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DEVELOPMENT OF SCIENTIFIC THINKING IN CONTEMPORARY UNIVERSITY EDUCATION: AN AMPLIFIED ANALYSIS

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Abstract: *The present paper elucidates the issue of developing scientific thinking in contemporary university education systematically, taking into account certain principles. The problem of forming scientific thinking in university education resides in two aspects. The first is related to students, their attitudes, skills, and motivation to develop scientific thinking. The second aspect concerns the ability of highly qualified teaching staff to ensure optimal development of scientific thinking in students. In this context, several internal and external factors contributing to the development of scientific thinking in university education are presented. As a result, three directions of intervention are proposed to shape scientific thinking at the initial and continuous training stage. As a basis, the analysis of the Domain-Specific Learning Model is proposed, which would allow students to assimilate scientific concepts limited to the field of their studies.*

Key words: *scientific thinking, principles, teaching staff, students, university education*

1. Introduction

In the 21st century, science influences our way of life and transforms our thinking and perspectives. It is an essential component of education, providing crucial tools for problem-solving and the practical application of acquired knowledge. The study of science develops skills such as formulating questions, collecting and organizing information, problem-solving, and the practical application of knowledge. This aspect becomes fundamental in lifelong learning and is integrated into all educational systems.

The impact of the study of science is felt not only at the individual level but also in the behavior of students, young people, and professionals, including teachers who promote the development of scientific thinking. International policies, such as the European Commission's Joint Research Centre 2030 Strategy, underline the importance of

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promoting research culture and scientifically literate citizens (The European Commission's Science and Knowledge Service, 2022).

In the digital age, with the transition to online education, the development of scientific thinking becomes crucial to overcome current challenges and to shape competent professionals adapted to socio-economic changes. This approach to scientific thinking is not only specific to researchers but has become an imperative condition in various fields of activity.

Thus, promoting and enhancing scientific thinking among educators in initial training and continuous education remain essential priorities in educational transformation and in preparing a new generation adapted to contemporary requirements.

In the literature, scientific thinking is presented as a higher-order cognitive mental process, oriented toward a specific goal based on profound functional scientific knowledge, formed by metacognition, declarative, procedural, and contextual knowledge. Here, the subject of knowledge examines the implications of ideas, compares viewpoints through scientific reasoning and arguments, and defines their attitude towards the surrounding reality, having the capacity to develop the quality of thinking. This is grounded in the values of knowledge, intelligence, and morality, oriented towards self-awareness and understanding of others (Sanduleac & Cuzneţov, 2021).

The Imperative of Quality in Education in the face of pandemic-related changes, technological ascendance, and beyond necessitates a reconsideration of the educational approach of the teacher. Consequently, the elaborated didactic strategies ought to be centered on cognitive learning and the modeling of student thinking (Panfilova, 2008). Another priority encompasses the development of an optimal framework for the coherent implementation of learning activities from the perspective of scientific thinking formation.

2. Theoretical Aspects regarding Scientific Thinking and its Determinants

From the analysis of the main theories regarding the modeling of scientific thinking, it has been observed that the unified training of cognitive mechanisms, stimulation of creativity, and learning through problem-solving are imperatively necessary. Thus, the integrative approaches to the phenomenon of scientific thinking assumes a comprehensive analysis of each phenomenon, the theory of multiple intelligences, strategies for optimization, and the qualitative modeling of student thinking (Gorobeț & Raileanu, 2021). A special role is attributed to scientific education, representing a strategic priority at the international level and contributing to the development of scientific thinking (Layton, 1981), serving as the foundation for optimizing the educational approach of the teaching staff.

Analyzing the literature regarding the principles of scientific thinking development, we observe the existence of multiple factors contributing to scientific thinking development. Creativity, abilities, behavior, personality Traits are included among these factors. They can be divided into intrinsic (Internal Factors, Such as Personality Traits or Experience) and extrinsic (External Factors, Primarily Related to the External Environment). There are factors involving the natural (inherent) development of scientific thinking, closely tied to aspects and elements of psychological development, consisting of artificial intervention in the development of scientific thinking and representing an infrastructure for scientific thinking formation. In our view, these can be divided into three main units of intervention: the operational aspect, the intellectual aspect, and the personality component. From a psycho-pedagogical intervention procedural perspective, this is indeed favorable. From an educational perspective, if we take into consideration the educability of thinking in general and scientific thinking in particular, it is necessary to enhance the trainee's capacity to be receptive to educational influences and, thus, achieve progressive accumulations manifested in different personality structures - the ensemble of possibilities to influence, through educational means, the formation of personality and the inborn characteristics that confer individuality to each (Vinnicenco, 2019). In this case, we will refer to the educational factor that aims to shape scientific thinking. Here, we can discuss the "formative potential - predominantly of a psychic nature and refer to thinking abilities, assimilation strategies" (Mogonea, 2010, p. 45).

The main goal in shaping scientific thinking is to make those undergoing training more efficient in scientific research and the resolution of scientific and social problems. The complexity of the process of forming scientific thinking stems from the fact that it cannot meet only pedagogical but also must include psychological conditions. Characteristics of the scientific thinking mode include objectivity, logic, continuity, depth, inter-, multi-, and transdisciplinarity (Sanduleac & Cuzneţov, 2021). The potential for training from a pedagogical and developmental psychology perspective involves at least two approaches implemented through activities to enhance scientific thinking and activities to model scientific thinking. Enhancing scientific thinking is characteristic of individuals with a certain potential for scientific thinking development, such as teachers, and scientific researchers, and aims to increase the depth of research and observations on the functioning of interconnections: thinking - scientific thinking - professional thinking - everyday thinking - lateral thinking - creativity - efficiency - professional and existential performance (Sanduleac & Cuzneţov, 2021).

To ensure an optimum development of scientific thinking within university education, a multidimensional approach involving three intervention directions is necessary. The intervention direction related to incursions into the trainee's personality involves improving communicative and organizational skills and changing the attitude toward the learning process, allowing the optimization of the trainee's creative potential (Sanduleac, 2017). In this context, knowledge components based on metacognition are welcomed. Only the harmonization of metacognitions and the choice of an effective form for developing metacognitive capacities can serve as support for personality development (Voiculescu, 2011).

The intellectual intervention direction implies the development of cognitive abilities of the trainees. To facilitate the operational aspects of thinking, an individual must possess a specific intellectual foundation, which according to the literature, takes the form of scientific literacy or scientific knowledge. There is international consensus that scientific literacy represents an essential objective of science education (Roberts, 2007). Scientific literacy is presented firstly as an ascending, dynamic, and continuous process, and then analyzed as a measurable product that involves understanding the main concepts and principles of science, awareness of limits in various fields, having the ability for scientific thinking, and using science and scientific thinking for personal and societal goals (Bybee, 2015). At this point, there is a transition from metacognitive skills to the consolidation of declarative, factual, and conceptual knowledge, where the trainee, within the intellectual intervention direction, accumulates specific scientific information by evoking knowledge about a particular scientific phenomenon, with the conceptual ability to understand and classify the accumulated information, comprehend relationships and connections between concepts, and provide scientific explanations. This enables reaching a level of comprehension in understanding phenomena by capturing, and discovering the meaning, essence, or significance of a thing, object, phenomenon, event, or fact, resulting in the development of a solution to a significant problem.

The operational intervention direction involves the development of analytical and critical thinking skills. An essential characteristic of scientific thinking that gives it superiority over critical thinking is comprehension - the subject's ability to understand, including depth of understanding, completeness, promptness, coherence, and scientific context (Sanduleac, 2017). Scientific context provides an opportunity for further transcendence from declarative, factual, and conceptual knowledge to contextual and procedural knowledge. This implies that the trainee will work with problematized situations in the field of science, seeking solutions through knowledge, scientific analysis skills from other works, and practical skills in developing their scientific work, reflecting a certain level of development of scientific thinking (Sanduleac & Cuzneţov, 2021).

Returning to the personality dimension, to advance in the efficiency of scientific thinking, the trainee must possess specific personality traits. Therefore, to be scientifically creative and satisfy the inventive component, R.S. Mansfield and T.V. Busse highlighted six personality traits that have consistently correlated with success in science and proposed a model consisting of four personality traits: autonomy, personal flexibility, openness to new experiences, and sensitivity to aesthetic things. These help the trainee avoid constraints and establish a commitment to work and the need for professional recognition (Stumpf, 1995). G. Feist concluded that openness is one of the fundamental factors that differentiate scientists from those who do not possess a predominant scientific thinking style (Feist, 1998). There are numerous practical implications of openness as a key trait for individuals with a predominant scientific thinking style. Firstly, openness is relevant for career planning, for students considering specializing in scientific activity, for school students, and for individuals considering becoming scientists (Lounsbury et al., 2012). Openness represents the path to self-actualization, providing the individual with the opportunity for personal development and being a fundamental characteristic of a perseverant and efficient trainee in scientific education (Stamatin, 2017).

R. J. Sternberg argued 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 labeled these six attributes as the Investment Theory because, in the author's opinion, investment assumes that an individual makes a conscious choice to see a final result for gain. Therefore, R. J. Sternberg clarifies that the attributes in the investment theory are "inputs" into the result of a creative process (Sternberg, 1997). D. W. MacKinnon cited by H. Stumpf, highlighted the major issue of most studies being more retrospective than creative, focusing on attempts to solve problems with the latter having success. Because less capable trainees, try to copy, not create, from a desire to create something new, or they cannot do it as well as students with high potential of scientific thinking. D. W. MacKinnon postulates that at this stage, subjects of scientific thinking 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).

In conclusion, certain personality traits favor the development of scientific thinking in university students, and, at the same time, the low levels of these personality traits or, more precisely, their negative polarity creates shortcomings in persevering in scientific thinking skills. Therefore, a student with a predominant scientific thinking style will have the courage to face obstacles, demonstrate collective involvement in a study; be able to assert their point of view; act quickly and take risks; be self-confident, optimistic, energetic; prefer variation and diversity; have the ability to get to the essence of the problem; demonstrate independence in action, be self-critical and willing to experiment, allowing them to persevere in the performed activity and seek to meet new people to exchange experiences, being always ready to learn something new (Sanduleac, 2017).

The intellectual factor involved in the development of scientific thinking encompasses profound scientific knowledge, scientific literacy, and the ability to approach issues scientifically. This entails an understanding and application of scientific vocabulary, persistence in problem-solving, the establishment of causal connections between phenomena, comprehension, explanation, and beliefs about the nature of knowledge (Faye, 2014).

Sufficient content knowledge is requisite for rational and critical scientific thinking. According to The Model of Domain Learning (MDL) proposed by P. A. Alexander (Alexander, 1995), learners must progress to the competence stage of knowledge development before possessing enough knowledge to engage in critical reasoning. Therefore, instructors must assess the fundamental knowledge level of students and identify misconceptions and alternative concepts before addressing each new subject. All these take the form of scientific literacy that must be considered by the educational framework (Alexander, 1995).

This corresponds to the initial stage in The Model of Domain Learning (MDL) proposed by P. A. Alexander, involving familiarization with limited domain knowledge. Domain knowledge refers to the breadth of knowledge in a field, and subject knowledge pertains to the depth of knowledge about specific topics in that field. The lack of knowledge and experience during this phase poses risks for students to have limited individual interest or situational interest influenced by environmental and cultural factors. Consequently, due to this lack of knowledge and interest, acclimating students lack the strategic processing skills necessary to master content, which materializes in the second stage as competencies, including an increase in domain knowledge, and familiarization with scientific notions and concepts. Due to this broader and deeper knowledge base, students can apply various information processing strategies from simple to complex

(Alexander, 2004). According to T. Shamos, this would imply the stage of functional scientific literacy, which refers to the ability to master the scientific lexicon and to be capable of conversation, coherent reading, and writing using scientific terms, not necessarily in a specific context but still meaningful (Shamos, 2018).

Scientific thinking cannot be perceived outside the act of learning, without which its development would not have been possible due to the lack. The confirmation of this fact is found in numerous scientific research studies; therefore, it is opportune to include instrumental strategies of self-regulated learning in the program for the development of scientific thinking (Zimmerman & Schunk, 2001).

This situation is characteristic of students and young researchers aspiring to achieve significant results in a limited time and who aim to obtain investigative competence. Simultaneously, self-regulated learning contributes to fostering independent thinking, emphasizing personal understanding through exploration, research, problem-solving, and creative activities.

Such changes in knowledge and strategic processing are further associated with the increase in individual interest since learners no longer have to rely on situational characteristics of the environment to pay attention to presented scientific content. The third stage, competence, is marked by a strong and deep knowledge base as well as high individual interest. More importantly, learners use deep cognitive processing strategies to explore the domain with probing questions and new ideas. P. A. Alexander asserts that few ever reach this stage (Alexander, 2004).

The Domain Learning Model (DLM) is advantageous in several facets that differentiate it from traditional expertise models. Firstly, while other models examine expertise as manifested in specific activities (e.g., dance, medical diagnosis), the DLM focuses on development in academic domains. This focus helps guide educators in teaching approaches and allows for a better understanding of learners. Additionally, this model considers affective factors (e.g., interest, motivation), often overlooked in traditional expertise models.

Another procedurally elucidated direction in the training of scientific thinking in teachers and students is related to the operational aspect. The operational component refers to how students think, what they are involved in when problem-solving, and how they ultimately act. This component demonstrates the ability to integrate information and concepts into existing knowledge, determine and establish connections between different disciplines (interdisciplinarity), support thinking with logical reasoning, formulate judgments using scientific criteria, standards, and principles, apply what has been learned in new situations, make generalizations, and make assumptions based on data. Most of these skills are related to the ability to think critically and logically as defining elements of scientific thinking. From the functional perspective of scientific thinking, critical, logical, and analytical thinking serve as operational components of scientific thinking, facilitating its development. In this case, it can be stated that the structure of critical thinking is very similar to that of scientific thinking (Magno 2010).

M. Demirel and B. Gücüm argue that the high level of scientific thinking is formed in the initial training stage and then developed through continuous training. But this is possible through the training of specific competencies like creativity and research or problem-solving skills (Demirel & Gücüm, 2009).

3. Conclusions and Discussion

It is essential to emphasize that the development of scientific thinking in university education is a complex challenge, and addressing this issue requires a deep understanding of the involved factors. The role of professors in the development of scientific thinking in university education is crucial as the professor becomes the architect of this essential formative process. Professors in higher education act as essential mentors, providing not only academic knowledge but also guidance and modeling. Interactions with these mentors directly influence the critical and analytical skills of students, fundamental elements of scientific thinking. Scientific thinking is often a collaborative effort. Professors create environments that encourage teamwork and the exchange of ideas. These social skills are as essential as technical knowledge in a scientific context. It is important to mention the necessity of training teaching staff to promote the systemic development of scientific thinking in university education.

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