starting from the modeling pedagogical convergences (Chapter 2), it is undeniable that we could develop and complete this tool with a number of distinct qualities such as: *the ability to think scientifically; the ability to design and develop disciplinary*

curricula; the operational-actional ability to develop and apply teaching strategies, technologies; the ability to self-evaluate and evaluate students' competences effectively and objectively, etc.

In the diversity of the research direction, we aim to conceptualize the self-improvement of teachers in the context of improving scientific thinking and its value in everyday life and lifelong professional activity. To this end, it is rational to examine the impact of the native/ hereditary factor by reactualizing the fundamental meanings *of the Biological Theory of Enneatypes/ Enneagram* [50], which we have correlated with the basic positions of *cognitive education theory* [21], *constructivist theories of learning* [10], (cognitive constructivist theory/ J. Piaget; social constructivist theory/ Л. С. Выготский, which formed the basis for the foundation of the cognitive-constructivist paradigm in pedagogy); the development of the levels of the human cognitive system and the impact of the theory of self-efficacy and the socio-educational environments, i.e. educational institutions, including professionalization, which directs us to emphasize the importance of the opportunities and possibilities of self-improvement of teachers in order to make the development of scientific thinking more effective.

In the analysis it became evident and clear that ST is closely connected to *everyday thinking* [2], *lateral thinking* [50**Eroare! Fără sursă de referință.**] and *professional thinking*, because the first one ensures the detection, understanding and solution of existential problems; the second one - allows the individual to be inventive, to develop alternative, non-standard/ original ideas, and the third type of thinking, being scientifically oriented, involves the development and solution of hypotheses, specialized problems, gives cognitive-constructivist ability in approaching the educational process. In this context, the socio-pedagogical opportunities of initial and continuing training have been delimited in ***two conditions – paths, one institutionalized***, officially founded and managed, systematically initiated and carried out by higher educational institutions through the organization of bachelor's, master's, continuing education courses, doctorates, etc. and another – ***free, autonomous***, self-improvement through self-evaluation, planning and carrying out independent actions [10; 11 etc].

Getting to the essence of the epistemological milestones and shaping the pragmatic dimension of the development and effectiveness of ST ensured the elaboration of the basic pedagogical construct, entitled *Pedagogical Model of the Development and Effectiveness of ST in Pedagogues*, which incorporates the scientifically grounded theoretical and praxeological milestones. Thus, the model consists of two major components: *theoretical and praxeological benchmarks*, which, in turn, contain a number of constituent elements, which represent the theoretical, methodological and technological structures of the process of development and effectiveness of the development and effectiveness of the ST, approached in a dual way, aimed at teachers and students, thus emphasizing the dependence of the quality of education of educators on the respective competence of teachers.

Thus, starting from the epistemological dimensions and coordinates, from the conceptualization made on the development and effectiveness of ST (Chapters 1 and 2) and from the models generated by the cognitive-constructivist paradigm, through methodological conversion, we have developed and explained the structure, flowchart/flowchart and content of *the Pedagogical Model of the development and effectiveness of ST in pedagogues* (Figure 3.1). The proposed model represents

a *complex* pedagogical construct, *dual* and *interactional* at the same time. The arguments supporting this qualification are summarized in the following considerations:

- the act of development-effectiveness of ST in teachers is perceived and approached in a dual way, i.e. in the correlational context with the same actions needed to be capitalized in the training of students, teachers and pupils;
- the educational situations in which teachers and pupils find themselves are created by the former through the active involvement of the educated;
- the construct is analytic, categorical in its essence, complex in its structure and oriented towards training (development, effectiveness) as an action and process in the realization plan;
- the double/dual dimension of behaviors on the part of educational actors interact on the axis of functions, process and purpose, framed in a cause-effect relationship, in which the correlation and dependence of the development of ST in students and its efficiency, including the honing and improvement of the respective pedagogical competences, which contribute to continuous professional self-actualization in the targeted field, is observable;
- The mission of the model is focused on the formation of competences at the integrative level through the development-effectiveness of the ST at both sides-actors of the educational process in the context of increasing the quality of literacy and scientific education, the formation of intellectual skills and metacognitive skills for lifelong learning.

Obviously, the proposed model has an open structure that can be developed and completed. **The model is envisioned to fulfill several important functions:**

a) *the function of framing* the essential actors in the process of development-effectiveness of the ST;
b) *the conceptual-theoretical function,* which determines the theories, conceptions, scientific approaches underlying the epistemology of the development- effectiveness of the development of the ST;
c) *instrumental-regulatory function,* which guides the application of pedagogical tools in the organization and implementation of actions in the process of development and improvement of the development- effectiveness of the ST in teachers (but also in students);
d) *the information function*, which involves the transmission and study of new knowledge through problem-formulation and problem-solving and research/heuristic orientation;
e) *the function of activating and exploring the intellectual potential* in an optimal way depending on the particularities of the age, the objective/discipline taught, etc.;
f) *the function of stimulating metacognition, creativity, inventiveness, transfer of knowledge into practice* by valuing reasoning and all types of thinking (analytical, lateral, divergent, convergent, panoramic, etc.).

As can be seen, the organizational chart of the model represents a structural-organizational scheme (Figure 3.1), the components of which are detailed and explained below.

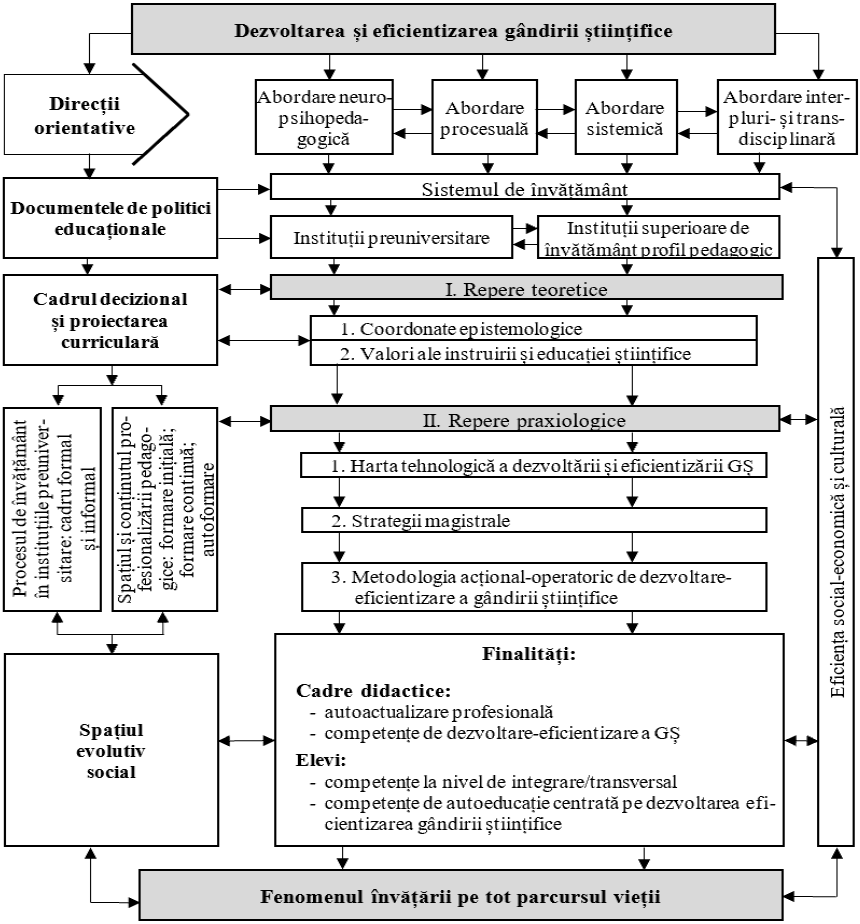

Figure 3.1. The pedagogical model of the development and effectiveness of scientific thinking in pedagogues

In anticipation of its detailed description and interpretation, we consider it important to mention that the envisaged goals have an evolutionary-social impact, they determine the professional, social-economic and cultural efficiency of the teacher. Analyzing the structure of the model, we become aware that the development and effectiveness of ST in pre-university school students, in fact, prepares them in the context of OECD approaches and the formation of intellectual skills and competences necessary for lifelong learning.

The theoretical/ epistemological landmarks are elucidated and concretized in the previous chapters. They have been determined through the theoretical study based on analysis, synthesis, specification, conceptualization and generalization of information in the framework of interpretation and the realization of a series of reasoning and conclusions.

The praxiological milestones, *included in the pedagogical model of development and effectiveness of ST in pedagogues, contain three large blocks of elements:* The technological map of development and effectiveness of ST includes Objectives/ goals (objectives Inputs and competences as Outputs), Master Strategies, process forms (ways of organization, conduct and evaluation of ST ST), action-operational methodology of ST (Table 3.1).

Table 3.1. Operational-action methodology of development and effectiveness of ST in teachers

No. d/o	Proposed module	Form of organization	Strategies and methods
1	**2**	**3**	**4**
1.	• SS in the context of developing pedagogical competences; • The advantages of ST and how it helps us to optimize the educational process in normal and crisis (pandemic) situations.	Pedagogical innovation workshop	*The learner-centered strategy in combination with the heuristic strategy:* • Lecture • Heuristic conversations • Individual study method • Problematization method • Academic controversy
2.	• The development-efficiency competencies of STG and their basic characteristics; • Types of thinking: characteristics and scope.	Pedagogical innovation and creation workshop	*Exploring educational reality strategy* • Project method • Brainstorming • Heuristic conversations • Phillips-66 debate method • Sinectica • Creative controversy • Individual study method
3.	• ST in the context of neurobiological and psychological sciences; • Modeling student thinking in the school environment (offline and online).	*Information and modeling workshop*	*Strategy for activating and streamlining learning, teaching-learning and assessment* • Lecture with PPT • Explanation • Practice • Modeling • Heuristic conversations • Sinectica
4.	• ST, theory and praxiology of enneatypes: individual-typological peculiarities; • The psychological profile of the teacher with ST.	*Information and documentation workshop*	*Strategy for activating and streamlining learning, teaching-learning and assessment* • Lecture with opponents • Discuss • Brainstorming • Problematizing • Creative controversy • Modeling • Independent reading • Information techniques
5.	• Metacognition and critical thinking as essential components of ST; • Harnessing information and communication technologies in the context of the development-effectiveness of the ST.	*Practical conference*	*Streamlining learning strategy* • Scheduled training • Teaching algorithm • Summary comments • Application of educational software • Modeling educational technologies

Continuation of table 3.1

1	2	3	4
6.	• Lateral thinking as a factor in the development of ST; • Scientific reasoning in the context of lateral thinking.	*Round table*	*The Reflection Strategy* • Practice • Modeling • Analysis and summaries • Structuring information and developing educational alternatives • Project method • Sinectica • Independent reading
7.	• Logical thinking as a praxiological foundation for the development of ST; • Scientific argumentation and problem solving.	Creation and innovation workshop	*Heuristic strategy* • Problematizing • Heuristic conversations • The method of developing and solving problems • Reflection • Guided reading followed by reflections
8.	• ST in the context of teaching real science; • Development-effectiveness of ST in teachers and students: educational technologies.	Praxiological training and modeling workshop	*The school reality exploration strategy* • Story • Explanation • Exchange of experience • Modeling • Sinectica • Reflection • Reading
9.	• ST in the context of humanities teaching; • Foundations for optimizing learning, instruction and science education.	Praxiological training and modeling workshop	*The school reality exploration strategy* • Story • The conversation • Explanation • PPT • Problematizing • Sinectica • Independent reading • Project method
10.	• Asessment strategies for student ST and self-assessment in teachers; • ST in lifelong learning.	Totalization conference	*Strategy focused on generalization and conclusions* • Modeling • Reflection • Presentation of a personal portfolio on the topic addressed • Individual study • Generalizing and developing personal perspectives

Anticipating the description and interpretation of the pedagogical experiment, we note that the value of the model is mainly methodological, since it serves as a tool for orientation, training, observational analysis and recording-evaluation of the behavior (the goals obtained) of the teacher and students.

Therefore, we set up a process of development- effectiveness of the ST in pedagogues, following its impact on students, and also determined, formulated/ defined the theoretical and praxiological benchmarks of the phenomenon researched.

Chapter 4, ***Experimental coordination of the development and effectiveness of scientific thinking in pedagogues***.

The research was focused on exploring the theoretical, experiential and experimental framework of the development and effectiveness of scientific thinking

in pedagogues, based on specific normativity objectified in the set of laws, laws, principles and rules of investigation. The theoretical landmarks determined and elucidated on the development and effectiveness of scientific thinking in teachers and the identification of the tendencies of reconfiguration of the educational process from the perspective of the confluence of factors and conditions of the development of scientific thinking in teachers and students in school have founded the applied research and have guided us in starting the pedagogical experiment.

Our preliminary research activity lasted 7 months and included a stratified sample of 248 students from 12th grade of high school; 195 students-pedagogic students and 272 students-master students, Faculty of *Education Sciences*, UPSC. Thus, in total we interviewed 715 subjects in order to satisfy ourselves about the correctness of the determination and formulation of the research topic and problem. The analysis and interpretation of its results were elucidated in chapter three of the paper.

The basic pedagogical experiment was multilevel and stratified, structured in three stages: observation, training and verification/control. We worked with the *Before-and-After-Method*, because it allows to detect and highlight the general/final and sequential results, which ensures the necessary modification, correction and timely completion of the formative program, actions and investigative strategies applied.

The research with the involvement of the first sample, consisting of 511 subjects, teachers from 224 educational institutions in the Republic of Moldova and Romania (rural and urban) contributed to determining the knowledge and opinions on the definition of ST, the importance of its development in students and teachers, specifying the conditions, ways of training and making ST more effective, identifying personality traits that impact on its development.

Table 4.1. Experimental research design

Milestones	**I. PRELIMINARY INVESTIGATION**
1	**2**
Objectives	• Identification of teachers' representations of ST; • Analysis of the disciplinary curriculum, i.e. the aims and contents; • Establishing the opinions and level of scientific thinking among high school graduates (Chapter 3); • Assessing and valuing the level of scientific thinking in student teachers and master students (Chapter 3); • Scientific substantiation and elaboration of criteria, indicators and descriptors of the DEST and of the deepening competences of the four levels of the *cognitive system* in teachers: • Development and validation of instruments to assess the level of scientific thinking of teachers; • Elaboration of educational technologies for the development and effectiveness of scientific thinking in teachers.
Plots explored in the preliminary experiment	1. Independent sample, consisting of **511** subjects (teachers from 224 educational institutions in Moldova and Romania in rural and urban areas). 2. Independent batch of high school students, grade 12, consisting of **248** students. 3. Independent group of student teachers, consisting of **195** subjects. 4. Independent batch of master students, consisting of **272** subjects.
Deadlines	Second semester, academic year 2020-2021
Tests applied	Questionnaire – application to identify the representations of scientific thinking; Tests for the evaluation and valorization of scientific thinking in high school students, student-pedagogues and master students.

Continuation of table 4.1

1	2
Impact and results	- Study and preliminary analysis of representations of teachers' scientific thinking; - Study and preliminary analysis of the opinions and level of development of scientific thinking in high school students; - Study and preliminary analysis of the level of development of scientific thinking in student teachers; - Study and preliminary analysis of the level of development of scientific thinking in master students; - Directions for the development of scientific thinking in teachers were established; - The model and the set of pedagogical tools for DEGS has been developed; - Validation of instruments to check the level of scientific thinking in pedagogues.
Milestones	**II. THE VERIFICATION EXPERIMENT**
Objectives	• *To identify the level of scientific thinking and the competences of teachers' cognitive system development (the four levels).* - obtaining relevant information about the level of skills and knowledge of the subjects before the formative intervention; - identification of the initial needs and difficulties of the subjects in terms of developing-efficiency of scientific thinking; - planning and adapting the training program and specific interventions to form the competence development-effectiveness of scientific thinking in teachers in the framework of the observation experiment.
Experimental batches	• I. **Initial training.** Sample - **130 student-pedagogues** from the field of *Education Sciences* (initial training) from the first undergraduate cycle, from all years of study. • II. **In-service training** sample - **288 teachers** from Romania and the Republic of Moldova (women, n = 275), (men, n = 13), 62 subjects come from rural areas and 226 from urban areas, from different educational institutions (pre-school, primary, secondary, high school and specialized medium); 15 are chemistry and biology teachers, 17 foreign language teachers, 32 Romanian language teachers, 41 educators, 21 psychology teachers, 23 history and geography teachers, 67 are primary school teachers, 10 are mathematics and physics teachers, 11 computer science teachers, 5 are physical education teachers, 46 are teachers of different specialized fields (**139** s. are from Romania, **149** s. are from the Republic of Moldova). • III. The sample consisted of 288 s. (teachers were involved in the formative experiment on two strands: observation and training on the development-effectiveness of the ST and deepening-extension of the cognitive system).
Deadlines	Semester I-II, academic year 2021-2022
Tests applied	*Forms:* Questionnaire - application to identify the level of development of scientific thinking in teachers; *Methods:* questioning, analyzing and synthesizing, expert assessment method.
Impact and results	- Experimental sampling; - The observational investigations on the development of scientific thinking in teachers were carried out; - The following were specified: the level of development of scientific thinking, competences regarding the deepening of the cognitive system of the investigated subjects; - The building blocks of the pedagogical model and tools have been finalized and specified; - The training program for the DEST in pedagogues was developed.
Milestones	**III. THE FORMATIVE EXPERIMENT**
Objectives	• Implementation of the intervention model and technology for developing and making scientific thinking in pedagogues more effective;

Continuation of table 4.1

1	2
Experimental plots explored	• **Comparative experiment:** 1. Experimental group - **144** teachers from different levels of education, selected on the basis of the criteria of the level of development of scientific thinking (in-service training) 2. Control group - **144** teachers from different levels of education, selected on the basis of the criteria of the level of development of scientific thinking (in-service training) 3. Mixed experimental group - **65** student-pedagogues from the field of *Education Sciences* (initial training) 4. Mixed control group - **65** student-pedagogues from the field of *Education Sciences* (initial training) • **Experiment conducted according to the *before and after method*** Independent experimental plot - 288 s.
Deadlines	Semester II, academic year 2022- Semester I, academic year 2023
Investigation activities and methods	*Forms:* training sessions, instruction, practical activities, case studies, workshops of pedagogical creation and innovation; workshops of improvisation and reflection, etc. *Methods and strategies:* collaboration and reflection, self-reflection, explicit meta-cognition learning, developing self-monitoring skills, strategic learning, encouraging critical questioning, constructive feedback, hands-on approach and repetition. *The method of study and learning through scientific observation (MSÎOŞ)* *Method for Developing Scientific Thinking through Educational Experiments (MDSTEP).* *The method of deep and powerful reading (MLAP)* *The epistemologically reflective epistemological learning-study method (REELS)* *Reading Technique with Text Editing (LRT)* *Experiential learning method (ELM)* *Personalized learning through the ERRQ strategy* *Methods for developing heuristics (MDE)* *Inventive Problem Solving Method (ARIZ)*
Impact and results	Teachers have achieved a higher level of development and effectiveness of scientific thinking manifested by: • a deep understanding of the context and meaning of educational phenomena, data and information; • the ability to make connections between different facts and data in order to build a broader and more complex picture; the ability to argue, synthesize, draw conclusions, make predictions, etc. • generating new and original ideas by extrapolating and applying concepts to unusual/ordinary situations; • Strengthening pedagogical competences to understand, apply and train metacognitive skills of critical thinking and scientific thinking in pupils and cognitive system deepening skills in teachers. Qualitatively, teachers have obtained efficiency in execution; neuroplasticity and fluency in the theoretical exposition of the subject matter and execution of actions of analysis, synthesis, comparison, systematization, generalization, generalization, inferences, judgments and reasoning; better adaptability, ability to develop effective metacognitive strategies; increased ability to achieve knowledge and skills transfer; optimization of creativity, ST, imagination and pedagogical rationalization, etc.
Milestones	**IV. CONTROL EXPERIMENT**
Objectives	Establishing the relationship between the stage of ascertainment and the stage of training and validating the effectiveness of *the pedagogical model of the development and effectiveness of scientific thinking in pedagogues*. To ascertain the formative impact of the experimental intervention oriented towards the development-effectiveness of the ST in teachers (initial and in-service training).

Continuation of table 4.1

1	2
Plots explored in the control experiment	• **Comparative experiment:** 1. Experimental group - **144** teachers from different levels of education, selected on the basis of the criteria of the level of development of scientific thinking (in-service training) 2. Control group - **144** teachers from different levels of education, selected on the basis of the criterion of the level of development of scientific thinking (in-service training) 3. Mixed experimental group - **65** student-pedagogues from the field of *Education Sciences* (initial training) 4. Mixed control group - **65** student-pedagogues from the field of *Education Sciences* (initial training) • **Experiment conducted according to the *before and after method*** Independent experimental plot - 288 s.
Deadlines	First semester, academic year 2023
Investigation activities and methods	*The same tools and evidence were applied as for the finding.* *Ancillary methods:* questioning, analysis and synthesis, expert evaluation method; scientific observation, case study, studying the products of teachers' work.
Impact and results	*The Pedagogical Model of the Development and Effectiveness of Scientific Thinking in Pedagogues (TMDEST)* was validated. On the basis of the results of the implementation of the pedagogical model, the *Curriculum of Education from the perspective of the development of scientific thinking* was developed; The activities of supervision of pedagogues were outlined from the perspective of development - making scientific thinking more efficient.

The design of the pedagogical experiment was outlined based on six research axes: Investigating teachers' **knowledge of** the concept of scientific thinking and its characteristics, the role of cognition, metacognition and critical thinking in the development of scientific thinking; Investigating teachers' involvement in **facilitating** the development of a sense of intellectual curiosity and wonder at the first stage in the development of scientific thinking in students; Facilitating and developing scientific thinking in students in general; Investigation of **strategies, methods and procedures applied** in the development of scientific thinking in students by teachers in curricular and non-formal activities; Study and analysis of **personality traits** that can contribute to the formation of scientific thinking in students and adults/ pedagogues from a psycho-pedagogical perspective; Investigation of the conditions of **facilitating** the development of scientific thinking in students; selection and analysis of **practical proposals**; Investigation of teachers' representations and perceptions **of the professional portrait of the teacher**, who shows scientific thinking.

The aim of the pedagogical experiment: to determine by means of follow-up, formative and verification/control actions the specifics of the development-effectiveness of the development-efficiency of the ST in pedagogues through the implementation of *the Pedagogical Model of the development and effectiveness of scientific thinking*, which, in essence, incorporates the theory and methodology of the targeted process.

General hypothesis of the research: the scientific foundations of the DEST in pedagogues will be relevant as a distinct research direction, if, they will constitute the epistemic core and the ordered theoretical-applicative structure of the targeted process, through:

- in-depth study and analysis of the situation in the investigated field, which will ensure conceptualization, elucidation of the genesis of the concept and phenomenon of ST;
- the theoretical and methodological coherence of the set of neurobiopsychological premises, laws, legalities, principles, psycho-pedagogical conditions, modeling pedagogical convergences and inter-, pluri- and transdisciplinary strategies of DEST;
- the determined and grounded theoretical landmarks, approached as starting points in establishing methodological and praxiological particularities of the development of scientific thinking in teachers in the context of lifelong learning;
- the pedagogical model, including the technological map and the operational-operational methodology of teachers' (in the process of initial and in-service training) elaborated and scientifically based.

Experimental research objectives:

- Identification and argumentation of the neurobiopsychological premises, laws, legalities, principles, psycho-pedagogical conditions, modeling pedagogical convergences and inter-, pluri- and transdisciplinary strategies of DEST;
- Elaboration, scientific substantiation and validation of *the Pedagogical Model of the development and effectiveness of scientific thinking in pedagogues (which contains all the theoretical and applied tools);*
- Elaboration and validation of the pedagogical model, including the technological map and the action-operational methodology of DEST for teachers (in the process of initial and in-service training).
- Experimentation of the *octional-operational methodology of the DEST in pedagogues, including the formative program*.

The dependent *variables* subject of the research are: teachers' knowledge and skills regarding pedagogical professionalization from the perspective of development - making the ST effective, facilitating the development of scientific thinking in students (teachers' actions); application of methods and procedures by teachers in the development of scientific thinking in students; personality traits of the student who possesses developed scientific thinking; conditions that facilitate the development of scientific thinking; professional portrait of the teacher with developed scientific thinking.

The preliminary investigative approach is detailed in the Experimental Design of the research (Table 4.1).

The qualitative data processing of the preliminary experiment allowed us to determine the criteria, indicators and descriptors of the DEST in teachers.

In the light of the foregoing and based on *B. S. Bloom revised by L. W. Anderson and D. Krathwohl*, which is based on *the structuring and formation of declarative, factual, conceptual, procedural and metacognitive cognitive knowledge and skills* [55]; from the particularities of the teleological approach to competences in the education system, namely transversality as an important characteristic of key competences [17, p. 17-19], and from the theoretical landmarks of conceptualization of the university curriculum, we have developed the assessment tool for assessing the competences of the ST which includes the competences of systemic and critical thinking, objectified in the indicators and descriptors of the formation and effectiveness of scientific thinking in pedagogues presented in Table 4.2. The indicators and descriptors of the formation and effectiveness of scientific thinking

in pedagogues are based on the methodological principles and requirements for the construction of the competence-centered curriculum [23, pp. 86-88]:

Thus, **transversal professional competences.** *Vocational competence* is the demonstrated ability to select, combine, synthesize and make appropriate use of relevant knowledge, skills, values and attitudes in order to deal effectively with a given set of work or learning situations specific to a given occupation [19].

Cross-curricular competences are those capacities, skills and abilities that go beyond a specific subject area or program of study, as they are developed through inter- and transdisciplinary approaches. They include team working skills, oral and written communication skills in the mother tongue or foreign language, use of information and communication technology (ICT), problem solving, decision making, recognizing and respecting diversity and multiculturality, autonomy in learning, initiative and entrepreneurship, openness to *lifelong learning*, respect for and development of professional values and ethics, etc. Cross-cutting competences are inter- and transdisciplinary. They are considered and assessed as *terminal objectives of integration*, as *macro-competences*, because they manifest themselves in complex situations, which can only be solved if all the necessary acquisitions are made aware, integrated and structured. ***Transversal competences are terminal because they aim to establish a final synthesis, after a year or after a cycle, which assesses the level of training, the ways in which the holder of these competences manifests him/herself in a complex situation of real integration*** [17].

As terminal objectives, these competences activate different ways of approaching the forms of combination of acquisitions: by interrelating the specific elements of the domain in question; by mobilizing and coordinating this body of elements in complex real situations; by making all the mobilized and activated elements flexible and polarized towards a goal.

The transversal competences/integration competences derive into core competences, and each of these derive into other specific adjacent competences, which can be found in the training profile at different levels.

Professional competences are therefore a unitary and dynamic set of knowledge and skills. *Knowledge* is expressed by the following descriptors: knowing, identifying, characterizing, understanding and using specific language; explaining and interpreting.

Skills are expressed by the following descriptors: application, transfer and problem solving; critical and constructive reflection; creativity and innovation.

Each qualification linked to a specific study cycle (bachelor, master, doctorate) is defined on the basis of the general description of learning outcomes and is expressed by: *general professional competences*, which are developed within the broader framework of the field of study; *specific professional competences*, which are developed within the narrower framework of a study program.

Transversal competences are value and attitudinal acquisitions that transcend a particular field/program of study and are expressed by the following descriptors: autonomy and responsibility; optimal social interaction and integration; effective personal and professional development [23, pp. 86-88].

These clarifications highlight the fact that the professional competences of the teacher contain cognitive structures (theoretical and practical), permanently oriented towards the development – making more efficient the ST, whereas transversal competences are based on complex mental actions of transfer, synthesis, conceptualization, systematization, generalization and prediction [29].

Table 4.2. Indicators and descriptors of the formation and effectiveness of scientific thinking in teachers

Nr.	Indicators	Descriptors of the formation and effectiveness of scientific thinking in teachers		
		Lower level (1)	Medium level (2)	Top level (3)
1. Knowledge				
1	**2**	**3**	**4**	**5**
1.1.	Knowledge of basic concepts of scientific thinking (item 1 and 2)	Correctly explain 2-4 scientific concepts (about scientific thinking)	Correctly explain 5-7 scientific concepts (about scientific thinking)	Correctly explain 8-10 scientific concepts (about scientific thinking)
1.2.	Representations of the role of cognition and metacognition in the development of scientific thinking (item 6)	Knows and characterizes 1-2 components of cognition and metacognition and explains their role in developing scientific thinking	Know and characterize 3-4 components of cognition and metacognition, explaining their role in the development of scientific thinking	Know, explain and characterize the components of cognition and metacognition and their role in the development of scientific thinking
1.3.	Knowledge of creating the conditions for developing scientific thinking in pupils (item 4, 9)	Name 1-2 necessary conditions to be met to facilitate the development of scientific thinking in pupils	Identifies the conditions that need to be met to facilitate the development of scientific thinking in pupils at each age stage	Identifies the conditions to be met to facilitate the development of scientific thinking in pupils at each age stage (develops practical proposals)
2. Apply				
2.1.	Developing strategies (forms, methods, procedures, techniques) for developing scientific thinking in pupils (item 5)	Name 1-2 methods and processes focused on developing scientific thinking in students	Identifies forms, methods and processes in the development of scientific thinking in students taking into account the age specificity (consistently explain each method presented)	Develops strategies, methods of developing scientific thinking in students, taking into account the age specificity (consistently exposes each form presented, explaining its influence on the development of scientific thinking)
2.2.	Determining personality traits that would facilitate the development of scientific thinking in pupils (item 8)	Name 1-2 personality traits needed to facilitate the development of scientific thinking in students	Name 3-4 personality traits necessary for the development of scientific thinking in students, explaining how to model students' behavior according to certain personality traits	Characterize the personality traits necessary for the development of scientific thinking in students, explaining how to model students' behavior according to certain personality traits and age specificity
2.3.	Developing students' sense of intellectual curiosity and satisfaction to develop scientific thinking (item 3)	Know some methods to stimulate curiosity in children (explain 1-2 methods)	Systematically use 3-4 methods to develop a sense of curiosity and intellectual satisfaction in students	It uses a set of methods to develop a sense of curiosity and wonder in students, mentioning the specifics of the activity, didactic games, for various ages. Gives details, presents own strategy used

Continuation of table 4.2

1	2	3	4	5
		3. Integration		
3.1.	Skills for integrating scientific knowledge to solve teaching/learning problems (item 10)	Mention 1-2 proposals for applying scientific knowledge in school practice	Propose 4-5 strategies for applying scientific knowledge in school practice	Propose a project containing strategies, practical solutions for applying scientific knowledge in school activities
3.2.	Skills to facilitate the formation of personal and peer scientific thinking (*training of trainers*, lifelong learning) (item 11)	Develop 1-2 suggestions on facilitating the formation of scientific thinking in colleagues/teachers (exchange of experience)	Develops a set of activities on facilitating scientific thinking among peers (briefly describing some aspects of developing scientific thinking)	Develops an *Agenda for promoting the development of scientific thinking in colleagues* (outlining strategies for developing scientific thinking, including methods of scientific thinking training, glossary of scientific terms, etc.).
3.3.	Skills to apply and integrate scientific knowledge to solve existential/ everyday problems (item 7)	Develop 1-2 proposals for applying scientific knowledge in everyday/ existential practice	Propose 4-5 strategies for applying scientific knowledge in everyday practice	Propose a project containing strategies, practical solutions for applying scientific knowledge in everyday work

As can be seen in Table 4.2, the *indicators and descriptors of the formation and effectiveness of scientific thinking in pedagogues* reflect the set of competences at the level of *knowledge, application and integration*, as set out in the *Recommendations for the development and effectiveness of ST for student-pedagogues in master's programs.*

The situation presented here reveals significant scientific gaps in addressing and resolving practical issues related to the development of scientific thinking in teachers. It is evident that teachers do not have an algorithm or tools for effective intervention that would effectively enable them to assess and contribute to the development of their own scientific thinking, including in students. Although the research shows that a small percentage of pedagogues possess a high level of scientific thinking, they do not possess the necessary competences to develop this ability in pupils (they admit this themselves). As promoters and due to their professional activities, pedagogues intuitively identify the right methods, but through their answers they confirm that they have never had in their professional background an effective pedagogical mechanism or model that would facilitate the development of scientific thinking in pupils and ensure their own professionalization from this perspective. All actions taken in this respect are largely based on intuition, their own previous experience and not on a solid scientific basis.

So far, both at the international and national level, the education system has not paid attention to assessing the level of scientific thinking in teachers or facilitating its development. The training activities carried out so far have been sporadic, without a coherent theoretical and methodologically structured framework for the development of scientific thinking in teachers. On the other hand, teachers have been involved in STEAM (Science, Technology, Engineering, Arts and Mathematics) projects, which involve the development of STEM, direct experimentation with scientific concepts and their translation into real contexts. However, failures and difficulties in the implementation of STEM education in some

countries have re-emphasized the need to re-conceptualize and restructure the initial and in-service preparation of pedagogues for the development of scientific thinking, with a focus on three operational aspects.

The first aspect refers to the development and deepening of the cognitive system of the teacher and the students, respecting the condition of knowing and stimulating its referential.

The second aspect concerns the training of teachers in scientific thinking through STEAM projects. Teachers need to acquire a deep understanding of STEM subjects and how they can be integrated into educational activities. ***The third issue*** concerns assessment and outcome measurement in STEM programs. Assessing student performance in the context of STEM activities can be a *challenging/ challenging* aspect, as the STEM approach encourages the development of skills, such as critical thinking, scientific thinking, problem solving and collaboration, etc., which can be more difficult to quantify and assess using traditional methods. Therefore, it is essential to develop and elaborate on the theory and methodology of DEST, appropriate tools and methods of assessment to evaluate the success of targeted programs and students' progress in developing scientific thinking.

In conclusion, in order to ensure a coherent and effective development of scientific thinking in teachers and students, it is necessary to involve all educational actors, all levels of education, but first of all, it is necessary to prepare teachers, starting with initial training and actively, insistently and systematically exploring continuous training through increased professionalization focused on the development and effectiveness of ST. A process that we perceive as an active one, which should be carried out in an intermittent circuit, ensuring the transfer of knowledge and skills, transversal competences from one educational level to another in accordance with the age and subject specificities of the school. This process should provide the necessary support and resources for the development and effectiveness of scientific thinking in both teachers and pupils. By promoting an integrated approach to STEM education and by developing appropriate assessment tools and methods that would ensure a significant streamlining of the learning and development of scientific thinking in the education system.

Based on the theoretical and methodological landmarks outlined above and starting from the conceptual scheme of the DEST for teachers (Chapter 4, Figure 4.19), we propose ***a set of operational strategies***, which, consistently and consciously used, contribute to the *effectiveness of the development of scientific thinking* in teachers (initial and continuing training), as follows:

- ***Strategy focusing on deepening and harmonizing the four levels of the cognitive system;***
- ***Strategy focusing on critical reading and*** reflection;
- ***The strategy of developing lateral and critical thinking skills, approached as an essential element of scientific thinking;***
- ***Strategy focused on self-improvement, self-efficacy and self-actualization.***

The exploratory study carried out through preliminary samples allowed the identification of gaps in teacher training on the development of scientific thinking, as well as the directions of praxiology for measuring scientific thinking, including student-teachers. The given activity experimentally validated the level of development-effectiveness of the development of scientific scientific thinking in pedagogues, which allowed the subsequent establishment of a training program, being scientifically substantiated and specified ***the psycho-pedagogical conditions of development of scientific scientific thinking in students (Decalogue)***.

Chapter 5, ***Experimental Validation of the Pedagogical Model of Developing and Effectiveness of Teachers' Scientific Thinking***, details the formative experiment and highlights all its nuances.

The aim of the formative experiment lies in the implementation and experimental validation of the *Pedagogical Model of the development and effectiveness of scientific thinking in pedagogues,* which incorporates the theory and methodology of the DEST, in particular the theoretical and applied foundations of this educational process. In carrying out the pedagogical experiment we followed the training program based on the indicators and descriptors developed in advance. As mentioned above, the program included a number of specific forms/activities and interventions for the development and effectiveness of scientific thinking in teachers.

The first step was to check the homogeneity at the ascertainment stage of the control (CG) and experimental groups (EG) on all three parts of the questionnaire-application. This assertion was verified by the ***U-Mann Whitney test*** for independent samples.

Taking into account that the *Scale - Application for Assessing the Level of Scientific Thinking Development in Teachers* (**AALDST-DEST**) consists of three distinct parts, we report the results for each part separately. *The U-Mann Whitney test* used to check the homogeneity of the control and experimental groups did not identify statistically significant differences between the control group (CG) and the experimental group (EG) in part I (U = 10177,00, p = 0,787), part II (U = 9399,00, p = 0,161), part III (U = 9865,00, p = 0,437). However, there is very little variation explained by the difference between the groups, and this may be due to the natural variability of the scores. The graphical representation can be visualized in Figure 5.1.

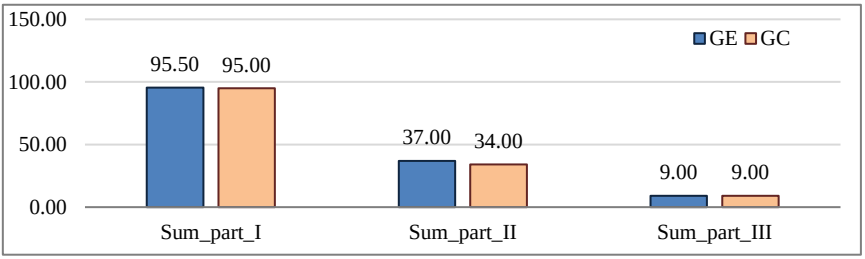

Figure 5.1. Median scores for CG/ pretest and EG/ pretest on the Scale - Application to assess the level of development of scientific thinking in teachers (AALDST-DEST)

The median scores on the first part of the AALDST-DEST for GE/pretest were as high (median = 95.5) as for CG/pretest (median = 95.0). On the second part of the questionnaire the median scores for EG/pretest were as high (median = 37.0) as for CG/pretest (median = 34.0). The median of the scores on the third part of the AALDST-DEST for EG/pretest was as high (median = 9.0) as for CG/pretest (median = 9.0).

The next step was to identify the differences between EG and CG following the experimental intervention at the post-test stage.

The U-Mann Whitney test used to test for differences between the experimental and control groups identified significant differences between the Control Group (CG) and the Experimental Group (EG) in Part I (U=4808.50, p=0.001), Part II (U=3725.50, p=0.001), Part III (U=4842.50, p=0.001). The graphical representation can be visualized in Figure 5.2.

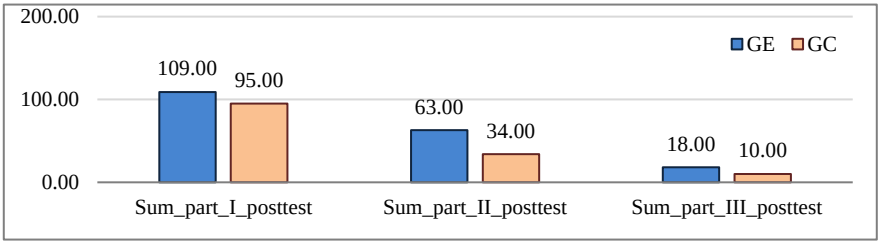

Figure 5.2. Median scores for CG/posttest and EG/posttest on the Scale - Application to assess the level of development of scientific thinking in teachers (AALDST-DEST)

Median scores on the first part of the AALDST-DEST for GE/posttest were significantly higher (median = 109.0) compared to CG/posttest (median = 95.0).

On the second part of the questionnaire, again the median scores for GE/posttest were significantly higher (median = 63.0) compared to CG/posttest (median = 34.0).

The median scores on the third part of the AALDST-DEST for GE/posttest were also significantly higher (median = 18.0) compared to CG/posttest (median = 10.0).

The effect size of the experimental intervention on the *first part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in the level of* ***metacognition***, a significantly large effect of the experimental intervention (d=0.90), with a 95% confidence level.

The development of *metacognition* in relation to the transfer of ideas, expressed by the ability to analyze and understand one's own thinking process, has had a significant impact on the awareness of teachers' intellectual processes. This development has led to a deeper understanding of how pedagogues think, learn and solve problems, as well as to the development of the ability to supervise, regulate and refine their own and students' cognitive skills, which also involve ST.

The effect size of the experimental intervention on the *second part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in* ***declarative, factual and conceptual knowledge***, a significantly large effect of the experimental intervention (d=1.36), with a 95% confidence level. Taken together, these results indicate that at the specified sample size, with the set significance level and specified effect size, the probability of detecting the desired effect is 95.2%, thus reflecting a good efficiency/power of the test.

Thus, the development of scientific thinking in pedagogues involves the concurrent development of declarative, factual and conceptual knowledge, focused on the exploration of scientific thinking. ***Declarative knowledge***, which refers to theoretical information and its awareness, plays a fundamental role in the development of scientific thinking in teachers, as it serves as an epistemological basis for teachers and enables teachers to understand and apply scientific concepts, strategies and principles in different areas of teaching. ***Factual knowledge***, which includes specific data or scientific definitions, provides a sound methodological foundation for the functioning of scientific thinking, including and operationalizing practical actions. This knowledge helps teachers to convey accurate and reasoned information to students and to reinforce their understanding of various scientific data, topics, issues. ***Conceptual knowledge***, which involves an understanding of concepts and the relationships between them, is essential for the development of scientific thinking, as it enables teachers to transfer and connect ideas, to think analytically and critically in a variety of contexts (academic, social, school). ***The development of scientific thinking in teachers is not only possible through knowledge of a single type of knowledge, but through the concurrent deve-***

lopment of declarative, factual and conceptual knowledge, as well as through the application of intellectual transfers. These three types of knowledge interact to provide the subjects with a solid basis for understanding, applying and transmitting information, constantly exercising the pupils' scientific thinking.

The analysis of the experimental approach allows us to state that the effect size of the investigative intervention involving the *third part of the questionnaire* indicates that the training intervention has the following impact: a *clear increase in* ***procedural knowledge***, a significantly large effect of the experimental intervention (d=0.93), with a 95% confidence level. Taken together, these results indicate that at the specified sample size, with the set significance level and the specified effect size, the probability of detecting the desired effect is 95.3%, indicating a good test efficiency.

The evident increase in ***procedural knowledge*** *is manifested by the development of metacognitive skills and transversal competences/ at the level of optimal integration* into the formal and non-formal educational process through the development and application of strategies for planning, monitoring, evaluation, regulation, adjustment, restructuring, interpretation, generalization, argumentation, prediction of complex educational phenomena (in fact, constitutive elements of scientific thinking). More precisely, the teacher has become much more effective in solving pedagogical problems and dilemmas, including various tasks that require the teacher to be a creative and reflective executor, efficient organizer and a skilled expert.

The evident increase in ***procedural knowledge*** *is manifested by the development of metacognitive skills and transversal competences/ at the level of optimal integration* into the formal and non-formal educational process through the development and application of strategies for planning, monitoring, evaluation, regulation, adjustment, restructuring, interpretation, generalization, argumentation, prediction of complex educational phenomena (in fact, constitutive elements of scientific thinking). More precisely, the teacher has become much more effective in solving pedagogical problems and dilemmas, including various tasks that require the teacher to be a creative and reflective executor, efficient organizer and a skilled expert.

Before describing the variables under investigation, we performed descriptive statistics and carried out a normality test for each subscale separately. The next experimental stage consisted in comparing the paired samples by means of the Wilcoxon test.

The negative values of the Z-statistics according to the Wilcoxon test suggest that the post-test measures are generally higher than the pretest measures for each subscale. Values less than 0.05 of p (all are 0.001) indicate that the observed differences are statistically significant, i.e., the probability of obtaining the observed differences by chance is very small.

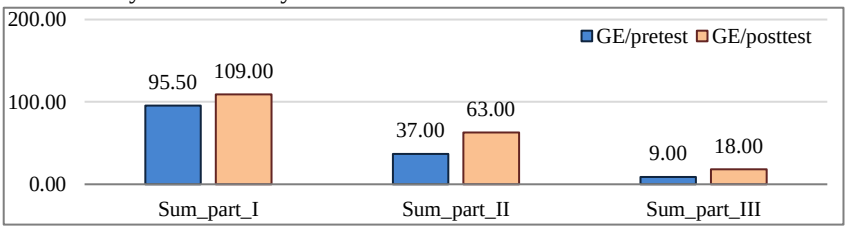

Figure 5.3. Median scores for EG/ pretest and EG/ posttest on the Scale - Application to assess the level of development of scientific thinking in teachers (AALDST-DEST)

Median scores for each subscale of the AALDST-DEST in the experimental group (EG) were analyzed at two different time points: at ascertainment/ pretest and

after training/posttest. The results indicate the following significant trends: for the first subscale, at posttest (median = 109.0), the median scores were significantly higher than at pretest (median = 95.5), suggesting a significant improvement in ***metacognition-related*** outcomes. Similarly, for subscale two, the median scores at posttest (median = 63.0) were significantly higher than at pretest (median = 37.0), indicating a significant improvement in performance on ***declarative, factual, and conceptual*** knowledge. Regarding the third subscale, the median posttest score (median = 18.0) was significantly higher than the pretest (median = 9.0), showing a significant improvement in performance in this subscale which refers to ***procedural knowledge***.

These observations suggest that the experimental intervention had a positive, significant impact on the development of scientific thinking among teachers in the experimental group (EG). For a more comprehensive perspective, it is recommended that other factors and appropriate statistical analysis be considered.

The effect size of the experimental intervention on the *first part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in the level of* ***metacognition***, a significantly large effect of the experimental intervention (d=0.78), with a 95% confidence level.

The effect size of the experimental intervention on the *second part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in the level of* ***declarative, factual and conceptual knowledge***, a significantly large effect of the experimental intervention (d=0.98), with a 95% confidence level.

The effect size of the experimental intervention on the *first part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in the level of* ***procedural knowledge***, a significantly large effect of the experimental intervention (d=0.76), with a 95% confidence level.

Z values are close to zero in all cases, suggesting that there are no significant differences between posttest and pretest measurements for each subscale within the control group. The p-values are greater than 0.05 in all cases, indicating that the observed differences are not statistically significant.

The results suggest that there were no changes in the post-test measurements compared to the pretest in the control group (CG).

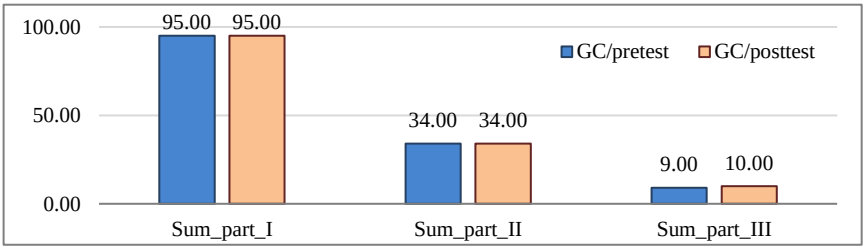

Figure 5.4. Mean scores for CG/pre-test and CG/post-test on the Scale - Application to assess the level of development of scientific thinking in teachers (AALDST-DEST)

Median scores for each subscale of the AALDST-DEST in the control group (CG) were examined at two separate stages: pretest and posttest. The data reveal the following relevant findings: First subscale: pretest median (CG): 95.00; posttest median (CG): 95.00. In the case of this subscale, the median scores remained constant between pretest and posttest within the control group. This indicates that no signi-

ficant changes in metacognition-related outcomes were observed among participants in the control group.

Second subscale: pretest median (CG): 34.00, posttest median (CG): 34.00. Similarly, for subscale two, median scores remained constant between pretest and posttest within the control group. This suggests that there were no significant improvements in performances related to declarative, factual and conceptual knowledge. Third subscale: pretest median (CG): 9.00, posttest median (CG): 10.00. Regarding the third subscale, the median scores showed a slight increase from pretest to posttest in the control group. However, the posttest median value remains relatively modest, suggesting a potential improvement in procedural knowledge scores, but this is not significant.

In conclusion, the control group's median scores remained constant or showed minimal change between pretest and posttest in the three subscales. This suggests that there was no significant change in the development of scientific thinking among teachers in the control group compared to the experimental group.

Based on the above, we can state that in the experimental group (EG), the intervention had a significant impact in improving the results measured in all three subscales of the scientific thinking assessment test for teachers (*metacognition, declarative, factual and conceptual knowledge, procedural knowledge*). These findings suggest that the experimental intervention had a positive effect in streamlining the development of scientific thinking among teachers in the experimental group (EG).

In contrast, for the control group (CG), the *Wilcoxon test* results showed no significant differences between pretest and posttest measures for the three subscales, indicating that no significant changes in the development of scientific thinking occurred in this group.

Overall, the results clearly demonstrated that the experimental intervention had a positive impact on the development of scientific thinking among teachers in the experimental group (EG). On the other hand, the unchanged results in the control group (CG) indicated that this group did not show significant improvements in the development of scientific thinking throughout this period.

Generalizing the results of the control experiment in terms of EG teacher training, we can draw the following conclusions: ***following the experimental intervention the subjects have obtained scientific thinking skills at least one step higher than the level they had at the beginning. This development manifested itself in a particular way, specific to each participant. The subscale analysis reveals that this process involved different stages, starting from meta-perception and continuing through the optimal use of declarative, factual and conceptual knowledge to the final stage of effective use of procedural knowledge.***

All the three variables measured by means of *the Scale - Application for Assessing the Level of Scientific Thinking Development in Teachers* (AALDST-DEST) (metacognition, declarative, factual, conceptual and procedural knowledge), divided into three subscales, allowed to obtain **results related to the formation of individual competences: advancement in the *development of scientific thinking skills***: Participants demonstrated a significant improvement in their skills of observation, critical analysis, problem solving and logical thinking in the pedagogical context; *increased confidence and motivation*: participants developed confidence in their abilities to think, develop and make effective their ST and were motivated to use these skills in their pedagogical practice. Positive changes were noted in their attitude and confidence in their own abilities.

Results related to the improvement of the quality of the learning process: *improvement of the quality of the learning process*: participants learned more effective strategies and methods in transiting knowledge and stimulating critical and creative

thinking in students; *transfer of skills into practice*, which means optimal functioning of the ST. The participants were able to develop their ability to transfer the scientific thinking skills acquired in the pedagogical experiment into their daily teaching activities and interaction with students. This led to an improvement in the learning process and greater efficiency in achieving educational goals.

From the above, we note that the pedagogical experiment conducted according to the developed training program had a positive impact on the development and effectiveness of scientific thinking in teachers. The participants experienced a significant increase in cognitive skills and were able to transfer these skills into their pedagogical practice, thus contributing to the improvement of the learning process and the achievement of the desired educational outcomes.

Likewise, the investigation of the deepening and the efficiency of the four levels of the cognitive system in teachers and student teachers on a before and after sample showed evident performances.

At the same time, the experimental intervention led to a significant development of metacognition, declarative, factual and conceptual knowledge, as well as procedural knowledge among the teachers in the experimental group. This growth had a significant impact on observation, critical analysis and problem-solving skills, contributing to the improvement of the quality of the learning process and to the transfer of the acquired competences and skills into pedagogical practice. The findings reveal a significant development of scientific thinking in the experimental group.

The systematization and generalization of the obtained results allowed us to draw up the scheme of the *integral process of teachers' DEST* (Chapter 5), which elucidates the investigative actions and the route followed in the organization and conduct of the theoretical study and pedagogical experiment.

As can be seen, the process has an integral character. The process is guided by fundamental principles (*principles of cognitive education, constructivist principles, principles of scientific education, principles of social semiotic education, principles of sociocultural theory*) and, at the same time, takes into account practical principles, based on a set of theoretical landmarks and pedagogical strategies (*strategy of harmonization of the four levels of the cognitive system, strategy focused on critical reading and reflection, the strategy of developing critical thinking skills, the strategy of self-improvement and self-actualization*), which emerges from the epistemology of the process of development and effectiveness of the development and improvement of the DS and the methodology of the DEGS, based on and described in Chapter 3 (concretized from the perspective of three training axes, experimentally demonstrated and validated, *metacognition, declarative, factual, conceptual and procedural knowledge*). All three axes have been realized through the implementation of *the Pedagogical Model of the development and effectiveness of scientific thinking in pedagogues*, following the respective process (Figure 5.11). These results are materialized in the form of cognitive competences and cognitive products, i.e. individualized and psychically internalized scientific reasoning, manifested in pedagogical behaviour demonstrating a conduct focused on the development-effectiveness of pedagogues' scientific thinking. This is expressed by making decisions and prognoses based on scientific arguments and putting them into practice. ***The process culminates in a cognitive leap, which manifests itself as a higher level of scientific thinking and professional self-actualization. The leap is determined by a number of descriptors reflecting the high level of development of scientific thinking.***

With regard to the domain of development of scientific thinking in **student-teachers**, it should be mentioned that initially the homogeneity of the control (CG) and experimental (EG) groups was assessed at the ascertainment/ pretest stage. This

was validated by means of the ***U-Mann Whitney* test**, used to compare independent samples. Given that the *Scale - Application to Assess the Level of Scientific Thinking* (AALDST-DEST), which was structured into three distinct sections. In the following we present separate results for each section.

The ***U-Mann Whitney*** test used to verify the homogeneity of the control and experimental groups did not identify statistically significant differences between the control group (CG) and the experimental group (EG) in part I (U=2029,000, p=0.697), part II (U=1953,000, p=0.447), part III (U=1982,000, p=0.497). The variability of the scores can be visualized in figure 5.15.

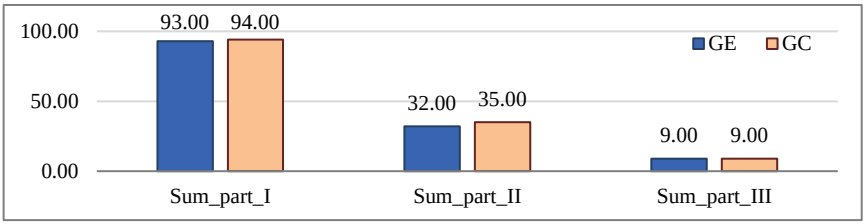

Figure 5.5. Median scores for CG/pretest and EG/pretest on the Scale - Application to assess the level of development of scientific thinking in student teachers (AALDST-DEST)

The median of the scores on the first part of the **AALDST-DEST** for EG/ pretest was as high (median = 93.00) as for CG/ pretest (median = 94.0). On the second part of the questionnaire the median of the scores for EG/ pretest was as high (median = 32.0) as for CG/ pretest (median = 34.0). The median of the scores on the third part of the **AALDST-DEST** for EG/ pretest was as high (median = 9.0) as for CG/ pretest (median = 9.0).

The next step was to identify the differences between EG and CG following the experimental intervention at the post-test stage.

The ***U-Mann Whitney*** test used to test for differences between the experimental group and the control group identified significant differences between the Control Group (CG) and the Experimental Group (EG) in Part I (U = 1194.00, p = 0.001), Part II (U = 773.50, p = 0.001), Part III (U = 951.00, p = 0.001). The graphical representation can be visualized in Figure 5.6.

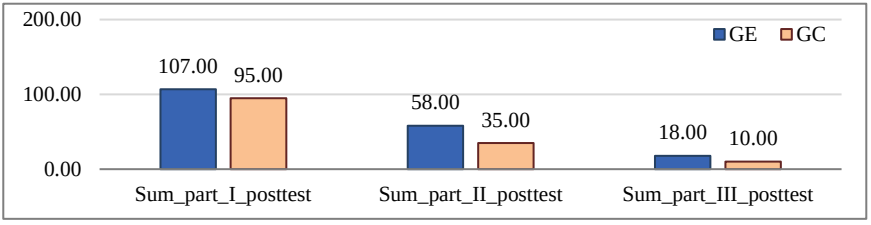

Figure 5.6. Median scores for CG/posttest and EG/posttest on the Scale - Application to assess the level of development of scientific thinking in student teachers (AALDST-DEST)

Median scores on the first part of the **AALDST-DEST** for EG/posttest were significantly higher (median = 107.0) compared to CG/posttest (median = 95.0). On the second part of the questionnaire scores were significantly higher (median = 58.0)

compared to CG/posttest (median = 35.0). On the third part of the questionnaire scores were significantly higher (median = 18.0) compared to CG/posttest (median = 10.0).

The effect size of the experimental intervention on the *first part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in* ***metacognition***, a significantly large effect of the experimental intervention (d=0.68), with a 95% confidence level.

The positive **Cohen's *d* Cohen**'s coefficient results indicate that the group that was exposed to the experimental intervention performed better compared to the control group. Thus, metacognition of student teachers' metacognition was significantly developed by enhancing the same factors as in the teachers, through self-reflection, explicit metacognition learning, development of self-monitoring skills, strategic learning, encouragement of critical debate, constructive feedback, and through hands-on approach and repetition.

Considering that metacognition is precisely the act of reflective self-observation of one's own cognitive processes, of the way of constructing and using cognitive schemas, of learning and knowledge strategies, but also of cognitive deficiencies and shortcomings, of one's own gaps. The student-pedagogues acquired skills of active monitoring, adjusting and combining their own knowledge and skills according to certain concrete objectives, which were set during the experiment. As a consequence, the student-pedagogues' knowledge about the functioning of their own thinking and its mechanisms of self-control and self-regulation were optimized through activities involving thinking and regulating learning and cognitive functioning: planning activities: imagining how to act to solve a problem and developing strategies, learning tools, etc.; prediction activities: estimating the quantitative outcome of a specific cognitive activity, such as the time needed to find the solution to a given problem; performance improvement activities: testing hypotheses, experimenting with strategies, revising, adjusting, improving; monitoring and evaluation activities: measuring and evaluating the results of an action in relation to the aim and objectives.

Therefore, we can conclude that the development of metacognition has had a significant impact on the perception and management of cognitive processes of student teachers. It facilitated more effective adaptation to intellectual demands, improving self-regulation and optimizing performance in learning, problem solving and decision making.

The effect size of the experimental intervention on the *second part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in* ***declarative, factual and conceptual knowledge***, a significantly large effect of the experimental intervention (d=1.29), with a 95% confidence level.

The positive ***Cohen's d*** index values indicate that the experimental intervention group rated better than the control group in demonstrating *declarative, factual and conceptual knowledge*.

The obvious increase in these types of knowledge becomes evident through the improved ability to solve complex problems, to participate actively in in-depth discussions in various scientific fields, to approach new contexts with confidence and understanding, and the ability to apply the knowledge gained effectively in practical and real-life situations.

The effect size of the experimental intervention on the *third part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in* ***procedural knowledge***, a significantly large effect of the experimental intervention (d=0.99), with a 95% confidence level.

Procedural knowledge is defining for the understanding and application of information in different domains, including in the professionalization of teachers, since

it is procedural knowledge, by interconnecting *declarative knowledge-procedural knowledge-conceptual knowledge*, that ensures the formation-deepening of the human cognitive system, thus underpinning the development of scientific thinking. *Procedural knowledge* includes both *problem-solving techniques* and scientific research methods and strategies, and in the pedagogical sciences it is a decisive component of the *architecture and technology of the educational process*. The targeted knowledge, in essence, was developed through practical actions (practice) and direct experience, when it was necessary to solve certain problems of various nature.

The next sequence of the experimental method materialized in making comparisons for the paired samples by means of the ***Wilcoxon*** test.

In order to investigate to what extent the changes listed above are due to the program for training/developing and making scientific thinking more effective in student teachers, the results obtained in the **EG** in the pretest and posttest, as well as the results obtained in the **CG** in the pretest and posttest were examined.

Negative Z-statistic values suggest that the posttest measures are generally higher than the pretest measures for each subscale. Extreme p values of less than 0.05 (all are 0.001) indicate that the observed differences are statistically significant, i.e., the probability of obtaining the observed differences by chance is very small.

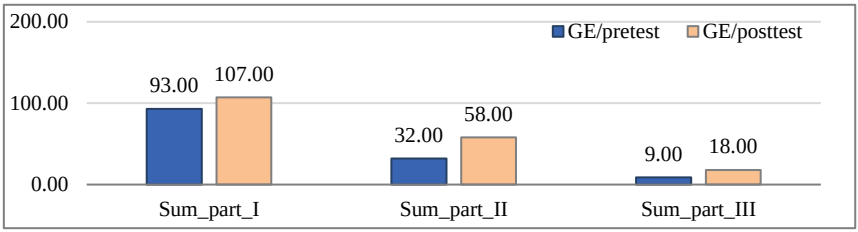

Figure 5.7. Mean scores for EG/pre-test and EG /post-test on the Scale - Application to assess the level of development of scientific thinking in teachers (AALDST-DEST)

Median scores for each subscale of the **AALDST-DEST** in the experimental group (**EG**) were analyzed at pretest and posttest. Results indicate the following significant findings: for the first subscale, at posttest (median = 109.0), the median scores were significantly higher than at pretest (median = 95.5), suggesting a significant improvement in ***metacognition-related*** outcomes. Similarly, for subscale two, the median scores at posttest (median = 63.0) were significantly higher than at pretest (median = 37.0), indicating a significant improvement in performance on ***declarative, factual, and conceptual*** knowledge. Regarding the third subscale, the median posttest score (median = 18.0) was significantly higher than the pretest (median = 9.0), showing a significant improvement in performance in this subscale relating to ***procedural knowledge***. These observations suggest that the experimental intervention had a significant positive impact on the development of scientific thinking among the student-teachers in the experimental group (**EG**). The effect size of the experimental intervention on the *first subscale of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in* ***metacognition***, a significantly large effect of the experimental intervention (d = 0.72), with a 95% confidence level. The effect size of the experimental intervention on the *second part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in* ***declarative, factual and conceptual knowledge***, a significantly large effect of the experimental intervention (d=0.89), with a 95% confidence level. The effect size of the

experimental intervention on the *third part of the questionnaire* indicates that the training intervention has the following consequence: a *clear increase in* ***procedural knowledge***, a significantly large effect of the experimental intervention (d=0.64), with a 95% confidence level. Z-values are close to zero in all cases, suggesting that there are no significant differences between post-test and pretest measurements for each subscale within the control group. The p-values are greater than 0.05 in all cases, indicating that the observed differences are not statistically significant.

In conclusion, the results obtained suggest that there were no changes in the post-test measurements compared to the pretest in the control group (CG).

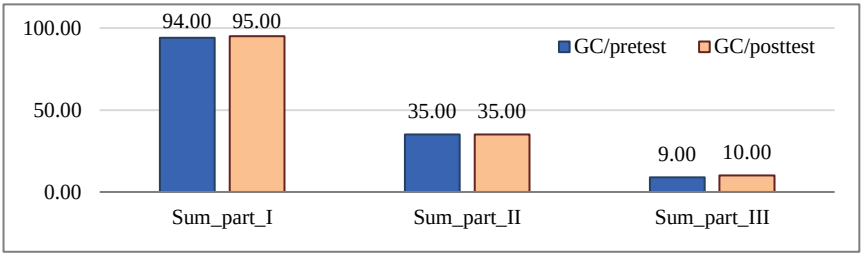

Figure 5.8. Mean scores for Control Group (CG)/pre-test and CG/post-test on the Scale - Application to Assess the Level of Development of scientific thinking in teachers (AALDST-DEST)

Median scores for each subscale of the AALDST-DEST in the control group (**CG**) were examined at ascertainment/ pretest and after training/posttest. The data reveal the following relevant findings: First subscale: Pretest median (**CG**): 94.00; Posttest median (**CG**): 95.00. In the case of this subscale, the median scores remained constant between pretest and posttest within the control group. This indicates that no significant changes were observed in metacognition-related outcomes among participants in the control group. Second subscale: Median pretest (**CG**): 35.00, Median posttest (**CG**): 35.00. Similarly, for subscale two, the median scores remained constant between pretest and posttest within the control group. This suggests that there were no significant improvements in performance on declarative, factual and conceptual knowledge. Third subscale: Median pretest (**CG**): 9.00, Median posttest (**CG**): 10.00. Regarding the third subscale, the median scores showed a slight increase from pretest to posttest in the control group. However, the posttest median value remains relatively modest, suggesting a potential improvement in procedural knowledge scores, but this is not significant. Median scores within the ***control group*** remained constant or showed minimal change between pretest and posttest in the three subscales. This suggests that there was no significant change in the development of scientific thinking among student teachers in the control group compared to the experimental group.

In the context of the above, a number of activities to supervise students and teachers from the perspective of developing scientific thinking are relevant.

In order to support the continuous process of developing and making teachers' scientific thinking more effective, supervision is needed. Supervision of teachers to develop scientific thinking can involve a number of concrete strategies, based on the issues mentioned above. These implemented strategies can be tailored to the individual needs of the teachers and contribute to the professionalization of pedagogy through the development and effectiveness of ST in the context of lifelong learning (in both initial and in-service training contexts).

The research was concluded with the General Conclusions and Recommendations, which provide a general analysis of the research by summarizing the main ideas and scientific-experimental results and recommendations for teachers, trainers, school managers, students, educational policy specialists. Finally, suggestions for future research on the development of scientific thinking in pupils from the age-specific perspective are presented.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The investigative approach, in its entirety, represents a framework of maximum generality and significant praxiological relevance, driven and motivated by pedagogical, social, neuropsychological, and epistemological considerations.

The comprehensive analysis from pedagogical, neurodidactic, philosophical, neurobiopsychological, social, and logical perspectives lends novelty, originality, and scientific coherence to the theoretical and applied aspects of the investigation.

This approach underscores the importance of enhancing the process of pedagogical professionalization through the development and effectiveness of scientific thinking in educators, both in initial and in-service training. The results derived from the theoretical foundation and the research into the experiential and experimental aspects of the issue at hand, rooted in inter-, pluri-, and transdisciplinary pedagogical inquiry, affirm the necessity and relevance of scientifically grounding the theory and methodology for the development and effectiveness of ST in educators (both in initial and continuing professional development).

The analytical-synthetic research, conceptualization, epistemological and methodological grounding, praxeological configuration, and experimental investigation into the development and effectiveness of the ST for educators has enabled the formulation of the following overarching **conclusions and recommendations:**

1. The topicality and urgency of advancing the development and effectiveness of ST for teachers are underscored by contemporary strategic trends and priorities at the European, international, and national levels. These include the promotion of research culture, the enhancement of innovation capacity, the revision of the concept of innovation, and the fostering of scientific literacy among the population. Additionally, the valorization of scientific competencies within the framework of continuing adult education as a key component of lifelong learning is increasingly emphasized. These targeted approaches advocate for a new model of teacher professionalization, alongside a reevaluation of curricular policies that prioritize the development and effectiveness of SSE for both teachers (through initial and ongoing training) and the younger generation. The cultivation of openness among all educational stakeholders to the new UNESCO recommendations on sustainable societal development (2015) and the guidelines from the *International Commission on Education in the 21st Century* are also crucial. These recommendations align with those set forth in *Moldova's National Development Strategy 2030* [35, p. 7].

2. The theoretical foundations of the development and effectiveness of ST in educators were examined and clarified from a socio-psychopedagogical perspective. This analysis focused on several key concepts, including instruction and scientific education, development, training, efficiency, and modeling, as well as paradigms, theories, and the professionalization of teachers. Additionally, the interventions aimed at enhancing the effectiveness of the development of the ST were identified, which led to the formulation of the general characteristics of the ST. These characteristics were organized into eight core tasks, each aligned with the functions of modeling educational activities for students at various developmental stages. The tasks also incorporated the principles of science education and future-

oriented teaching, with a focus on expanding and deepening the cognitive system of the educator across four levels of knowledge: acquisition, processing, algorithmic-representational, and implementation. This framework facilitated a more nuanced explanation of the phenomena of educability and cognitive architecture, adopting a complex cognitive-constructivist perspective. The approach is centered around three fundamental principles: (1) prioritizing the development of mental processes over the mere acquisition of knowledge, (2) emphasizing critical analysis and metacognition, and (3) recognizing the teacher's role as a mediator in the construction of knowledge and the facilitation of learning. [35, p. 10].

3. The conceptualization of the development and effectiveness of ST in educators has prompted an in-depth analysis of human cognition, alongside the examination of established theses and definitions of scientific thinking. This process contributed to the development of a **Matrix of Definitions of ST**, which facilitated the identification of two primary axes in its evolution: the first axis focuses on the individual/particular aspect of ST, while the second axis is oriented toward the development of ST within the context of professionalization. Furthermore, the analysis led to the identification of three perspectives on the professionalization of teachers in relation to the development and effectiveness of ST. These perspectives are as follows: (1) the development of higher-order ST, conditioned by the functioning of cognitive mechanisms, with an emphasis on scientific literacy and scientific reasoning; (2) the cultivation of teaching skills that promote the development of ST in students; and (3) the enhancement of personality traits that enable educators to persist in this process, fostering a commitment to lifelong learning and continuous self-actualization. [35, p. 31].

At the same time, ***the conceptualization of the researched problem ensured the explanation of the phenomenon of neurodidactic transposition, which consists in the translation/transfer of knowledge elements into elements of didactic content***, which implies creativity, active and inspired intervention of the teacher in the educational process and records the quintessence of the competence and professional conduct of the teacher, focused on the development-effectiveness of the students' and pupils' ST.

4. The conceptualization process employed a transdisciplinary, analytical, synthetic, and comparative approach to the development of scientific thinking in general, and scientific thinking in particular. This approach underscored the necessity of incorporating three fundamental components into instruction: *the transfer of skills, critical thinking, and problem-solving.* Additionally, it emphasized the optimal utilization of various types of thinking, categorized according to nine criteria: (1) the orientation of the thinking process, (2) the types of operations involved, (3) the intended outcomes, (4) the evolution of thinking, (5) the logic underlying the approaches, (6) the method of proceeding, (7) the value of thinking, (8) the correspondence with reality, and (9) the adaptability of thinking to different contexts. Within this framework, the personality traits that contribute to the development and effectiveness of scientific thinking were identified, representing the biopsychological foundation of this process. These traits are essential in cultivating the type of thinker that can be nurtured through both initial and continuous teacher training, aligned with the formulation of specific educational goals.

5. The theory of the development and effectiveness of ST not only substantially modifies the existing general view of the professionalization of the teaching career, but also includes a new vision of the aims of initial and in-service teacher training, the curricular content of university subjects, teaching technologies and strategies, and the preparation of teachers from a *lifelong learning* perspective, their valorization and their intellectual capacities through the achievement of *the objec-*

tives of scientific literacy, training and education at the system and process level in correlation with the criteria and indicators determined and validated as a constituent element of the developed pedagogical model and *professional scientific literacy*, referred to the specifics of scientific reasoning, approached as a methodological benchmark of the development-effectiveness of the ST in pedagogues. Theoretical-analytical research and syntheses carried out on the definitions and acceptions of the concept of ST of many researchers contributed to the outlining of its particularities, its characteristics and the elaboration of its own definition, by which we note that: ***Scientific thinking is a higher-order, purposeful, and systematic cognitive process, typically manifested in complex or problematic existential situations (such as social, personal, educational, or professional contexts). It necessitates the application of scientific knowledge, alongside cognitive and metacognitive skills. This process involves the optimal exploration of various operations, forms, and types of thinking, through which an individual formulates and tests hypotheses, employs heuristic strategies, engages in reflection, makes inferences and judgments, and applies reasoning. Additionally, it encompasses the transfer of ideas, conclusions, and predictions, while providing relevant justifications for the actions taken and the outcomes achieved.***

6. To ensure that the conceptualization aligns with the broader scientific framework and adheres to the emerging research focus on the theory and methodology of developing and enhancing scientific thinking (ST) in educators, the study undertook a *comprehensive determination and theoretical grounding of the neurobiological premises. It also explored the pedagogical convergences with an applied character, aimed at the development and effectiveness of ST, within the pedagogical norms specific to the field of Educational Sciences. This approach facilitated the identification and explanation of several* ***key principles*** *governing the process in question, including: the principle of motivation and preparation for the development and effectiveness of ST within the context of learning and the professionalization of the teaching career; the principle of transfer and the establishment of reciprocal connections with direct and multiple impacts on the development and effectiveness of ST; the principle of learning, which emphasizes the organization of logical structures within curricular content and the construction of new mental maps; the principle of valuing aptitude structures in the context of learning and developing ST; the principle of exploring inter-, multi-, and transdisciplinary approaches within cognitive-constructivist learning frameworks for the development and effectiveness of ST; and the principle of prioritizing the exercise of scientific thinking throughout lifelong learning. These principles are further analyzed in relation to the delineation and examination of the fundamental criteria of scientificity, which are outlined in a set of 16 distinct criteria.* In this context, *the epistemological coordinates of the development and effectiveness of ST* from the perspective of teachers' professionalization *were established*, objectified in:

- ***optimizing neurodidactic principles*** (pr. knowledge of the functioning of the human brain and stimulation of the functioning of the modal brain potential; pr. stimulation of the activities of both hemispheres; pr. combination and stimulation in learning of all cognitive mental processes with emphasis on the development of memory, language and various types of thinking; pr. centering the individual on the respect of psycho-emotional balance and healthy lifestyle as a biopsychological basis for stimulating the activity of neurons; pr. knowledge and effective exploration of the neurodynamics of learning through the development and effectiveness of the individual's ST);

- **the psycho-pedagogical conditions for the development and effectiveness of ST in pedagogues** (*approach and valorization of learning in correlation with the development and effectiveness of ST*; the psycho-pedagogical condition of respecting the principles and strategies of cognitive constructivist; optimal valorization of learning styles and development of ST; ensuring the development of multiple intelligences in complex learning and the development and effectiveness of ST; ensuring the formation of connections between the development and effectiveness of ST, complex learning and the specifics of the profession);
- ***development of the pedagogical synthesis tool Epistemological coordinates of the development and effectiveness of ST in teachers***, which involves ***three important methodological aspects***: *the epistemological coordinates themselves and its essential characteristics* (the cognitive-constructivist paradigm; Stages of cognitive development; Levels of the human cognitive system; Principle and condition of scientific of pedagogical knowledge; Scientific learning theory and Education for science and the future; Neurodidactic principles optimizing learning and development of ST), *researchers and directions of analysis*, including *application openings*.

The exposed dimensions have been approached in a diachronic and synchronic way, being presented as elements of the theory and, partially, of the methodology of the development and effectiveness of the ST in pedagogues, contributing to the constitution of the new research direction in *Educational Sciences*.

7. The demonstration of the psycho-pedagogical and philosophical value of the development and effectiveness of ST in the professional training of teachers led to the configuration of the *Master Strategy of* this process (composed of six operational strategies) and to the elaboration of ***the Mechanism of development and effectiveness of ST***, which is constituted by the *Master Strategy, which includes the cognitive-constructivist technology, facilitating personality traits, enabling educational environment*, the interconnection of which contributed to the *formation of the framework of scientific education and self-education, ensuring the self-actualization of the pedagogue in order to develop transversal competences, to cultivate a personality focused on the competences of development-effectiveness of the ST and to enhance the value of the ST in the educational process*. At the same time, the internal and external factors related to the development and effectiveness of ST were identified and described, which allowed to highlight ***four decisive constants*** on which the quality of the process in question depends. ***These are:***

- Ensuring the optimal dependence-independence balance of social cognition, cognition of the specifics of everyday thinking and exploration of cognition through ST;
- Ensuring personal and social control over the valorization of the information assimilated and transformed into one's own experiences producing certain philosophical-pedagogical and existential behaviors and attitudes;
- ensuring knowledge and valorization of psychological and professional personality characteristics;
- ensuring a harmonious education through the interrelated exploration of the dimensions of moral, intellectual, technological, aesthetic, psychophysical education with openings *to new education.*

8. In the given context, the *classical pedagogical model of teaching, the andragogical model of learning* with the 20 auxiliary principles elaborated from the perspective of *behaviorist, cognitive and motivation theories of personality* were analyzed interpretatively, being compared, specified and completed; *the develop-*

ment process of metacognition (metacognitive knowledge and skills) and *critical thinking*, approached as theoretical-applicative determining motives of the development-effectiveness of the ST, an important aspect that allowed to deduce and configure the ***psycho-pedagogical conditions of development of metacognition and critical thinking in student teachers***.

The trends of reconfiguration of the educational process in the contemporary school from the considerations of the development of ST in students and the professionalization of the pedagogical career were highlighted on the basis of the study of the possibilities of implementation of the strategies of **STEM/ STEAM/ STREAM Education**, key competences on sustainable development of society (OECD) and key competences on lifelong learning.

9. ***The synthesis of the values and functions inherent in the cerebral hemispheres, along with the competencies resulting from their activity, and their correlation with pedagogical competencies and personality traits, provided the epistemological foundation for the development of the Professional Portrait of the student-educator possessing scientific thinking (ST).*** *This portrait encompasses a comprehensive set of 12 trait clusters, including: perseverance, self-confidence, optimism, moral and intellectual coherence; promptness in action and willingness to take risks; the ability to develop and substantiate new and original ideas; the capacity to generalize, draw conclusions, make predictions, and formulate perspectives; an inclination towards reflexivity and experimentation, as well as inventiveness; the ability to address core issues in a comprehensive manner; a preference for novelty and diversity, along with self-directed learning; a focus on self-actualization, active engagement in learning and research; an emphasis on constructive learning and metacognition; intellectual curiosity, principled orientation, and motivation; and finally, tolerance, understanding, independence, and a self-critical attitude.*

10. By broadening and deepening the boundaries of theoretical research and the complex framework of pedagogical reality, we have succeeded in conceptualizing the self-improvement of teachers in the context of making scientific thinking effective and exploiting it in professional activity oriented on *lifelong learning* and its application in everyday life by demonstrating the impact of the native/ hereditary factor, reactualizing the specific and fundamental meanings *of the biological theory of enneatypes/ enneagram*, which have been correlated with: *Cognitive Education Theory, Constructivist Learning Theories*, *Human Cognitive System* Development and *Self-Efficacy Theory*. Thus, the preliminary research carried out on a group of **248** high school students and **467** student-pedagogues (undergraduate and master's students) demonstrated the necessity of moving from knowledge and awareness to the formation and valorization of professional beliefs and competences in the context of *systemic realization of interconnections*: *thinking - scientific thinking – professional thinking - everyday thinking - lateral thinking - creativity - efficiency - professional and existential performance*.

11. The experimental research has demonstrated the functionality and efficiency of ***Pedagogical Model of Development and Effectiveness of Scientific Thinking in Pedagogues***, which is the central construct with a dual and interactional purpose for teachers, student-pedagogues and students, which includes two major components, configured in theoretical and praxeological landmarks, which in turn are constituted by *epistemological coordinates, values of instruction and scientific education; Technological map, master and operational strategies; and the methodological-operational methodology of ST.* They are in correlation with the *Guiding Directions* (educational policy documents; the decision-making framework and curriculum design; the educational process in pre-university institutions; the space and content of pedagogical

professionalization: initial and continuous training); the *evolutionary-social space and the social-economic and cultural efficiency of society*, all of which are valorized on the basis of the following approaches: neuropsychopedagogical, processual, systemic, inter-, pluri- and transdisciplinary with an emphasis *on lifelong learning*.

12. The experimental validation of the model was conducted based on a system of criteria, indicators, and descriptors developed in alignment with the Conceptual Orientative Outline and the theoretical and praxiological framework for the formation of competencies related to the development and effectiveness of scientific thinking (ST). This framework was structured at three levels: knowledge, application, and integration. Concurrently, the evaluation and assessment reference for the level of development and effectiveness of scientific thinking (DEST) in teachers was employed as an auxiliary tool. This approach ultimately led to the establishment and configuration of a synthesis instrument, termed the Integral Process of Development and Effectiveness of ST in Teachers. This tool encompasses all facets of DEST, specifying the content elements and nuances, as well as the procedural path followed in the research on the development and effectiveness of scientific thinking.

In conclusion, the **investigative approach allowed to deduce that**:

a) The elaboration, scientific substantiation and implementation of the research project was carried out in an innovative and pioneering framework based on the concept of developing and making more efficient the development of ST in pedagogues;
b) The inter-, pluri- and transdisciplinary approach of the DEGS in pedagogues in the context of professionalization and lifelong learning, the correlation and interconnection of analytical-synthetic, hermeneutic and technological/praxiological investigative approaches led to the ***scientific foundation of a new research direction in educational sciences – Theory and Methodology of DEST in Educators***;
c) The set of tools: the model, the definitions of SDGs and epistemological coordinates; the *mechanist of development and effectiveness of SDGs* in pedagogues, criteria, indicators, descriptors, the referential of evaluation and assessment of the DEST, the training program, etc., is theoretically grounded and experimentally validated, representing *real and functional technological devices*, approached prospectively and innovatively with openings for application in the *theory and methodology of STs in teachers*, student-pedagogues and students.
d) The problems related to curriculum design in higher and pre-university educational institutions continue to be topical, particularly in terms of formulating and correlating objectives and transversal / integration level competences, including more effective interdisciplinarity from the perspective of valuing neuroscience, scientific education and training; developing and making more effective the development of ST in teachers.
e) The values identified and elaborated in the research have ensured the explanation of *the psycho-pedagogical phenomenon of neurodidactic transposition*, which consists in the transfer of knowledge elements into elements of didactic content and pedagogical *architecture*, oriented towards the DEST in the trained and educated.

All these conclusive findings reflect the realization of the aim, objectives and denote the confirmation of the research hypothesis.

Limit

Although *the theory of cognitive education* and the *cognitive-constructivist paradigm*, the vertiginous development of neurosciences and information technologies, their use in training, are undergoing an evolutionary ascent, however, the

possibilities of DEST in adulthood and the elderly, an important and promising aspect not only in the direction of the development of intelligence and professional and social efficiency, but also in the context of achieving a sustainable prophylaxis of human dementia, are still in the shadows and are insufficiently investigated.

This research opens real prospects for further investigation of the development of scientific thinking in students in formal education (especially in the process of studying socio-humanistic subjects) and non-formal education.

Recommendations for:

1. *Decision-makers (macrostructural level):*
   - Reconceptualization of educational policies (including curricular) from the perspective of the DEST, approached as a theoretical and applied foundation for the sustainable development of society;
   - Optimizing quality management structures at national and local (university) level;
2. **Research institutions:**
   - Revision and elaboration of a new thematic investigative framework, correlated with *the STREAM Education* rigors and the creation of optimal conditions for the promotion and implementation of the research direction, configured in the *Theory and Methodology of development and effectiveness of the ST in teachers and students* (young generation).
   - Diversification and deepening of professional training programs (initial and in-service) on the development of intellectual potential through the use of scientific training and education from the perspective of DEST in teachers and students.
   - Development of a methodological guide for teachers. Developing and making scientific thinking more effective in pupils: strategic and tactical referential according to age.
3. **Educational establishments:**
   - Linking and managing the design and implementation of subject and curriculum design and implementation to the educational institution's decision on TMDEST (in students-pedagogues and pupils).
   - Reactualization of the design and formulation of objectives vs. transversal/ integration level competences from the perspective of the interconnected valorization of the types of thinking, its forms and operations of thinking in the context of the formation of systematization, conceptualization, generalization, prognosis, argumentation, elaboration and scientific substantiation of the promoted ideas.
   - Monitoring the actual implementation of STREAM Education strategies by systematically and systematically capitalizing on the Pedagogical Model for the development and effectiveness of scientific thinking.

BIBLIOGRAPHY

1. ANGHELUTA, S. Alfabetizarea științifică cu ajutorul învățării pe tot parcursul vieții. In: https://epale.ec.europa.eu/ro/blog/alfabetizarea-stiintifica-cu-ajutorul-invatarii-pe-tot-.parcursul-vietii 11/02/2020 (accesat 28.07.2021)
2. BONCU, Ș., HOLMAN, A. Cum gândim în viața de zi cu zi. Iași: Polirom, 2019, 500 p. ISBN 978-973-46-7794-8
3. BORZEA, A. P. Integrarea curriculară și dezvoltarea capacităților cognitive. Iași: Polirom. 2017. 271 p. ISBN 978-973-46-7012-3
4. CERGHIT, I. Metode de învățământ. Ediția a IV-a. Iași: Polirom. 2006. 315 p. ISBN 973-46-0175-X
5. Codul Educației al Republicii Moldova. Nr. 152 din 17.07.2014.In: https://www.legis.md/cautare/getResults?doc_id=110112&lang=ro (accesat 07.02.2021)

6. COJOCARU, V. GH., COJOCARU, V. Formarea cadrelor didactice din perspectiva profesionalizării carierei didactice: semnificații și implicații actuale. Chișinău: CEP UPSC. 2020. 216 p. ISBN 978-0075-46-455-0
7. COJOCARU, V. Instruire inovațională-prioritate a transferului inovațional. In: *Educația în fața noilor provocări*. 5-6 noiembrie 2021, Chișinău: Universitatea de Stat din Tiraspol, 2021, Vol.1, pp. 128-134. ISBN 978-9975-76-372-1 (PDF).
8. COSMOVICI, A. Psihologie generală. Iași: Polirom, 1997. 253 p. ISBN 973-9248-27-6
9. CRAHAY, M. Psihologia educației. București: Trei. 2009. 528 p. ISBN 9789737072481
10. CUZNEȚOV, L. Gândirea științifică în educație și instruire. Baze psihopedagogice de optimizare a învățării prin prisma dezvoltării gândirii științifice. În: Revista UST Acta et Commentationes. Științe ale Educației. Nr. 4 (22), 2020. pp. 110-121. ISSN 1857-0623. DOI: 10.36120/2587-3636.v22i4.110-121
11. CUZNEȚOV, L. Prioritățile educației filosofice și asigurarea condiției de științificitate în procesul studierii disciplinelor pedagogice. În materialele Conferinței Științifice Internaționale Învățământ postmodern. Eficiență și funcționalitate, 17-18.11.2013, USM.
12. CUZNEȚOV, L. Valorificarea proprietății intelectuale în domeniul educației și științelor educației; importanța explicației științifice. În: Revista Intellectus, nr.1-2 din 2019, ISSN 1810-7079, CZU: 37.012:001.891
13. DE BONO EDWARD. Gândirea laterală. București: Curtea Veche Publishing, 2018. ISBN 978-606-44-0166-3
14. FLUIERAR, V. Facilitarea învățării prin modelarea didactică în învățământul primar. In: *Materialele Conferinței Republicane a Cadrelor DidacticeÎnvățământul preșcolar. Învățământul primar*. Online. 26 February 2022. p. 165–171. ISBN 978-9975-76-382-0. https://ibn.idsi.md/ro/vizualizare_articol/153254
15. GARDNER, H. Inteligențe multiple. Noi orizonturi. București: Sigma, 2019. 320 p. ISBN 978-606-727-063-1
16. GOLU M. Fundamentele psihologiei. Ed. a V-a, Vol. I. București: Ed. Fundației România de Mâine, 2007. 832 p. ISBN 978-973-725-857-1
17. GUȚU, Vl. Abordarea teleologică a competențelor în sistemul de învățământ. In: Abordarea prin competențe a formării universitare: probleme, soluții, perspective: Materialele Conferinței Științifice Internaționale consacrată aniversării a 65-a de la fondarea Universității de Stat „Alecu Russo" din Bălți, 25 mai 2011, Bălți. Bălți: Tipografia Universității de Stat „Alecu Russo" din Bălți, 2011, pp. 14-20. ISBN 978-9975-50-060-9 https://ibn.idsi.md/ ro/vizualizare_articol/92283
18. GUȚU, Vl. Andragogie. Monografie [Andragogy. Monograph]. Chisinau: CEP USM. 2023. 280 p. ISBN 978-9975-62-580-7
19. GUȚU, Vl. Pedagogia. Chișinău: CEP. USM, 2013. 508 p. ISBN 978-9975-71-450-1
20. IONESCU, M. Instrucție și educație. Ediția a 3-a. Arad: „Vasile Goldiș" University Press, 2007. 130 p. ISBN 978-973-664-200-5371
21. JOIȚA, E. Educația cognitivă. Fundamente. Metodologie. Iași: Polirom. 2002. 243 p. ISBN 973-681-100-X
22. JOIȚA, E. Esența constructivismului și învățarea școlară. In: Profesorul și alternativa constructivistă a instruirii. Material - suport pedagogic pentru studenții - viitori profesori (II). 2007. p.10 https://cis01.ucv.ro/DPPD/profesorul%20_si_ alternativa_ constructivista_ a_instruirii.pdf
23. JOIȚA, E. Metodologia educației. Schimbări de paradigme. Iași: Institutul European, 2010. 288 p. ISBN 978-973-611-661-2
24. Legea educației naționale a României nr. 1/2011. In: https://www.edu.ro/sites/ default/files/ legea-educatiei_ actualizata%20august%202018.pdf (accesat 08.02.2022)
25. MANZAT, I. Psihologia sinergetică. București: Univers Enciclopedic. 2010. 320 p. ISBN 978-606-816-2621
26. MICLEA, M. Psihologie cognitivă. Modele teoretico-experimentale. Iași: Polirom, 1999. 344 p. ISBN 973-683-248-1
27. MINDER, M., Didactica funcțională. Obiective, strategii, evaluare. Chișinău: Cartier educațional, 2003. 360 p. ISBN 9975-79-39-16
28. NEACȘU, I. Metode și tehnici de învățare eficientă. Fundamente și practici de success. Iași: Polirom. 2015. 314 p. ISBN 978-973-46-5258-7
29. NEACȘU, I. Neurodidactica învățării și psihologia cognitivă. Ipoteze. Conexiuni. Mecanisme. Iași: Polirom. 2019. 192 p. ISBN 978-973-46-7849-5
30. Planul de Acțiuni Uniunea Europeană – Republica Moldova: Ghid. Chișinău: Gunivas, 2006. 80 p. ISBN 978–9975–908–05–4
31. RACU, IG., RACU, IU. Psihologia dezvoltării. Chișinău: UPS „Ion Creangă" 2013 p. ISBN 978-9975-71-478-5
32. **SANDULEAC, S.** Formarea gândirii științifice la studenții din învățământul universitar. Red. șt. Racu Jana. (Monografie). Chișinău. Ed. Garomont Studio. 2017. 231 p. ISBN: 978-9975-136-61-7 In: https://ibn.idsi.md/ro/book_view/198 (accesat 20.04.2023)
33. **SANDULEAC, S.** Perspectivele dezvoltării gândirii științifice la elevi în școala contemporană (Sesiune plenară). În: *Asistența psihologică la etapa contemporană: realități și perspective.* Conferință științifică națională cu participare internațională din 23 octombrie 2023. Universitatea de Stat „Alecu Russo" din Bălți. p. 16-20. ISBN 978-9975-50-314-3

34. **SANDULEAC, S.** Procesul de dezvoltare și eficientizare a gândirii științifice la cadrele didactice în contextul realităților secolului XXI. In: *Știință, educație, cultură* . Vol. 2. 2023. Comrat. pp. 19-22. ISBN 978-9975-83-254-0. 978-9975-83-256-4. https://ibn.idsi.md/ vizualizare_articol/179702
35. **SANDULEAC, S.** Teoria și metodologia dezvoltării și eficientizării gândirii științifice la pedagogi (formarea inițială și continuă). Monografie. Chișinău: Lexon-Prim. 2024. 441 p. ISBN 978-9975-172-86-8
36. **SANDULEAC, S.**, CUZNEȚOV, L. Dezvoltarea gândirii științifice la cadrele didactice: fundamente teoretice și aplicative. Ghid metodologic. Chișinău: Pulsul Pieței. 2021. 151 p. ISBN 978-9975-3000-9-4
37. Strategia Europeana a Republicii Moldova In: https://ipp.md/old/print.php?l=ro&idc=171&id=256 (accesat 30.10.2023)
38. ȘLEAHTIȚCHI, M. Arborele cauzal al didactogeniei. Ramificația *SER*. În: *Akademos*: Revistă de știință, inovare, cultură și artă, 2021, nr.2 (61), pp. 141-149 ISSN 1857 – 0461, E-ISSN 2587-3687 http://akademos.asm.md/ files/Akademos_2_2021_ web_21_ august_ 0.pdf
39. ȘLEAHTIȚCHI, M. Thêmata, gândirea științifică și reprezentarea socială. In: *Revista de Știință, Inovare, Cultură și Artă „Akademos”*, 2018, nr. 1(48), pp. 128-131. ISSN 1857-0461
40. БАЕВА, И.А. Психологическая безопасность в образовании: Монография. СПб.: Издательство «СОЮЗ», 2002. 271 с. ISBN 5-94033-148-3
41. БРИТТ, А. Нейробиология роста. Как запрограмировать свой мозг на обучение новым навыкам. Минск: Попурри, 2020. 336 с. ISBN 978-985-15-4699-8.
42. БРУШЛИНСКИЙ, А.В. Психология мышления и проблемное обучение. Москва: Знание, 1983. 96 с.
43. ВЫГОТСКИЙ, Л.С. Мышление и речь. Собр. соч. Москва: Педагогика, 1982. Т. - 2. с. 5-361.
44. ГЕРШУНСКИЙ, Б.С. Компьютеризация в сфере образования: проблемы и перспективы. М.: Педагогика, 1987. 264 с.
45. ГЕССЕН, С.И. Основы педагогики. Введение в прикладную философию. Москва: Школа – Пресс. 1995. 448 с. ISBN: 5-88527-082-1 In: https://lib.agu.site/upload/ iblock/ba3/ Basics%20of%.%20 Introduction%20to%20Applied%20Philosophy.pdf (accesat 27.08.2021)
46. ЛЕОНТЬЕВ, А.Н. Избранные психологические произведения: В 2-х т. Т. I. М.: Педагогика, 1983. 392 с., ил. (Труды д. чл. и чл.-кор. АПН СССР).
47. ПОДДЬЯКОВ, А.Н. Исследовательское поведение: стратегии познания, помощь, противодействие, конфликт. М.: Эребус; Издание 3-е, испр. и доп. 2006. 372 с.
48. РУБИНШТЕЙН, С.Л. О природе мышления и его составе. Москва: АСТ. Астрель, 2008. с. 111-116.
49. ФЛЕМИНГ, С.М. Метамышление. Как нейронауки помогают нам понять себя. Москва: Индивидуум. 2023. 288 с. ISBN 978-5-6048294-1-7
50. ШАБШАЙ, Г., ШАБШАЙ, Е. Типы тела - типы мышления. Думай о стиле URGRADE. Стратегии гениальности. Сан-Петербург: Изд. группа Весь, 2017. 559 с.
51. 2019 Innovation Scoreboards: The innovation performance of the EU and its regions is increasing. In: https://ec.europa.eu/commission/ presscorner/ detail/en/ip_19_2991 (accesat 07.02.2021)
52. Adnan Sarkar. Here's Why Innovation is the Key to Success of Any Business. In: https://www.entrepreneur.com/article/319397 (accesat 28.04.2020)
53. American Association for the Advancement of Science (AAAS) (1993). Project 2061: Benchmarks for Science Literacy. New York: Oxford University Press. http://www. project2061.org/publications/bsl/online/index.php?chapter=1 (accesat 07.02.2022)
54. ANDERMAN, ERIC, M., SINATRA, GALE, M. The Challenges of Teaching and Learning about Science in the 21st Century: Exploring the Abilities and Constraints of Adolescent Learners. [Online] Available: https://sites.nationalacademies.org/cs/groups/dbassesite/ documents/ webpage/dbasse_ 072608.pdf [2018-04-28]
55. ANDERSON, L. W., KRATHWOHL, D.R., et al. A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy of educational objectives. Allyn & Bacon. Boston, MA (Pearson Education Group) 336 p. ISBN 978-0801319037
56. BYBEE, R. Scientific Literacy. In: Gunstone R. (eds) Encyclopedia of Science Education. Springer, Dordrecht. 2015. In: https://doi.org/10.1007/ 978-94-007-2150-0_178 (accesat 25.09.2020)
57. CHAKRADHARA, SI, ARUNDHATHI, BAI C. A study of scientific attitude and science interest of secondary school students in Prakasam District, Andhra Pradesh. In: Paripex - Indian Journal of research Volume-6, Issue-10 October-2017 pp. 11-13.
58. CHIRIȚĂ, A. Curs de neuropsihologie. Universitatea din București. 63 p. In: https://www. academia.edu/6055462/CURS_DE_NEUROPSIHOLOGIE (accesat 22.02.2024).
59. DE BOER, G. Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education. *Journal of Research in Science Teaching*, *37*(6), 2000. pp. 582-601.
60. DEBROY, A. What is STREAM Education & Why is It Gaining Popularity? In: https://edtechreview.in/trends-insights/insights/2968-what-is-stream-education. Published Oct 7, 2017 (accesat 26.01.2023)

61. DEWEY, J. How we think. New York: Mineola. Dover Publications, 1997. 240 p. ISBN 978-0486298955
62. DEWEY, J. Interest and effort in Education. In John Dewey: The middle works. Carbondale & Edwardsville: Southern Illinois University Press. 1913. 438 p.
63. DUNBAR, K., KLAHR, D. Scientific thinking and Reasoning In: https://www. researchgate.net/ profile/Kevin_Dunbar2/publication/232242213_Scientific_Thinking/links/0fcfd507c2ddce1a fb000000/Scientific-Thinking.pdf?origin=publication_detail pp. 611-628.
64. European Commission, Directorate-General for Research and Innovation, *Science education for responsible citizenship: report to the European Commission of the expert group on science education*, Publications Office, 2015, https://data.europa.eu/doi/ 10.2777/13004 (accesat 08.02.2022)
65. FEIST, G.J. A meta-analysis of personality in scientific and artistic creativity. Personality and Social Psychology Review. 1998. 2(4), p. 290-309. https://doi.org/10.1207/ s15327957pspr0204_5
66. FLAVELL, H. J. Metacognition and Cognitive Monitoring: A New Area of Cognitive-Develop-mental Inquiry. American Psychologist Journal. 1979. 34 (10). pp. 906-911 https://doi.org/ 10.1037/0003-066X.34.10.906
67. HALL, B. TANDON, R. TREMBLAY, C. Strengthening Community University Research Partnerships: Global Perspectives; University of Victoria: Victoria, BC, Canada, 2015
68. HAR, E. Contributions of cultural elements of modern science, scientific thinking skills, scientific thinking habits, to the culture of indigeous science. Research journal of Applied Sciences 11 (10): 2016. p. 985-991
69. HILGARD, E.R., BOWER, G.H. *Theories of Learning*. 3d ed. New York: Appleton-Century-Crofts; 1966. http://books.google.com/books?id=-J2cAAAAMAAJ. Accessed January 26 2023.
70. HOOVER, K., DONOVAN, T. The elements of social scientific thinking. Boston: Wadsworth Pre-Press PMG 2011. 198 p.
71. How people learn: brain, mind, experience, and school. In: J. D. Bransford, A. L. Brown, & R. R. Cocking (Eds.). National Academy of Sciences – National Research council. Commission on behavioral and social sciences and education. Washington DC: National Academies Press.
72. HUSEN, T. The School in Question: Comparative Study of the School and Its Future in Western Societies. Oxford, United Kingdom: Oxford University Press 1979. 196 p. ISBN13 9780198740858
73. KLAHR, D, ZIMMERMAN, C., et. all. Educational Interventions to Advance Children's Scientific Thinking. Science 333 (6045): 2011. p. 971–75. doi:10.1126/science.1204528
74. KOSLOWSKI, B. Theory and evidence: The development of scientific reasoning. Cambridge: MIT Press, 2008. 312 p. ISBN: 9780262512794 In: https://mitpress.mit.edu/ books/theory-and-evidence (accesat 13.08.2021)
75. KUHN, D. What is scientific thinking and how does it develop? In U. Goswami (Ed.). Blackwell handbook of childhood cognitive development. Oxford: Blackwell Publishing. 2002. pp. 371-393 http://onlinelibrary.wiley.com/doi/10.1002/9780470996652.ch17/ summary. (accesat 01.02.2017)
76. LEHRER, R., SCHAUBLE, L. Inventing data structures for representational purposes: Elementary grade students' classifications models. Mathematical thinking and learning, 2000. 2(1-2), pp. 51-74. https://doi.org/10.1207/S15327833MTL0202_3 (accesat 29.08.2021)
77. LI, J., KLAHR, D. The Psychology of Scientific Thinking: Implications for Science Teaching and Learning. In J. Rhoton & P. Shane (Eds.) Teaching Science in the 21st Century. National Science Teachers Association and National Science Education Leadership Association: NSTA Press. 2006 pp. 1-31 https://www.researchgate.net/publication/228379207 The_psychology_of_ scientific_thinking_ Implications_for_science_teaching_and_learning
78. MAGNO, C. A Measure for Scientific Thinking. The International Journal of Educational and Psychological Assessment. December 2010, Vol. 6(1) pp. 71-86 https://www.researchgate.net/ publication/277405386_A_Measure_for_Scientific_Thinking
79. MOLES, A. Les théories de l'action. Paris: Denoël. 1972. 328 p. ISBN 978-2282201825
80. National Academies Press (US); 2016 May 18. 3, The Culture of Undergraduate STEM Education. Available from: https://www.ncbi.nlm.nih.gov/books/NBK368176/ (accesed 13.08.2023)
81. NISBETT, RE., PENG, K., CHOI, I., NORENZAYAN, A. *Culture and systems of thought: holistic versus analytic cognition*. Psychological review. 2001 Apr;108(2):291.
82. OECD. (2013). PISA 2015 draft science framework. OECD. Retrieved from www.oecd.org/ pisa/pisaproducts/Draft%20PISA%202015%20Science%2 (accesat 20.10.2020)
83. OSBORNE, J. Science education for the twenty first century. Eurasia Journal of Mathematics, Science & Technology education, 2007. 3(3), pp. 173 -184.
84. PAUL, R., ELDER, L. A miniature guide for students and faculty to Scientific Thinking. Dillon Beach: Foundation for Critical Thinking, 2003. 48 p.
85. POPPER, K. The logic of scientific discovery. London and New York: Routledge Classics, 2002. 545 p. ISBN 0-203-99462-0 In: http://strangebeautiful.com/other-texts/popper-logic-scientific-discovery.pdf (accesat 27.08.2021)
86. PRATIWI, NI LUH PUTU YANTI. The Analysis of Instructional Process through Scientific Approach on Science Subject Matter and Its Effects toward Learning Achievement. Journal of

Psychology and Instruction Undiksha Press Volume 1(1) February 2017. pp. 1-10 http://ejournal.undiksha.ac.id/index.php/JoPaI/ (accesat 03.03.2017)
87. Report of the 2021 science europe High Level Workshop on ERA. Research Culture in the ERA: Ensuring the attractiveness of the research sector for current and future generations 24 NOVEMBER 2021. DOI: 10.5281/zenodo.5785761 https://www.scienceeurope.org/media/bpdib1xg/2021-science-europe-high-level-workshop-report.pdf (accesat 09.02.2022)
88. Report on the 46th session of the International Conference on Education: endorsement of the conclusions and proposals. UNESCO. General Conference, 31st, 2001 [1456]. In: https://unesdoc.unesco.org/ark:/48223/pf0000123896 (accesat 07.02.2022)
89. ROBERTS, D. Scientific literacy: Science literacy. In Abell & Lederman (Eds.), *Handbook of research on science education.* Mahway, New Jersey: Lawrence Erlbaum. 2007. pp. 729-780
90. SANDERS, M. STEM, STEM Education, STEMmania. Technology Teacher, 68(4), 2009. pp. 20-26. In: https://www.teachmeteamwork.com/files/sanders.istem. ed.ttt. istem.ed.def.pdf (accesat 10.02.2022)
91. SCHAFERSMAN, S. Naturalism Is Today An Essential Part of Science. In: Conference on Naturalism, Theism and the Scientific Enterprise. Miami: Miami University, 2006. p 1-30.
92. SCHAUBLE, L. The development of scientific reasoning in knowledge-rich contexts. Developmental Psychology, 32, 1996. pp. 102-119.
93. SHERRIFF, B. K. How exemplary teachers promote scientific reasoning and higher order thinking in primary science. 2019. In: https://ro.ecu.edu.au/theses/2246 (accesat 25.09.2020)
94. STERNBERG, R. J. Handbook of intelligence. New York: Cambridge University Press, 2000. 696 p.
95. STUMPF, H. Scientific Creativity: A Short Overview. Educational Psychology Review. 1995. 7(3). pp. 225-241. https://doi.org/10.1007/BF02213372.
96. The European Commission's science and knowledge service: Joint Research Centre Strategy 2030. In: https://ec.europa.eu/jrc/sites/default/files/jrc-strategy-2030_en.pdf 30 p. (accesat 08.02.2022)
97. TORBERT, W. R., TAYLOR, S. Action Inquiry: Interweaving Multiple Qualities of Attention for Timely Action. In: Reason & Bradbury (2e). The SAGE Handbook action research. (2nd ed). London: SAGE, pp. 239-251. http://www.williamrtorbert.com/wp-content/uploads/2012/06/HAR-chapter-Torbert-Taylor.pdf
98. WHITE, W.F. (Ed.). Participatory action research. Newbury Park, CA: Sage. 1991. 247 p.
99. WIGHTMAN, F.R., KLOPPENBERG, J.T. A companion to American thought. Oxford UK and Cambridge USA: Blackwell, 1995. 804 p. ISBN 978-0631206569
100. WOOLLEY, J. S., DEAL, A. M., et all. Undergraduate students demonstrate common false scientific reasoning strategies. In: Thinking Skills and Creativity. Volume 27, March 2018, pp. 101–113 https://doi.org/10.1016/j.tsc.2017.12.004
101. ZIMMERMAN, C. The Development of Scientific Thinking Skills in Elementary and Middle School. Developmental Review 27 (2): 2007. p. 172-223. doi:10.1016/j.dr. 2006.12.001

LIST OF THE AUTHOR'S PUBLICATIONS ON THE THESIS TOPIC

Single-author specialised books:

1. SANDULEAC, S. Teoria și metodologia dezvoltării și eficientizării gândirii științifice la pedagogi (formarea inițială și continuă), Chișinău: Lexon-Prim. 2024. 441 p. ISBN 978-9975-172-86-8

Articles in journals in other databases accepted by ANACEC (indicating the database):

1. PERJAN, C., SANDULEAC, S. Increasing the quality of university studies through the development of students' scientific thinking. *Journal of the Faculty of Technics and Technologies*, Trakia University. Vol. 6, No. 2, 2018. https://doi.org/10.15547/artte.2018.02.01
2. SANDULEAC, S. The level of professional skills of pedagogues in the context of the development of scientific thinking. *Journal Plus Education*. Online. 21 March 2024. Vol. 35, no. 1, p. 26–49. Available from: https://www.uav.ro/jour/index.php/jpe/article/view/1963 DOI: 10.24250/jpe/1/2024/SS/
3. SANDULEAC, S. Perspectives on the development and enhancement of scientific thinking among pedagogues. *Euromentor journal studies about education*. V 25. Nr. 2/June 2024. pp. 120-132. ISSN 2068-780X (IDB EBSCO, PROQUEST, CEEOL, INDEX COPERNICUS, CEDEFOP, ULRICH'S PERIODICALS DIRECTORY (CNCS recognized) https://www.proquest.com/openview/13653e8943c203391d3611ea2c480a83/1?pq-origsite=gscholar&cbl=1316370
4. SANDULEAC, S. Cunoștințele declarative, factuale și conceptuale în dezvoltarea gândirii științifice la cadrele didactice. *Revista de Psihologie. Academia Română.* nr. 3/2024 pp. 217-227. ISSN 0034-8759
5. SANDULEAC, S. Development of scientific thinking in contemporary university education: an amplified analysis. *Bulletin of the Transilvania University of Brașov*. Series VII: Social Sciences, Law. Vol. 17(66) No. 1 – 2024. https://doi.org/10.31926/but.ssl.2024.17.66.1.8

Articole în reviste de categoria B Articles in journals in the National Register of Journals (Category B)

1. SANDULEAC, S. Rolul metacogniției în dezvoltarea gândirii științifice la cadrele didactice. In: *Univers Pedagogic*. 2023, nr. 4(80), pp. 53-62. ISSN 1811-5470. https://doi.org/10.52387/1811-5470.2023.4.08
2. SANDULEAC, S. Demersuri metacognitive practice în contextul dezvoltării gândirii științifice la studenții-pedagogi: secvențe experimentale. In: *Revista Didactica Pro…, revistă de teorie și practică educațională*. 2024, nr. 1-2(143-144), pp. 7-10. ISSN 1810-6455. https://doi.org/10.5281/zenodo.10719394
3. SANDULEAC, S. Procesul de supervizare a pedagogilor din perspectiva dezvoltării gândirii științifice. In: *Vector European*. 2023, nr. 2, pp. 176-179. ISSN 2345-1106. https://doi.org/10.52507/2345-1106.2023-2.33
4. SANDULEAC, S. Tehnologii educaționale de dezvoltare și eficientizare a gândirii științifice la pedagogi. Revista *Moldoscopie*. 2023, nr. 1(98), pp. 113-121. ISSN 1812-2566. https://doi.org/10.52388/1812-2566.2023.1(98).09
5. SANDULEAC, S. Rolul științelor neurobiologice în formarea gândirii științifice. In: *Psihologie, revista științifico-practică*. 2022, nr. 2(41), pp. 51-60. ISSN 1857-2502. https://www.doi.org/10.46728/pspj.2022.v41.i2.p51-60
6. SANDULEAC, S. Gândirea științifică în științele reale și umanistice. In: Revista Acta etCommentationes, Sciences of Education, 2022, nr. 3(29), pp. 71-80. ISSN 1857-0623. https://doi.org/10.36120/2587-3636.v3i29.71-80
7. SANDULEAC, S. Procedural knowledge in the development of scientific thinking in teachers: some experimental sequences. In: *Studia Universitatis Moldaviae (Seria Științe ale Educației)*. Nr. 5(175), 2024, pp. 57-67. ISSN 1857-2103. https://doi.org/10.59295/sum5(175)2024_08

Articles in the proceedings of scientific events included in other databases accepted by ANACEC

1. SANDULEAC, S. Modelarea gândirii științifice a elevilor în activitățile educaționale. (Sesiune plenară) In: *SIMPOZIONUL NAȚIONAL CU PARTICIPARE INTERNAȚIONALĂ KREATIKON: CREATIVITATE-FORMARE-PERFORMANȚĂ. ”Creativitate și inovare – premise ale excelenței în educație”*. Ediția a XVIII-a din 30 martie - 1 aprilie 2023 Iași. pp. 72-77. ISSN 2068 - 1372
2. SANDULEAC, S. Epistemological constants in the development of scientific thinking from the perspective of the professionalization of teaching staff. *4th International Symposium of Scientific Research and Innovative Studies (ISSRIS 24)*. 13-16 March 2024. Turkey. pp. 327-332. ISBN 978-625-94317-1-0
3. SANDULEAC, S. Gândirea critică în contextul dezvoltării metacogniției și eficientizării gândirii științifice în cadrul formării inițiale. (Sesiune plenară) In: *SIMPOZIONUL NAȚIONAL CU PARTICIPARE INTERNAȚIONALĂ KREATIKON: CREATIVITATE-FORMARE-PERFORMANȚĂ. ”Creativitate și inovare – premise ale excelenței în educație”*. Ediția a XIX-a din 28 martie - 30 martie 2024 Iași. pp. 74-79. ISSN 2068 – 1372
4. SANDULEAC, S. Scientific literacy – an integrative development perspective and efficiency of scientific thinking. *Conferință științifică internațională. Autoconstituirea politică și economică: Migrație, inegalități și discriminare (PESC)*. Universitatea din Peloponez, Corint, Grecia, din 7-8 iunie 2024. https://docs.google.com/spreadsheets/u/0/d/e/2PACX-1vQ7xKj1Ww2QTYLDzDkfw4QtU5upbGlPQqBV7_XwoGBSpB0DU1e9KHbH-mCBRzl_zw/pubhtml?pli=1&urp=gmail_link

Articles in the proceedings of scientific events included in the Register of materials published on the basis of scientific events organised in the Republic of Moldova:

1. SANDULEAC, S. Constituent elements of scientific thinking development of future teachers. (Sesiune plenară) In: *International conference on theory and practice in science education ”Multidisciplinary perspectives on science teaching and learning”*, April 25, 2024. Chișinău. pp. 52-67. ISBN 978-9975-46-933-3
2. SANDULEAC, S. Perspectivele dezvoltării gândirii științifice la elevi în școala contemporană. In: *Asistența psihologică la etapa contemporană: realități și perspective*. 2023. Bălți, Republica Moldova. pp. 16-21. ISBN (pdf) 978-9975-50-314-3. https://ibn.idsi.md/vizualizare_articol/195737
3. SANDULEAC, S. Rolul gândirii științifice în menținerea familiei armonioase. (Sesiune plenară) In: *Familia – factor existențial de promovare a valorilor etern-umane*. Ediția a 3-a. 2023. Chișinău. pp. 62-70. ISBN (pdf) 978-9975-46-803-9. https://ibn.idsi.md/ vizualizare_articol/203272
4. SANDULEAC, S. Securizarea psihologică a elevilor prin exercitarea modelării versus formării gândirii științifice. In: *Securitatea psihologică la copii în perioadă de criză*. 2023. Chișinău. pp. 109-113. ISBN 978-9975-46-824-4. https://ibn.idsi.md/vizualizare_articol/196302
5. SANDULEAC, S. Procesul de dezvoltare și eficientizare a gândirii științifice la cadrele didactice în contextul realităților secolului XXI. In: *Conferința științifică internațională. Știință, educație, cultură*. Vol. 2. 2023. Comrat. pp. 19-22. ISBN 978-9975-83-254-0. 978-9975-83-256-4. https://ibn.idsi.md/vizualizare_articol/179702

6. SANDULEAC, S. Gândirea științifică ca fundament teoretico-aplicativ în formarea continuă a pedagogilor în era digitală. In: *Probleme ale științelor socioumanistice și modernizării învățământului*. Materialele conferinței științifice naționale cu participare internațională din 8-9 octombrie 2020, Universitatea Pedagogică de Stat „Ion Creangă". Ch., pp. 118-123. ISBN 978-9975-46-450-5 https://ibn.idsi.md/vizualizare_articol/117038
7. SANDULEAC, S. Gândirea științifică – concept fundamental în profesionalizarea cadrelor didactice. (Sesiune plenară) In: *Condiții pedagogice de optimizare a învățării în post criză pandemică prin prisma dezvoltării gândirii științifice.* Materialele conferinței științifice internaționale din 18 iunie 2021/ coord. șt: Sanduleac Sergiu; Universitatea Pedagogică de Stat „Ion Creangă". Ch., CEP UPS „Ion Creangă", 2021 pp. 9-15. ISBN 978-9975-46-541-0 https://www.doi.org/10.46728/c.18-06-2021.p9-15
8. SANDULEAC, S. Rolul gândirii științifice în asigurarea competenței de securizare psihopedagogică a elevilor din partea cadrelor didactice. (Sesiune plenară) In: *Aspecte psihosociale ale securității psihologice și manifestările ei în plan social la copii.* Materialele conferinței științifice internaționale din 29 octombrie 2021 / coord. șt: Sanduleac Sergiu; Universitatea Pedagogică de Stat „Ion Creangă". Ch., CEP UPS „Ion Creangă", 2021. pp. 6-11. ISBN 978-9975-46-564-9 https://ibn.idsi.md/vizualizare_articol/154083
9. SANDULEAC, S. Factori și condiții în dezvoltarea gândirii științifice la pedagogi prin prisma eficientizării procesului educațional. (Sesiune plenară). In: *Practici naționale și internaționale de profesionalizare a cadrelor didactice în contextul provocărilor societale.* Materialele conferinței științifice naționale cu participare internațională din 17 noiembrie 2021. Universitatea Pedagogică de Stat „Ion Creangă". Ch., 2021. pp. 80-93. ISBN 978-9975-46-567-0 https://ibn.idsi.md/vizualizare_articol/154724
10. SANDULEAC, S. The stages of development of scientific thinking – reality or fiction. In: *The contemporary issues of the socio-humanistic sciences*. Ediția 8, 8-9 decembrie 2017, Chișinău. Chișinău, 2018: "Print-Caro" SRL, 2017, pp. 65-67. ISBN 978-9975-3168-9-7. https://ibn.idsi.md/vizualizare_articol/96217
11. SANDULEAC, S. Noi abordări ale gândirii științifice. In: *Probleme ale științelor socioumanistice și modernizării învățământului*. Seria 19, Vol.1. 2017. Chișinău, Republica Moldova. pp. 4-13. ISBN 978-9975-46-333-1. https://ibn.idsi.md/vizualizare_articol/71417
12. SANDULEAC, S., STRATULAT, T. Valorificarea competentelor emoționale și a gândirii științifice în procesul creatiei artistico-plastice. In: *Probleme ale științelor socioumanistice și modernizării învățământului. Conferința științifică anuală a profesorilor și cercetătorilor UPS „Ion Creangă"*. Seria 18, Vol.1. 2016. Chișinău, Republica Moldova. pp. 90-95. ISBN 978-9975-46-293-8. https://ibn.idsi.md/vizualizare_articol/72834
13. SANDULEAC, S. Rolul gândirii științifice în luarea deciziilor sociale. In: Practica psihologica moderna. Materialele conferinței practico-științifice naționale. Ediția a 5-a. Chișinău: UPS „Ion Creangă" 2016. p.126-130
14. SANDULEAC, S. Problema obiectivismului și individualismului în gândirea științifică. In: *Probleme ale științelor socioumanistice și modernizării învățământului Conferința științifică anuală a profesorilor și cercetătorilor UPS „Ion Creangă"*. Seria 17, Vol.1. 2015. Chișinău, Republica Moldova. pp. 83-90. ISBN 978-9975-46-239-6. https://ibn.idsi.md/ vizualizare_articol/73086
15. SANDULEAC, S. Formarea gândirii științifice la cadrele didactice în contextul reformelor educaționale. In: *Școala modernă: provocări și oportunități*. 2015. Chișinău, Republica Moldova. pp. 429-432. ISBN 978-9975-48-100-7. https://ibn.idsi.md/vizualizare_articol/81845
16. SANDULEAC, S. Tranziția de la actul de gândire științifică la actul de gândire practică. In: *Știință, educație, cultură*. Vol.2. 2017. Comrat. pp. 255-257. ISBN 978-9975-83-040-9. https://ibn.idsi.md/vizualizare_articol/72949

Other works and achievements specific to different scientific fields (recommended for publication/approved by the UPSC Senate)

1. SANDULEAC, S., CUZNEȚOV, L. Dezvoltarea gândirii științifice la cadrele didactice: fundamente teoretice și aplicative. Ghid metodologic. Chișinău: Pulsul Pieței. 2021. 151 p. ISBN 978-9975-3000-9-

ADNOTARE

Sanduleac Sergiu, Teoria și metodologia dezvoltării și eficientizării gândirii științifice la pedagogi (formarea inițială și continuă), Teză de doctor habilitat în științe ale educației, Chișinău, 2024

Structura tezei. Teza cuprinde adnotări, lista tabelelor, lista figurilor, lista abrevierilor, introducere, cinci capitole, concluzii generale și recomandări, bibliografie din 386 titluri, 18 anexe, glosar de termeni și este perfectată pe 300 pagini, inclusiv 51 de figuri și 26 tabele. Rezultatele obținute sunt publicate în 35 lucrări științifice.

Cuvinte-cheie: gândire, gândire științifică, neuroștiințe, neurodidactică, gândire critică, gândire pedagogică, dezvoltare, eficientizare, formare, modelare, profesionalizare, alfabetizare științifică, instruire și educație științifică, cadre didactice, studenți-pedagogi, formare inițială, formare continuă, sistem cognitiv, educație cognitivă, metacogniție, cunoștințe declarative, cunoștințe factuale, cunoștințe conceptuale, cunoștințe procedurale.

Scopul cercetării constă în conceptualizarea, fundamentarea și validarea teoriei și metodologiei dezvoltării și eficientizării gândirii științifice la pedagogi, structurate în Modelul pedagogic al dezvoltării și eficientizării gândirii științifice la pedagogi.

Obiectivele cercetării: Examinarea aspectelor epistemologice a problemei prin analiza abordărilor teoretice, determinarea specificului conceptelor fundamentale și operaționale în cadrul de referință al dezvoltării-eficientizării gândirii științifice la pedagogi; Determinarea semnificației și a coordonatelor dezvoltării-eficientizării gândirii științifice în contextul profesionalizării cadrelor didactice; Sintetizarea tendințelor generale privind raportul gândire științifică – gândire critică – metacogniție – educație și instruire științifică; Stabilirea factorilor, legităților, condițiilor psihopedagogice și principiilor dezvoltării-eficientizării gândirii științifice în formarea inițială și continuă a cadrelor didactice; Fundamentarea cadrului strategic și tehnologic al dezvoltării-eficientizării gândirii științifice la pedagogi, corelat cu educația și instruirea științifică a elevilor; Elaborarea și fundamentarea metodologiei dezvoltării-eficientizării gândirii științifice la pedagogi; Elaborarea, fundamentarea și validarea experimentală a Modelului pedagogic al dezvoltării și eficientizării gândirii științifice la pedagogi (care include teoria și metodologia dezvoltării și eficientizării gândirii științifice); Demonstrarea funcționalității și valorii teoretico-aplicative a constructelor de bază ale Modelului pedagogic al dezvoltării și eficientizării gândirii științifice și a Programului integrat de educație și instruire științifică a elevilor (din învățământul preuniversitar).

Noutatea și originalitatea științifică a cercetării rezidă în elaborarea și fundamentarea științifică a *Teoriei și metodologiei dezvoltării și eficientizării gândirii științifice la pedagogi*, obiectivată într-un ansamblu de instrumente cu caracter epistemologic și aplicativ, care a fost validat în cercetarea experimentală.

Noua direcție de cercetare: *Teoria și metodologia dezvoltării și eficientizării gândirii științifice la pedagogi.* Rezultatele științifice care au condus la argumentarea noii direcții de cercetare sunt circumscrise unei *concepții de natură neuropsihopedagogică,* fundamentată în rezultatul studiului teoretic al conceptualizării acestuia; a efectuării cercetărilor consistente a cadrului experiențial și a celui experimental. Demersul investigativ a permis să demonstrăm că teoria și metodologia dezvoltării și eficientizării gândirii științifice la pedagogi face parte din teoria generală a educației și se constituie ca o abordare amplă inter-, pluri- și transdisciplinară de complexitate majoră epistemologică, pedagogică, psihoneurobiologică și filosofică. Concepția se bazează pe ideea postulată în formula: gândirea științifică reprezintă un proces cognitiv superior, care necesită o exersare pedagogică sistematică, multinivelară și multiaspectuală a potențialului intelectual uman.

Rezultatele principial noi pentru știință, care au condus la noua direcție de cercetare sunt configurate în următoarele entități: A fost clarificat prin actualizarea conceptelor fundamentale și operaționale din perspectiva sociopsihopedagogică *cadrul noțional al dezvoltării și eficientizării gândirii științifice la pedagogi*. Au fost aplicate abordările cognitiv-constructiviste în combinație cu cele neurodidactice pentru eficientizarea gândirii științifice. S-a elaborat o *Matrice a definițiilor gândirii științifice*, evidențiindu-se astfel axele individuale și profesionale de dezvoltare a gândirii științifice. A fost formulată definiția gândirii științifice abordată din perspectiva unui proces psihic superior, manifestat în situații complexe. A fost explicat *fenomenul transpoziției neurodidactice,* ce constă în transferul cunoștințelor în conținuturi didactice. În urma demersurilor experimentale s-a generat o nouă direcție epistemologică și pedagogică, susținută de teorii și legi specifice dezvoltării gândirii științifice. A fost elaborat și validat *Modelul pedagogic al dezvoltării și eficientizării gândirii științifice la pedagogi*.

Semnificația teoretică a lucrării: constă în conceptualizarea perspectivei de dezvoltare, formare, eficientizare a gândirii științifice din perspectiva profesionalizării cadrelor didactice, raportate la învățarea pe tot parcursul vieții în vederea evidențierii tendințelor de reconfigurare a procesului educațional în școala contemporană. Totodată, s-a evidențiat perspectiva dezvoltării gândirii științifice la elevi prin stabilirea confluenței factorilor și condițiilor dezvoltării acesteia la pedagogi. Cercetarea propune definirea conceptelor de: *gândire științifică, dezvoltare, eficientizare a gândirii științifice la cadrele didactice, formare, modelare, alfabetizare științifică, educație și instruire științifică, educație cognitivă, neurodidactică, metacogniție, profesionalizarea carierei didactice în contextul valorificării convergențelor pedagogice modelatoare și a transpoziției neurodidactice, care constă în transferul cunoștințelor în conținuturi didactice.* Conceptualizarea realizată și sintetizarea analitico-hermeneutică a tendințelor și perspectivelor actuale a procesului de formare profesională inițială și continuă a permis să determinăm temeiurile epistemologice și axiologice ale dezvoltării și eficientizării gândirii științifice la pedagogi, să elaborăm legitățile și principiile, modelul pedagogic și să fundamentăm direcția de cercetare a TMDEGȘ.

Valoarea aplicativă a lucrării: *Teoria și metodologia dezvoltării și eficientizării gândirii științifice la pedagogi* și formarea gândirii științifice la elevi asigură modernizarea și inovarea tehnologiei practicilor educaționale din perspectiva instruirii și educației științifice a elevilor prin sporirea profesionalizării cadrului didactic și plasarea acestuia la un nou nivel de conștientizare a rolului său în calitate de facilitator de gândire, generare a noi idei de învățare și dezvoltare a cunoașterii. În baza acestei direcții de cercetare au fost elaborate cursuri noi pentru ciclul II de studii *Fundamente teoretico-aplicative ale dezvoltării gândirii științifice la pedagogi*, un ghid metodologic pentru cadrele didactice: *Dezvoltarea gândirii științifice la cadrele didactice: fundamente teoretice și aplicative (relevarea perspectivelor micro- și macro-structurale*).

Implementarea rezultatelor cercetării. Rezultatele cercetării au fost utilizate în formarea inițială în cadrul programelor de mobilitate academică internațională *Erasmus Plus* în Serbia, România, precum și în formarea continuă a cadrelor didactice în cadrul a proiectelor internaționale: *Condiții pedagogice de optimizare a învățării în post criză pandemică prin prisma dezvoltării gândirii științifice (CPOED)* cu cifrul nr. 20.70086.32/COV (70105); în cadrul ofertei Orizont 2020, și *Pedagogical measures to increase learning efficiency by promoting scientific thinking during the protracted crisis caused by the pandemic Covid-19* cu cifrul nr. IN 2020-73615; în cadrul ofertei Civil Society Scholar Award (CSSA) of the Open Society Foundations. De asemenea, rezultatele cercetării au fost integrate în proiectul național: *Aspecte psihosociale ale securității psihologice și manifestările ei în plan social la copii*, cu cifrul nr. 20.80009.0807.31. La fel, rezultatele cercetării sub formă de module ale cursurilor predate au fost integrate în procesul didactic de pregătire și formare a studenților, masteranzilor și doctoranzilor la facultățile de pedagogie din instituțiile superioare de învățământ din Republica Moldova. De asemenea, au fost incluse în cadrul cursurilor de formare continuă organizate în instituțiile de învățământ preșcolar, preuniversitar și universitar (instituții de educație timpurie, gimnazii, licee, școli profesionale, colegii și centre de excelență, universități), experiment-pilot din Republica Moldova și România.

ANNOTATION

Sanduleac Sergiu, Theory and methodology of development and effectiveness of scientific thinking in pedagogues (initial and continuing training), Habilitation Thesis in Educational Sciences, Chisinau, 2024

Thesis Structure: The thesis contains the annotations, a list of tables, a list of figures, a list of abbreviations, an introduction, five chapters, general conclusions, and recommendations, a bibliography of 386 titles, 18 appendices, a glossary of terms, and is finalised on 300 pages, including 51 figures and 26 tables. The results are published in 35 scientific papers.

Keywords: thinking, scientific thinking, neurosciences, neurodidactics, critical thinking, pedagogical thinking, development, efficiency, training, modelling, professionalisation, scientific literacy, training and science education, teachers, student-teachers, initial training, continuous training, cognitive system, cognitive education, neuroscience, neuroeducation, neuroeidatics, metacognition, declarative knowledge, factual knowledge, conceptual knowledge, procedural knowledge.

Research Aim: consists of substantiating and validating the theory and methodology of the development and effectiveness of scientific thinking in pedagogues structured in the *Pedagogical Model of Development and Effectiveness of Scientific Thinking in pedagogues*.

Research Objectives: Examination of the epistemological aspects of the problem by analysing theoretical approaches, determining the specificity of fundamental and operational concepts in the frame of reference of the development-effectiveness of scientific thinking in pedagogues; Determination of the significance and coordinates of the development-effectiveness of scientific thinking in the context of teacher professionalisation; Synthesising the general trends concerning the relationship between scientific thinking - critical thinking - metacognition - scientific education and training; Establishing the factors, laws, psycho-pedagogical conditions and principles of development-effectiveness of scientific thinking in initial and in-service teacher education; substantiation of the strategic and technological framework of the development-effectiveness of scientific thinking in pedagogues, correlated with the scientific education and training of pupils; elaboration and substantiation of the methodology of the development-effectiveness of scientific thinking in pedagogues; elaboration, substantiation and experimental validation of the Pedagogical Model of Development and Effectiveness of Scientific Thinking in pedagogues (including the theory and methodology of the development and effectiveness of scientific thinking); Demonstration of the functionality and theoretical-applicative value of the basic constructs of the Pedagogical Model of Development and Effectiveness of Scientific Thinking and the Integrated Programme of Scientific Education and Instruction of Pupils (in pre-university education).

The scientific novelty and originality of the research lies in the elaboration and scientific substantiation of the theory and methodology of the development and effectiveness of scientific thinking in pedagogues, objectified in a set of epistemological and applicative tools, which has been validated in experimental research.

New Research Direction: *Theory and methodology of the development and effectiveness of scientific thinking in pedagogues*. The scientific results that led to the argumentation of the new research direction are circumscribed to a neuropsychopedagogical conception, based on the result of the theoretical study of its conceptualisation; the consistent research of the experiential and experimental framework. The investigative approach allowed to demonstrate that the theory and methodology of the development and effectiveness of scientific thinking in pedagogues is a part of the general theory of education and is constituted as a broad inter-, pluri- and transdisciplinary approach of major epistemological, pedagogical, psychoneurobiological and philosophical complexity. The concept is based on the idea postulated in the formula: scientific thinking is a higher cognitive process, which requires a systematic, multilevel and multiaspectual pedagogical exercise of human intellectual potential.

The fundamentally new results for science, which that led to the new research direction, are configured in the following entities: The *notional framework of the development and effectiveness of scientific thinking in pedagogues* was clarified by updating the fundamental and operational concepts from the socio-psychopedagogical perspective. Cognitivist-constructivist approaches in combination with neurodidactic approaches have been applied for the effectiveness of scientific thinking. *A Matrix of definitions of scientific thinking* was elaborated, thus emphasising the individual and professional axes of scientific thinking development. *The definition of scientific thinking* approached from the perspective of a higher psychic process, manifested in complex situations, was formulated. *The phenomenon of neurodidactic transposition*, which consists in the transfer of knowledge into didactic content, was explained. As a result of the experimental approaches, a new epistemological and pedagogical direction was generated, supported by theories and laws specific to the development of scientific thinking. The pedagogical *Model of development and effectiveness of scientific thinking in pedagogues* was developed and validated.

Theoretical significance of the work: consists in conceptualising the perspective of development, training, and making scientific thinking more efficient from the perspective of teachers' professionalisation, in relation to lifelong learning in order to highlight the trends of reconfiguration of the educational process in contemporary schools. At the same time, the perspective of the development of scientific thinking in pupils was emphasised by establishing the confluence of factors and conditions for its development in pedagogues. The research proposes the definition of the concepts of: scientific thinking, development, making scientific thinking effective in teachers, training, modelling, scientific literacy, scientific education and instruction, cognitive education, neurodidactics, metacognition, professionalisation of the teaching career in the context of the valorisation of pedagogical modelling convergences and neurodidactic transposition, which consists in the transfer of knowledge into didactic content. The conceptualisation and analytical-hermeneutic synthesis of the current trends and perspectives of the process of initial and continuing professional training allowed to determine the epistemological and axiological foundations of the development and effectiveness of scientific thinking in pedagogues, to elaborate the laws and principles, the pedagogical model and to base the research direction of theory and methodology of development and effectiveness of scientific thinking development.

Applicative Value of the research: *The theory and methodology of the development and effectiveness of scientific thinking in pedagogues* and the formation of scientific thinking in students ensure the modernisation and innovation of the technology of educational practices from the perspective of scientific instruction and education of students by increasing the professionalism of the teacher and placing him/her at a new level of awareness of his/her role as a facilitator of thinking, generation of new ideas for learning and development of knowledge. On the basis of this research direction, new courses were developed for the second cycle of studies Theoretical and applied foundations of the development of scientific thinking in pedagogues, a methodological guide for teachers: Development of scientific thinking in teachers: theoretical and applied foundations (revealing the macro-structural perspective).

Implementation of Research Results: The results of the research have been used in initial training within the *Erasmus Plus* international academic mobility programmes in Serbia, Romania, as well as in in-service teacher training within the international projects *Pedagogical conditions for optimising learning in post pandemic crisis through the development of scientific thinking* (CPOED) with the number no. 20.70086.32/COV (70105), in the framework of the Horizon 2020 call, and *Pedagogical measures to increase learning efficiency by promoting scientific thinking during the protracted crisis caused by the pandemic Covid-19* under the call no. IN 2020-73615, within the Civil Society Scholar Award (CSSA) of the Open Society Foundations, and they were also integrated into the national project: *Psychosocial aspects of psychological security and its social manifestations in children,* with the number 20.80009.0807.31. The research results in the form of modules of the courses taught were integrated into the didactic process of preparation and training of students, master's and doctoral students at the faculties of pedagogy of higher education institutions in the Republic of Moldova. They were also included in the in-service training courses organised in pilot pre-school, pre-university, and university educational institutions (early childhood education institutions, secondary schools, high schools, vocational schools, colleges and centres of excellence, and universities) in the Republic of Moldova and Romania.

SANDULEAC SERGIU

THEORY AND METHODOLOGY OF DEVELOPMENT AND EFFECTIVENESS OF SCIENTIFIC THINKING IN PEDAGOGUES (INITIAL AND CONTINUING TRAINING)

SPECIALTY 531.01. - GENERAL THEORY OF EDUCATION

Abstract of the Habilitation Thesis in Educational Sciences

Approved for printing: 14.11.2024 Paper size 60×84 1/16
Offset paper. Offset printing. Print run: 50 copies.
Printed sheets: 9 Order No. 22

Editorial-Polygraphic Center of the "Ion Creangă" State Pedagogical University of Chisinau, 1, Ion Creangă str., MD-2069