THE LEVEL OF PROFESSIONAL SKILLS OF PEDAGOGUES IN THE CONTEXT OF THE DEVELOPMENT OF SCIENTIFIC THINKING

Sergiu SANDULEAC, Ph.D.,
"Ion Creanga" State Pedagogical University of Chisinau, Republic of Moldova,
sanduleac.sergiu@upsc.md

Abstract: *Scientific thinking is essential for equipping students to tackle the complexities of the modern world, and teachers play an important role in nurturing this skill. To gain insights into the competencies utilized and developed by pedagogues in applying scientific knowledge to everyday problem-solving, we conducted an expansive survey to glean their perspectives. Presented herein are the synthesized and meticulously selected directions derived from the respondents' responses. The predominant focus of pedagogues lies in practical activities that intersect with daily life, encompassing both socially useful and cultural activities. This emphasizes the significant impact of culture on scientific education as a whole, and particularly on the development of scientific thinking. Our analysis of responses obtained through a comprehensive questionnaire administered to 511 educators revealed a discernible imperative for educators to elevate their proficiency in scientific thinking. Teachers require specific knowledge and skills to effectively professionalize in pedagogy related to the development and enhancement of scientific thinking. Foremost among these is an imperative foundation in comprehending scientific thinking as both a cognitive process and a human faculty, encompassing facets of critical, systematic, and reasoned analysis. While teachers adeptly employ abstract language, problematization methods, and acknowledge the significance of experiments a notable gap exists in their professional preparatory endeavors.*

Keywords: *development; pedagogues; professional skills; representations; scientific thinking.*

Introduction

Contemporary pre-university education encounters challenges in fostering an environment that nurtures the development of scientific

thinking in students. Despite earnest initiatives, the prevailing school curriculum predominantly fixates on the cultivation of critical thinking a precursor deemed fundamental for scientific thought among students (Hackling, 2015; Hyytinen, Toom, & Postareff, 2018; Paul & Elder, 2003). This endeavor, however, remains incomplete, leaving significant aspects of scientific thinking remaining largely unexplored.
Given that the onus of fostering scientific thinking predominantly rests upon universities, this approach ostensibly aligns with the difficulty in distinctly demarcating scientific thinking from its professional facets or directing it toward a specific scientific domain (the professionalization of thinking) (Șamsutdinova, & Shuvalova, 2016). Nevertheless, a candid acknowledgment is warranted: akin to schools, universities lack a robust system for evaluating the outcomes of effective scientific thinking training. Furthermore, the requisite instruments essential for the subsequent refinement of scientific thinking in a specified trajectory are yet to be meticulously formulated.

Literature Review

Scientific thinking represents a complex concept within specialized literature explored by numerous authors, each offering unique contributions that enrich the comprehension of this pivotal concept crucial for scientific advancement and understanding the surrounding world. Through the analysis of the proposed definitions, significant differences and common elements can be identified, bringing clarity to the various aspects of scientific thinking.
Dewey (1997) underscores the intimate link the scientific method and practical activity, positioning scientific thinking as an adaptable tool for various types of investigations. Popper (2002) highlights the organization of genuine forms of cognitive activity in scientific thinking, with the continuous testing of hypotheses and the potential for paradigm shifts. Kuhn (2002) defines scientific thinking as an intentional, consistent, and goal-oriented way of obtaining new and original knowledge, particularly focusing regarding the process of knowledge acquisition and transformation. Moles (1975) contributes a distinctive perspective, concentrating, focusing on heuristic strategies for problem-solving, highlighting the practical and operative nature of scientific thinking. Zimmerman (2007) outlines scientific thinking as a complex set of cognitive and metacognitive skills, underlining their development through exercises and practice, with an emphasis on its operational nature. Koslowski (2008) introduces a social dimension, defining scientific thinking as an applied process for problem-solving in both research and the social context. Paul and Elder (2003) expound on scientific thinking as a type of thinking specific to a particular problem or scientific domain, involving inferences and the evaluation

of scientific research. Dunbar (2012) describes scientific thinking as a higher mental process, active in presenting arguments and judging scientific content, emphasizing involvement in scientific activities. Lehrer and Schauble (2000) define scientific thinking through its capacity for scientific argumentation, highlighting the importance of argumentative skills in the scientific process.

These various definitions collectively underscore the intricate nature of scientific thinking, incorporating cognitive, metacognitive, and practical aspects.

The synthesis of previous studies (Paul & Elder, 2003; Hackling, 2015; Perjan & Sanduleac, 2018), conclude the imperative for in-depth research, focusing on a wide range of topics related to scientific thinking across varying age groups, as well as the essential role of teacher training in fostering the development of scientific thinking in students. For a student to become a highly potential scientific thinker, capable of scientific creativity, these characteristics should be inherent. Sternberg (1997) postulates that new scientific discoveries necessitate a predisposition or inclination for engagement, encompassing intellectual abilities, knowledge, and motivation, as well as problem-solving skills. He conceptualizes these predispositions as "thinking styles" (Sternberg, 1997). Sternberg (1997) argues that knowledge is a distinct and interconnected resource in the construction of intellectual abilities, along with creativity, thinking styles, personality, motivation, and the environment. He labels these six attributes as the *Investment Theory of Creativity*, as the author believes that investment implies a conscious choice to see a final outcome for gain. Thus, Sternberg clarifies that the attributes in the investment theory are "inputs" into the result of a creative process (Sternberg, 1997).

MacKinnon raises a critical point, noting that most studies tend to be more retrospective rather than creative, often focusing on successful problem-solving attempts. Individuals engaged in scientific thinking, especially those with less capability, might tend to imitate rather than originate due to a lack of confidence or proficiency in their scientific thinking potential. MacKinnon postulates that, at this stage, individuals engaged in the process of developing scientific thinking need a better understanding of the cognitive and motivational processes involved in the act of scientific thinking (Stumpf, 1995, 238).

Content knowledge plays a pivotal role in nurturing both scientific and critical thinking abilities. According to the *Domain Learning Model* (DLM) proposed by Alexander (Alexander et al., 1995), students must progress toward the competence stage of knowledge development to acquire the requisite foundation for critical thinking (Eric et al., 2018, 25). Therefore, teachers bear the responsibility of assessing students' foundational knowledge, identifying misconceptions and discerning alternative concepts prior to delving into new topics, all of which align with the premise of scientific literacy that the teacher must consider in the discipline (Alexander et al., 1995, 26). This corresponds to the initial stage according to the *Domain Learning Model* (DLM) proposed by Alexander, which involves familiarizing students with limited *domain knowledge*, and *subject knowledge* gradually progressing toward the depth of knowledge about specific subjects in that domain. During this nascent phase, students' lack of expertise and exposure in the given field poses a risk, potentially leading to limited or situation-based interest, heavily influenced by environmental and cultural factors. This lack of familiarity could hinder strategic processing skills crucial for content mastery, which materializes in the second stage in the form of skills, including an increase in domain knowledge, and familiarization with scientific concepts. Due to this broader and deeper body of knowledge, students can apply diverse information processing strategies from simple to complex (Alexander et al., 1995). According to Shamos (2012), this would imply the stage of functional scientific literacy, which refers to the ability to master scientific vocabulary, as well as to be able to converse, read, and write coherently, using scientific terms not necessarily in a specific context, but still meaningfully (Shamos, 2012, 88). Such changes in knowledge and strategic processing are further associated with an increase in individual interest, as students no longer need to rely on the situational characteristics of the environment to pay attention to presented scientific content.

The third stage, competence, is marked by a solid and deep knowledge foundation, accompanied by heightened individual interest. Notably, individuals at this stage deploy cognitive strategies for deep processing to explore the field with probing inquiries and innovative ideas. Alexander posits that attaining this stage is a rarity for most individuals (Alexander et al., 1995). Demirel and Gücüm (2009) argue that to have a high level of scientific thinking, necessitates its cultivation from the initial training phase, further developed through continuous and deliberate practice. This development is achievable through the cultivation of specific competencies such as creativity, research and problem-solving skills, etc.

The development of scientific thinking encompasses numerous contributing factors, spanning creativity, skills, behavior, personality traits, and others. These factors can be divided into intrinsic (internal factors, such as personality traits or experience) and extrinsic (external factors, mainly related to the external environment). There are factors that include the natural (inherent) development of scientific thinking and are closely related to aspects and elements of psychological development that consist of artificial intervention in the development of scientific thinking and represent an infrastructure for the development of scientific thinking. We propose a categorization into three primary domains: the operational aspect, the intellectual aspect, and the personality components. From an educational standpoint, discussing the teachability of thinking in general and scientific thinking in particular, it is necessary to amplify the student's receptiveness to educational influences and to achieve, thus, progressive accumulations materialized in different personality structures - the set of possibilities to influence with educational means the formation of the personality of each student and the innate characteristics that give each individuality.

Methodology

Research Questions

1. What knowledge and skills are essential for teachers to effectively professionalize in fostering scientific thinking development?
2. How do teachers actively promote the cultivation of scientific thinking in students?
3. What specific methodologies and approaches do educators utilize to nurture scientific thinking in students, and what influence do these methods wield on the learning process?

In the context of the provided exploratory research, the level of professional skills among pedagogues was investigated concerning the development and enhancement of scientific thinking. The conducted research delved into the theoretical, experiential, and experimental framework of the development and enhancement of scientific thinking in pedagogues, rooted in specific set of norms, laws, principles, and rules.

The design of the pedagogical experiment was shaped based on six research axes:

1. Examining teachers' comprehension of the concept of scientific thinking, including its defining characteristics and the role of cognition and metacognition in its evolution.
2. Investigating teachers' role in fostering curiosity and wonder in students at the initial stage of students' scientific thinking development, as well as facilitating and developing scientific thinking in students in general.
3. Analyzing the methods and procedures applied in the development of scientific thinking in students by teachers within both curricular and non-formal activities.
4. Studying and analyzing the personality traits that can contribute to the development of scientific thinking in students from a psychopedagogical perspective.
5. Investigating the conducive conditions for cultivating scientific thinking in students, coupled with the selection and analysis of practical proposals.

6. Exploring teachers' perceptions regarding the professional profile of an educator demonstrating strong scientific thinking skills

Therefore, the research focuses on several *dependent variables:*

- the knowledge and skills of teachers regarding pedagogical professionalization in relation to the development and efficiency of scientific thinking;
- the actions undertaken by teachers to facilitate the development of scientific thinking in students.
- the application of methods and procedures by pedagogues in the development of scientific thinking in students;
- the personality traits of students who exhibit well-developed scientific thinking;
- The conducive conditions fostering the development of scientific thinking.
- the professional portrait of the teacher exemplifying strong scientific thinking.

To evaluate the proposed variables, we developed a questionnaire containing open-ended questions. The applied questionnaire allowed us to determine the representations and knowledge about scientific thinking.

The construction of the questionnaire was rooted in several theoretical frameworks on scientific thinking development, grounded on identified criteria for developing scientific thinking in teachers and drawing from Bloom's Taxonomy revised by Krathwohl & Anderson, which is based on structuring and forming cognitive skills of factual, conceptual, procedural, and metacognitive types (Anderson et al., 2001); the teleological approach to competencies in the education system, specifically the cross-disciplinary nature as an important characteristic of key competencies (Guțu, 17-19); and the theoretical references for conceptualizing university curriculum (Cabac, 2011). This tool (questionnaire) includes complex and critical thinking competencies (Perjan & Sanduleac, 2018), outlined in the indicators and descriptors for the development and enhancement of scientific thinking in pedagogues. The indicators and descriptors for the development and enhancement of scientific thinking in pedagogues are based on the principles and methodological requirements for constructing competency-centered curriculum (Joița, 2010, 86-88).

The identified criteria for developing scientific thinking in teachers served as reference points for formulating specific indicators and descriptors, delineated as follows:

- Scientific thinking is an intentional, logical, consistent, and goal-oriented way of thinking.

- Scientific thinking employs heuristic problem-solving strategies (educational, disciplinary, every day).
- Scientific thinking underlies the development of the cognitive system of an individual (across the four cognitive levels: knowledge level, processing level, representational algorithm level, implementation level).
- Scientific thinking involves all operations and forms of human thinking (analysis, synthesis, judgment, reasoning).
- Scientific thinking encompasses cognitive and metacognitive abilities.
- Scientific thinking is a process that underlies scientific reflection and argumentation.
- Scientific thinking includes the values of knowledge, multiple intelligences, and moral intelligence, representing the axis of self-improvement for teachers.
- Scientific thinking incorporates various types of thinking (critical, lateral, axiomatic, etc.).

That means that we can classify descriptors in three main parts: at the knowledge level, at the application level, and integration level. Based on response quality, competencies in scientific thinking are assessed as inferior, moderate, or superior (See Appendix).
The questionnaire comprises 11 items aimed at exploring various dimensions of scientific thinking among educators:

1. How would you define scientific thinking?
2. Enumerate the key characteristics of scientific thinking.
3. In what ways do you foster students' curiosity and wonder to develop scientific thinking?
4. How do you support and facilitate the development of scientific thinking in students?
5. Specify the methods and procedures you employ to foster scientific thinking in students?
6. Do you perceive connections between cognition, metacognition, and scientific thinking? (Please provide a succinct explanation)
7. What strategies do you employ to foster scientific thinking in students during non-formal activities?
8. Which personality traits do you believe influence the enhancement of scientific thinking/its development in students?
9. What are the crucial conditions for the development of scientific thinking in students?
10. What recommendations or proposals do you have for enhancing scientific thinking in students within their academic disciplines?

11. Provide a succinct and essentialized portrait of the teacher who possesses a high level of scientific thinking.

Sample and Data Collection

The study was conducted on a sample of 511 experimental subjects, consisting of pedagogues from 224 educational institutions from the Republic of Moldova and Romania (rural and urban environment). These participants contributed significantly to the exploration of knowledge and perspectives regarding the conceptualization of scientific thinking. The study delved into the perceived significance of nurturing scientific thinking among both students and teachers, elucidating specific conditions, training methodologies, and strategies to enhance the efficacy of scientific thinking. Additionally, the research aimed to identify key personality traits influencing its development.

Data Analysis

The reliability analysis conducted aimed to ascertain the consistency of the items in measuring the construct of developing and enhancing scientific thinking in educators. Utilizing Cronbach's Alpha coefficient, we assessed the internal consistency of the questions (items) based on the teachers' response data from the questionnaire. The teachers' response data from the questionnaire were subjected to reliability analysis. The findings revealed a Cronbach's Alpha of 0.706, which is within the range acceptable for research. The Cronbach's Alpha based on standardized items is 0.724 (Cooksey, 2007).

Findings/Results

Item 1. How would you define scientific thinking? The findings from the analysis of responses to item 1 shed light on pedagogues' understanding of fundamental concepts related to scientific thinking. The observations indicate that educators predominantly perceive scientific thinking as a *mental or cognitive process* (64 expressions), a *human capacity* (262 expressions), an *ability to formulate ideas, a problem, or critically analyze* (267 expressions). In reflective terms, scientific thinking is expressed as critical, structured, rational, logical, and higher-order thinking skills. Similarly, it is viewed through the lens of logical reasoning as a form of thinking, through which induction, deduction, argumentation, abstraction.

Pedagogues also associate scientific thinking with various of science such as observations, experience, investigation, research, experimentation, scientific concepts, etc. They demonstrate an understanding of the scientific aspects inherent in the expression of scientific thinking. Additionally, they conceptualize scientific thinking as a framework for generalized reflections of reality from an objective

and rational standpoint.
Item 2. Enumerate the key characteristics of scientific thinking. The analysis of responses to item 2 illustrates that pedagogues prioritize specific characteristics when defining scientific thinking, with objectivity being the most emphasized attribute (86 expressions). This emphasis is closely followed by the qualities of *accuracy*, (42 expressions), and *rationality*, (67 expressions). Notably, the attribute of *real facts* surfaces in (65 expressions), suggesting an inclination towards *demonstrability* (45 expressions) - the capacity to validate information for factual accuracy. Additionally, respondents' express *communicability* as another significant aspect of scientific thinking, totaling (47 expressions).
All these characteristics predominantly manifest as nouns, accompanied by adjectives that vividly describe and enhance the nature of each trait. Respondents underscore the importance of achieving these characteristics *methodically* (148 expressions) and *systematically* (41 expressions), *analytically* (128 expressions), *symbolically* (112 expressions), *verifiably* (102 expressions), *transmissibly* (91 expressions), and *transcendentally* (88 expressions).
Item 3. In what ways do you foster students' curiosity and wonder to develop scientific thinking? The analysis of pedagogues' strategies in developing students' curiosity and wonder reveals a prevalence of abstract language and vague terminology. Terms such as *things* (50 expressions), is a common term usually used when one does not exactly know what the real possibility of intervention would be. Experimental subjects used this term in various contexts: researching things, workgroups, mysterious things, work material, concrete things, new things, and ways of working. Mostly, abstract notions are used, indicating the need for an activity but not specifying how to facilitate students' curiosity and wonder. Similarly, the term *activity* (12 expressions) and *research* (22 expressions) are frequently used in the same way. The term *problem* (56 expressions) is frequently used to emphasize the need for problematization methods, which, in the view of pedagogues, are strictly necessary to awaken a sense of curiosity and wonder in students. Another term frequently used by respondents is the word *experiment* (39 expressions). This term is used frequently, but the context in which it is evoked is mostly general and does not reveal the essence of the activity to express the need to awaken curiosity and wonder in students in the development of scientific thinking. In most cases, the experiment is used as a demonstrative example, i.e., a narrative formulation, and only a small percentage (approximately ≈ 5%) of subjects have stated that they have resorted to the experimental method and have described how it would influence the development of interest in scientific thinking. *Interest* (33 expressions) follows

experiment hierarchically in the context, indicating its importance in fostering scientific curiosity.
Subsequently, terms such as *project* (33 expressions), *group* (32 expressions), *game* (31 expressions), and *discovery* (29 expressions) are also described. These are used by subjects with the meaning of consolidating teams through educational games and experimenting with the discovery of new things, and the element of novelty would be the basis for these activities. Although the notion of *new* is not evoked by subjects, the notion of discovery in this case is directly proportional to that of experiment, activity, or research. In other words, subjects call for the active involvement of students in research activities in their proximal development zone. Some are aware of the need for student involvement in such activities, while others only focus on demonstrative aspects. One thing is certain: no teacher knows how this should be done in a system of concrete steps that would contribute to a reliable, feasible result and ensure durability and connection with other components.
Item 4. How do you support and facilitate the development of scientific thinking in students? Analysis of the responses provided to item 4 regarding the support given by pedagogues in facilitating the development of scientific thinking in students highlights their intention to develop these skills. The concept of *development* (76 expressions) emerges as the most frequently referenced concept among respondents, signifying their commitment to nurturing scientific thinking. Similarly, the subjects place great emphasis on *modern teaching-learning methods* (56 expressions), at times specifying certain methodologies while at other times simply affirming their necessity. The concept of "idea generation" (45 expressions) is another frequently used explanation, reflecting educators' inclination toward fostering individual thinking manifestations in students as a pathway to developing scientific thinking. The concept of *involvement* (43 expressions) represents a continuity of the vision that ideas need to be developed through modern, active methods (project-based learning, individual and group competitions, writing marathons, concept mapping, the method of titles, problematization method, etc.). The term *experiment* (36 expressions) is used by respondents to designate one of the fundamental methods contributing to the development of scientific thinking. However, no respondent provides details regarding the context of applying the experiment, does not identify specific directions, or exemplifies other effective methods that would provide clarity on how to facilitate the development of scientific thinking in students through this method. This leads us to conclude that the experimental method, in this case, is mentioned by subjects as necessary, but it is not fully utilized in the teaching-learning process.

Item 5. Specify the methods and procedures you employ to foster scientific thinking in students? The methods most frequently cited by educators for nurturing scientific thinking in students included: *the problematization method* (108 expressions), various *role-playing, logical, or didactic games* (106 expressions), *case study* (87 expressions), *experiment* (65 expressions), the *method of thinking hats* (63 expressions), *projects* (56 expressions), *concept mapping* (56 expressions), *analysis* (46 expressions), the *Cube method* (46 expressions), *learning by discovery* (43 expressions), *communication methods* (38 expressions), the *random stimulation method* (29 expressions), *Venn diagram* (24 expressions), the *Lotus method* (23 expressions), *research* (23 expressions), *debate* (22 expressions), *group or team activities* (21 expressions), the *observation method* (17 expressions), *computer-assisted instruction* (17 expressions), the *Mosaic method* (16 expressions), etc.

Analysis of the responses provided valuable insights: some pedagogues drew upon their professional experience, while others listed potential methods they believed could contribute to the development of scientific thinking. However, only a few respondents provided a detailed presentation of how they could engage with a specific method, outlining the necessary prerequisites for their successful application in advancing scientific thinking skills.

Item 6. Do you perceive connections between cognition, metacognition, and scientific thinking? (Please provide a succinct explanation) Pedagogues are uniformly tempted to present the same vision regarding the role of cognition and metacognition in the development of scientific thinking. The difference lies only in their ability to argue what the essence of this role is and how this relationship is mediated. Primarily, the term *knowledge* (229 expressions). emerges as a common component facilitating scientific thinking's development, acting as a mediator between cognition, metacognition, and scientific thinking. As a result, scientific knowledge emerges as a superior structure, as a product of this interrelationship. The reflection mode with subjective or objective orientation is also reflected through knowledge. Understanding through metacognition how things are reflected allows the respondents to analyze possible errors, find solutions and self-instruct to progress in the context of the development of scientific thinking. Objective knowledge stimulates the development of cognition, while metaknowledge favors the development of metacognition. In common terms, this would sound like *knowing about what you don't know* or *knowledge about ignorance*.

This relationship between knowledge and metaknowledge in the context of scientific thinking allows the individual to persevere and break out of existing paradigms, offering the individuals engaged in scientific thinking the opportunity to think differently, divergently, unconventionally, approaching things from various perspectives. Another element mentioned by respondents is the word *development* (86 expressions), which is most often expressed with meanings of developing capacities or competencies, cognitive abilities, scientific thinking, developing critical thinking. In the context where the respondents' style of expression is more argumentative, the term *development* appears in the semantic analysis of the text as a natural process followed by the term *metacognitio*n (264 expressions). Metacognition is represented as a *psychological process* (168 expressions) integral to fostering scientific thinking as most frequently expressed by subjects.

Item 7. What strategies do you employ to foster scientific thinking in students during non-formal activities? The analysis reveals defining elements that pedagogues associate with applying scientific knowledge to resolve everyday challenges. Among the concepts frequently mentioned, *development* (96 expressions) emerges prominently, in which subjects present through activities that develop creativity, imagination, intellect, self-confidence, etc. The second notion evoked by subjects was *game* (78 expressions), didactic, interactive, and role-playing games. Didactic play is used by most respondents as a fundamental didactic method for developing scientific thinking in students, *project* (48 expressions) specifically research projects, both individual and group, are also highlighted as essential methods. The notions of *visit* (40 expressions) and *excursions* (39 expressions) are used by subjects as some of the basic methods for applying scientific knowledge to solve everyday problems. *Involvement* (38 expressions) is invoked by subjects to denote any activity directed and guided by the teacher in which students work independently. The concept of *problem* (37 expressions) is used for problematization activities. Elements of *group activities* (36 expressions) and *communication* (34 expressions) imply collective activities related to interaction and collaboration, involving communication. *Extracurricular activities* (35 expressions) involve students in everyday contexts. Communication is presented by respondents in two aspects: the first aspect refers to communication as a skill, and the second refers to communication as a necessary resource for development, including communication training for students, communication with parents as support in the cultural acceptance of the need for scientific education. *Experiment* (29 expressions) is used by subjects to denote the exercise of basic competencies in applying scientific knowledge to solve everyday problems. Other concepts like *circle* (28 expressions), *problem-solving* (26 expressions), *interest* (24 expressions), and *museum* (23 expressions) were also articulated by the respondents.

Item 8. Which personality traits do you believe influence the enhancement of scientific thinking/its development in students?

The prevalent traits identified by respondents as contributing to the development of scientific thinking in students include: *self-confidence* (91 expressions), *creativity* (69 expressions), *self-esteem* (64 expressions), *capability* (49 expressions), *critical and analytical thinking* (47 expressions), *responsibility* (46 expressions), *courage* (40 expressions), *curiosity* (36 expressions), *motivation and enthusiasm* (35 expressions), *intelligence* (34 expressions), *perseverance* (33 expressions), *openness* (31 expressions), *sociability* (27 expressions), *optimism* (23 expressions), *independence* (17 expressions), *objectivity* (17 expressions), *assertiveness* (13 expressions), *pragmatism* (12 expressions), *enthusiasm* (10 expressions). From the insights gathered from teachers, a comprehensive profile delineating the essential personality traits contributing to the effective cultivation of scientific thinking in students has been compiled. In total, teachers have identified 18 personality traits that, in their opinion, can contribute to the development of scientific thinking in students. By organizing and prioritizing these traits according to their frequency of mention, we've discerned the pivotal characteristics deemed indispensable for a student's advancement in fostering scientific thinking, as per teachers' perspectives.

Item 9. What are the crucial conditions for the development of scientific thinking in students?

Respondents have cited the following conditions, taking into account the previously mentioned support methods, from which we will abstract. Most subjects have named conditions related to the development of critical thinking, which they know and largely apply in their practical activities: Establishing learning environments conducive to practicing critical thinking processes and allowing adequate time for such activities; Encouraging independent thinking, speculation, and reflection among students; Accepting diversity of opinions and ideas within the learning space; Actively engaging students in collaborative learning, promoting cooperative problem-solving approaches; Creating a safe environment where students feel secure expressing their opinions without fear of ridicule. Demonstrating belief in each student's capacity for critical thinking. Positively reinforcing instances of critical thinking exhibited in various learning scenarios; In addition to these, there is rigorous teacher preparation, correct guidance of students, stimulation of student interest, and adherence to certain psychopedagogical conditions (emphasis on interdisciplinarity; stimulation of self-confidence, self-respect, etc.).

Item 10. What recommendations or proposals do you have for enhancing scientific thinking in students within their academic disciplines? The analysis of this item has revealed key insights into the aspects emphasized by pedagogues when applying scientific knowledge to address teaching and learning challenges. Among the most frequently mentioned concepts, *intellect* (664 expressions) stands out, indicating a significant focus on cognitive capacities. This is closely followed by *action* (409 expressions), then *education and teaching* (372 expressions), *fundamental concepts* (293 expressions), *school context* (119 expressions), the *human factor* (97 expressions), *temporal aspect* (85 expressions), *willingness* (62 expressions), *dosage and processing capacity of information* (41 expressions), *affectivity* (33 expressions), etc.

The examination of proposals aimed at fostering scientific thinking across disciplines and honing competencies in applying scientific knowledge to address teaching and learning challenges provides insights into pedagogues' emphasis on enhancing intellectual capacities. This orientation effectively supports the goal of cultivating scientific thinking among students. Intellectual capacities, accomplishing the task of developing scientific thinking in students.

The most frequently evoked concept is *intellect*, appearing 664 times, suggesting special attention given to the development of cognitive abilities and intellectual processes in the learning process. Next is the concept of *order and measure* with 525 mentions, indicating the importance of structuring and organizing information and activities in the learning process.

The concept of *action* is mentioned 409 times, emphasizing the necessity of active involvement and effective practice in the development of scientific thinking. *Education and teaching* are mentioned 372 times, reflecting the focus on the educational process and the transmission of knowledge and skills in the development of scientific thinking.

The notion of *fundamental concepts* appears 293 times, suggesting the importance of understanding and applying basic principles and concepts in the development of scientific thinking. The *school* context is mentioned 119 times, highlighting the importance of the influence of the school environment and social relationships in the development of scientific thinking in students.

The *human factor* is mentioned 97 times, indicating the importance of the involvement and interaction of individuals in the learning process. The *temporal aspect and willingness* are mentioned 85 and 62 times, respectively, emphasizing the importance of time management and motivation in the development of scientific thinking. *Dosage and the capacity to process information* are evoked 41 times, highlighting the need for an appropriate approach to presenting and processing information in the learning process. *Affectivity* is mentioned 33 times, underlining the influence of emotions and affective states on the development of scientific thinking.

While the sequence of emphasis varies, the internal factors like knowledge, critical thinking, and creativity take precedence. External aspects such as interactive methods, skill development, and school environment are also deemed significant. However, the discussion lacks concrete strategies to integrate scientific knowledge effectively into practical problem-solving within the educational framework.

Item 11. Provide a succinct and essentialized portrait of the teacher who possesses a high level of scientific thinking. The analysis of competencies mentioned by subjects regarding the facilitation of scientific thinking formation among colleagues has allowed the clarification of aspects related to the professional profile of an educator who demonstrates scientific thinking: *open-minded* (48 expressions), *creative* (34 expressions), *efficient* (33 expressions), *skilled* (32 expressions), *competent* (31 expressions), *confident* (29 expressions), *works with relevant information* (28 expressions), *articulates thoughts clearly* (24 expressions), *objective* (21 expressions), *professional* (20 expressions), *logical* (19 expressions).

Analysis of the relevant competencies, in response to item 11, brings to the forefront a detailed portrait of the teacher who embodies scientific thinking.

Firstly, a teacher oriented towards the development and enhancement of scientific thinking is receptive to new ideas, innovative methodologies, and changes in their field of expertise. They are not confined to what they already know but are willing to explore and integrate new concepts into their educational practice. Creativity serves as a cornerstone in fostering scientific thinking, enabling the exploration of unconventional solutions and encouraging divergent thinking among students. Efficient teaching involves not just technical prowess but also strong interpersonal skills, allowing effective content delivery that maximizes understanding and engagement. A "good" teacher, is seen as a mentor and role model, capable of efficiently imparting solid knowledge to students. This aspect indicates that the teacher not only possesses solid knowledge but also efficiently imparts it to students.

Self-confidence can significantly influence the impact of a teacher. Confidence in manifesting scientific thinking can inspire and instill confidence in students in their own ability to think scientifically. A teacher with a high level of scientific thinking understands the importance of relevant information. This indicates the ability to select and use essential information to support the educational process. This, in turn, facilitates a teacher's ability to express complex ideas in an accessible and intelligible manner, be objective, and stimulate critical thinking and neutral evaluation of information.

These qualities culminate in professionalism, fostering mutual respect between teacher and students. A professional teacher prioritizes both academic and personal growth, shaping students into independent thinkers. Lastly, logical thinking guides students toward structured and reasoning-based thought processes, essential in a teacher embodying scientific thinking.

By analyzing these expressions (mentions), we obtain a detailed picture of the qualities and competencies inherent in a teacher with scientific thinking, underscoring their significance in the educational sphere. These characteristics not only improve the learning process but also contribute to forming a scientific mindset among students.

However, the limited awareness among some respondents reaffirms the prevailing lack of openness regarding the necessity for interventions to enhance teachers' scientific thinking and foster its development among students. There exists a lack of clarity on the methodologies or strategies required for this enhancement, posing uncertainties about potential interventions, their scope, and the associated opportunities and perspectives.

Discussion

The examination of pedagogues' perspectives on scientific thinking reveals several noteworthy insights. Scientific thinking is predominantly viewed as both a cognitive process and a human capacity, encompassing critical, structured, and rational analysis. The understanding extends to logical reasoning, incorporating induction, deduction, and other higher-order thinking processes. Elements intrinsic to the scientific method such as observation, experience, and research, are integral to this conception. Notably, pedagogues stress the importance of methodical and systematic application of characteristics like objectivity, accuracy, and rationality in fostering scientific thinking. Pedagogues view scientific thinking as a cognitive process involving critical and rational analysis, consistent with Dewey's emphasis on practical activity Dewey (1997). Moreover, the importance of logical reasoning, induction, deduction, and higher-order thinking processes resonates with the views presented by Kuhn (2002) and Popper (2002).

Facilitating curiosity and wonder involves abstract language and an emphasis on problematization methods. While experiments are recognized, there is a notable gap in detailing their effective application. Pedagogues highlight various activities like projects, games, and discovery-based learning to consolidate teams and stimulate curiosity. The pedagogues stress the significance of methodical and systematic application of characteristics like objectivity and accuracy, aligning with Zimmerman's emphasis on the operational character of scientific thinking (Zimmerman, 2007).

Supporting scientific thinking development is expressed through the intent to develop skills via modern teaching methods, idea generation, and student involvement. However, the practical application, especially concerning the experimental method, remains somewhat elusive.

Pedagogues cite a plethora of methods for scientific thinking development, encompassing problematization, games, case studies, and experiments. While some draw from personal experience, others list methods they believe could contribute, lacking detailed practical applications.

In linking cognition, metacognition, and scientific thinking, knowledge emerges as a common thread. Metacognition is presented as a psychological process significantly contributing to scientific thinking development.

Non-formal activities focus on creativity, imagination, and intellect development, often through didactic games, projects, and excursions. Personality traits such as self-confidence, creativity, and critical thinking are identified as crucial contributors to efficient scientific thinking development in students.

Conditions for development involve creating critical thinking situations, encouraging independent thought, accepting diversity, and actively involving students. Rigorous teacher preparation and adherence to psychopedagogical conditions are underscored.

In proposing methods across disciplines, emphasis is placed on promoting intellectual capacities, active involvement, and understanding fundamental concepts. The profile of a teacher fostering scientific thinking is characterized by professional competence and personal attributes, including open-mindedness, creativity, and logical thinking.

In summary, the insights from pedagogues provide a nuanced understanding of scientific thinking, stressing both theoretical understanding and the practical application of diverse methods. The identified gaps suggest opportunities for further exploration and refinement in pedagogical practices.

Conclusion

Teachers need specific knowledge and set of skills for effective pedagogical professionalization concerning the development and enhancement of scientific thinking. This includes a comprehensive grasp of scientific thinking as both a cognitive process and a human capacity, involving critical, structured, and rational analysis. This includes knowledge of logical reasoning, induction, deduction, and

higher-order thinking processes. Familiarity with the components of science, such as observation, experience, and research, is important. Methodical and systematic application of characteristics like objectivity, accuracy, and rationality is emphasized. Additionally, teachers should possess skills in abstract language, problematization methods, and the effective application of experiments.
These skills, fostered through modern teaching methods and active student engagement, are fundamental for teachers committed to fostering scientific thinking among their students.
Teachers use abstract language, problematization methods, and recognize the importance of scientific thinking. Various activities like projects, games, and discovery-based learning are employed to consolidate teams and stimulate curiosity. Teachers support scientific thinking development by intending to develop skills through modern teaching methods, idea generation, and student involvement. However, there's a noted gap in detailing the effective application of experimental methods.
Pedagogues employ diverse methods for fostering scientific thinking, including problematization, games, case studies, and experiments. While some draw from personal experience, others propose methods without detailed practical applications. Knowledge is identified as a common thread in linking cognition, metacognition, and scientific thinking. Metacognition is highlighted as a psychological process contributing significantly to scientific thinking development. Non-formal activities focus on creativity, imagination, and intellect development through didactic games, projects, and excursions. Personality traits such as self-confidence, creativity, and critical thinking are crucial contributors. Conditions for development involve creating critical thinking situations, encouraging independent thought, accepting diversity, and actively involving students. Rigorous teacher preparation and adherence to psych pedagogical conditions are underscored. Proposed methods across disciplines emphasize promoting intellectual capacities, active involvement, and understanding fundamental concepts. The profile of a teacher fostering scientific thinking is characterized by professional competence and personal attributes, including open-mindedness, creativity, and logical thinking. The identified gaps suggest opportunities for further exploration and refinement in pedagogical practices.

Recommendations

The participant group of this study consists of pedagogues working and living in Republic of Moldova and Romania. Therefore, it is recommended to broaden the scope of future studies by including participants from various countries. Future research initiatives should consider a more globally representative participant pool, contributing to a broader and more universally applicable understanding of the subject. This expansion would not only enhance the external validity of the study but also contribute to a more nuanced and globally applicable perspective on the subject matter. This study covers the motherhood experiences of the scientific thinking skills. While this study delves into the perspectives of educators on scientific thinking skills, a valuable extension could be a study focusing on the educational needs of participants. Carrying out a comparable study with participants involving students of varying age groups would enhance the comprehensiveness of the results. Consistent with the study's findings, it becomes evident that pedagogues also require support in the development of their scientific thinking skills, suggesting potential areas for further research and professional development.

Limitations

The scope of the study is confined to participants residing in the Republic of Moldova and Romania, thereby delineating certain limitations. One primary constraint lies in the geographical specificity, as the findings may not be immediately generalizable to individuals from other regions or countries. The cultural, educational, and contextual factors inherent to Moldova and Romania may contribute unique nuances to the participants' experiences, potentially limiting the applicability of the study's conclusions to a broader international context. Moreover, the restriction to participants solely from the Republic of Moldova and Romania also raises questions about the transferability of the findings to educational systems with distinct structures and practices. Each country possesses its distinct own educational policies, curriculum frameworks, and pedagogical approaches, potentially limiting the study's ability to fully encompass the intricacies of other educational landscapes.

References

Alexander, P. A., Jetton, T. L., & Kulikowich, J. M. (1995). Interrelationship of knowledge, interest, and recall: Assessing a model of domain learning. Journal of Educational Psychology, 87, 559-575. https://doi.org/10.1037/0022-0663.87.4.559

Anderson, L. W., Krathwohl, D. R., et al. (Eds.). (2001). A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy of educational objectives. Allyn & Bacon. https://shorturl.at/rwNO6

Cabac, V. (2011). Conceptualizarea curriculumului universitar: logica competenţelor şi logica obiectivelor [The conceptualization of the university curriculum: the logic of competences and the logic of objectives]. Proceedings of "Alecu Russo" State University of Balti. Competence-based approach to university education: problems, solutions, perspectives. https://ibn.idsi.md/vizualizare_articol/92281

Cooksey, R. W. (2007). Illustrating Statistical Procedures: For Business, Behavioural and Social Science Research. Tilde University Press. https://hdl.handle.net/1959.11/2452

Demirel, M., & Gücüm, B. (2009). Scientific thinking skills of prospective teachers. 1st International Conference on Education and New Learning Technologies, 3834-3844. Barcelona. https://shorturl.at/syJS6

Dewey, J. (1997). How we think. Mineola. Dover Publications.

Dunbar, K., Klahr, D. (2012). Scientific thinking and Reasoning. In: Oxford Handbook of Thinking and Reasoning. (1st ed., pp. 611-628). Oxford University Press.

Eric M. Anderman, Gale Sinatra, M. (2018). The Challenges of Teaching and Learning about Science in the 21st Century: Exploring the Abilities and Constraints of Adolescent Learners. https://shorturl.at/vFT17

Guțu, V. (2011). Abordarea teleologică a competenţelor în sistemul de învăţămînt [The teleological approach to competences in the education system]. Proceedings of "Alecu Russo" State University of Balti. Competence-based approach to university education: problems, solutions, perspectives. https://ibn.idsi.md/vizualizare_articol/92283

Hackling, M. (2015). Preparing today's children for the workplace tomorrow: The critical role of STEM education. International Journal of Innovations in Science and Mathematics Education, 23(3), 59-62. https://core.ac.uk/download/pdf/229408375.pdf

Hyytinen, H., Toom, A., & Postareff, L. (2018). Unraveling the complex relationship in critical thinking, approaches to learning and self-efficacy beliefs among first-year educational science students. Learning and Individual Differences, 67, 132-142. https://doi.org/10.1016/j.lindif.2018.08.004

Joița, E. (2010). Metodologia educației. Schimbări de paradigm [Methodology of education. Paradigm changes]. Institutul European.

Koslowski, B. (2008). Theory and evidence: The development of scientific reasoning. MIT Press.

Kuhn, D. (2002). What is scientific thinking and how does it develop? In: U. Goswami (Ed.), Blackwell handbook of childhood cognitive development, 371–393. Blackwell Publishing https://doi.org/10.1002/9780470996652.ch17

Moles, A. (1975). Les théories de l'action [The theories of action]. Machette.

Paul, R., & Elder, L. (2003). A miniature guide for students and faculty to Scientific Thinking. Foundation for Critical Thinking. https://shorturl.at/oqCO5

Perjan, C., & Sanduleac, S. (2018). Increasing the quality of university studies through the development of students' scientific thinking. Journal of the Faculty of Technics and Technologies, Trakia University, 6(2). https://doi.org/10.15547/artte.2018.02.01

Popper, K. (2002). The logic of scientific discovery. Routledge Classics.

Lehrer, R., & Schauble, L. (2000). Inventing Data Structures for Representational Purposes: Elementary Grade Students' Classification Models. Mathematical Thinking and Learning, 2(1-2), 51-74. https://doi.org/10.1207/S15327833MTL0202_3

Șamsutdinova, R. G., & Shuvalova, E. M. (2016). Дидактические условия формирования профессионального мышления у студентов-историков [Didactic conditions for the formation of professional thinking in history students]. Monograph. Kazan: Kazan University. https://shorturl.at/crxLX

Shamos, T. (2012). Scientific literacy for all. Journal of Faculty of Educational Sciences, 40(2), 233-256.

Sternberg, R. J. (1997). Thinking Styles. Cambridge University Press. https://doi.org/10.1017/CBO9780511584152

Stumpf, H. (1995). Scientific Creativity: A Short Overview. Educational Psychology Review, 7(3), 225-241. https://doi.org/10.1007/BF02213372

Wightman, F.R., Kloppenberg, J.T. (1995). A companion to American thought. Blackwell.

Zimmerman, C. (2007). The Development of Scientific Thinking Skills in Elementary and Middle School. Developmental Review, 27(2), 172-223. https://doi.org/10.1016/j.dr.2006.12.001

Appendix

Table 1. Indicators and Descriptors for the Development and Enhancement of Scientific Thinking in Pedagogues

Nr.	Indicators	Descriptors of the development and efficiency of scientific thinking in pedagogues		
		Inferior level (1)	Middle level (2)	Superior level (3)
1. Knowledge				
1.1	Knowledge of the basic concepts of scientific thinking (item 1 and 2)	Explain 2-4 scientific concepts correctly (regarding scientific thinking)	Explain 5-7 scientific concepts correctly (regarding scientific thinking)	Explain 8-10 scientific concepts correctly (regarding scientific thinking)
1.2	Representations regarding the role of cognition and metacognition in the development of scientific thinking (item 6)	Know and characterize 1-2 components of cognition and metacognition and explain their role in the development of scientific thinking	Know and characterizes 3-4 components of cognition and metacognition, explaining their role in the development of scientific thinking	Know, explain and characterizes the components of cognition and metacognition and their role in the development of scientific thinking
1.3	Knowledge regarding the creation of conditions for the development of scientific thinking in students (item 4, 9)	Name 1-2 necessary conditions to be met to facilitate the development of scientific thinking in students	Identify the conditions that must be met to facilitate the development of scientific thinking in students, for each age stage	Identify the conditions that must be met to facilitate the development of scientific thinking in students for each age stage (mentions practical proposals)
2. Application				
2.1	Development of strategies (forms, methods, procedures, techniques) for the development of students' scientific thinking (item 5)	Name 1-2 methods and procedures focused on the development of scientific thinking in students	Identify forms, methods and procedures in the development of scientific thinking in students, taking into account the specific age (consistently explains each method	Elaborate methodical strategies for the development of scientific thinking in students, taking into account the specific age (consistently explains each form presented, explaining its influence on the

			presented)	development of scientific thinking)
2.2	Determining the personality traits that would facilitate the development of scientific thinking in students (item 8)	Name 1-2 personality traits necessary to facilitate the development of scientific thinking in students	Name 3-4 personality traits necessary for the development of scientific thinking in students, explaining the ways of modeling student behavior according to certain personality traits	Characterize the personality traits necessary for the development of scientific thinking in students, explaining the ways of modeling the behavior of students according to certain personality traits and the specific age
2.3	Developing the sense of curiosity and satisfaction in students to develop scientific thinking (item 3)	Know some methods of stimulating curiosity in children (shows 1-2 methods).	Systematically use 3-4 methods of developing a sense of curiosity and intellectual satisfaction in students	Use a set of methods to develop a sense of curiosity and wonder in students, also mentioning the specifics of the activity, didactic games, age-specific. Give details or present your own strategy used
3. Integration				
3.1	Competences to apply scientific knowledge to solve teaching/learning problems (item 10)	Mention 1-2 proposals for applying scientific knowledge in school practice	Proposes 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	Competencies to facilitate the development of scientific thinking in self and colleagues (training of trainers, lifelong learning) (item 11)	Elaborate 1-2 suggestions on facilitating the training of scientific thinking in colleagues/teachers	Elaborates a set of activities regarding the facilitation of the formation of scientific thinking among colleagues (in which it briefly describes some aspects of the	Elaborate an Agenda for promoting the development of scientific thinking among colleagues (in which it briefly describes the strategies for the development of scientific thinking,

			development of scientific thinking)	including methods of training scientific thinking, glossary of scientific terms, etc.)
3.3	Competences to apply scientific knowledge to solve existential / everyday problems (item 7)	Mention 1-2 proposals for applying scientific knowledge in daily / existential practice	Proposes 4-5 strategies for applying scientific knowledge in daily practice	Propose a project that contains strategies, practical solutions for applying scientific knowledge in everyday activity