INCREASING THE QUALITY OF UNIVERSITY STUDIES THROUGH THE DEVELOPMENT OF STUDENTS' SCIENTIFIC THINKING

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Abstract: *The paper examines theoretical perspectives of scientific thinking development in university students as an element of quality. Scientific thinking is a key element that serves as a base in scientific and professional formation of university students. The problem of its development in students was first raised in 20th century. Students encounter the activities in line with their professional goals but there are no specific activities oriented specifically towards scientific thinking development. As a result of this study, a theoretical model of scientific thinking development is proposed. It is based on three components that suggest a solution to improve quality in university studies, and enable ways for students to explore the concepts of spinning across the science projects. It is also presented a psychological portrait of a student with high level of scientific thinking and the most important traits that emphasize cognitive dispositions are highlighted. This can engage and also help students to make a research and to be creative in their own scientific activity.*

Keywords: *scientific thinking, skills, students, quality, studies, development, components of scientific thinking.*

1. INTRODUCTION

At the end of the twentieth century, the popularization of science became a defining phenomenon. With the emergence of global information networks, the role of the teacher changes, associating with the pretense of building the learning process from the perspective of research technology accessible to those who live a daily investigative practice [31]. Synthesizing the concerns about capitalizing on the personality of the student and ensuring quality education, we note one of the priorities of quality of university studies - the formation/development of scientific thinking in university students. Scientific policy is a phenomenon of the third millennium. Under the new conditions, the formation of research competence becomes an educational priority, which explains the concern of researchers with this subject [24].

Whereas the need for scientific advances is at its peak, adolescent learning about science in school is facing critical challenges [6] and there is no connection between high school and undergraduate studies in the field of science education.

"Scientific inquiry has its roots in the inherent restlessness of the human mind. We humans have pursued our passion to explore far beyond any other inhabitant of the planet. Curiosity is the basic human trait that has ensured both our survival as a species and our continuous cultural evolution" [18, p. 5].

That's why scientific thinking as a process that facilitate scientific inquiry, has been worldwide the source of both technological superiority, economic and social well-being.

J. S. Woolley and other scholars identified notions such as scientific process skills, procedural skills, experimental and investigative science, habits of mind, scientific inquiry abilities, or scientific reasoning skills intentional knowledge-seeking behaviors and the coordination of theory and evidence; the skills involved in inquiry, experimentation, evidence

evaluation, and inference that are done in the service of conceptual change or scientific understanding [29, p. 102].

Others have defined them as “critical thinking skills” or just “critical thinking” [22] or ‘science process skills’ encompassing the skills used by scientists, such as identifying causal questions, proposing hypotheses, predicting outcomes, modeling, using mathematical reasoning, interpreting graphs, etc. [10].

According to C. Magno, a psychological perspective in the study of scientific thought can provide a model to understand and further explain expertise and exemplified skills, derive processes that help educators develop students with potential scientific-related careers, focus on skills that further strengthen the scientific thinking for practitioners in science, and integrate other psychological variables to create theories to explain it [16].

The aim of this paper is to reveal essential characteristics of a good scientific thinker and the possibilities to develop scientific thinking in university students under specially organized conditions integrated into a special course dedicated to this purpose, to advance in scientific creativity and discovery in an appropriate time.

2. THEORETICAL BACKGROUND

There are two paths that can lead us to what scientific thinking is, how to develop it, and what are its components. The first vision is philosophical one and it involves aspects of truth, reality, subjectivity of thinking and where did it actually come from [13].

The second approach (direction) is based on psychopedagogical aspects, how to motivate students to do science in educational context, to think like a scientists, to develop specific research skills and how to actively participate in it, presented in John Dewey's model of learning through reflective inquiry [4, 5], W. R. Torbert [27], B.L. Hall, R. Tandon [9], W. F. White [28] and others (Participatory Approach to Research); Poddyakov A.N. (research behaviour) [34]; W. H. Kilpatrick [20], N. Iu. Pahomova [33], V.V. Guzeev [32], O.G. Smolyaninova [35], (project method); J. Bruner [2] D. Patrascu [19] (research technology and discovery learning). D. Klahr, D. Kuhn, C. Zimmerman [30], Schauble L. [23], C. Magno [16] (scientific thinking and reasoning skills). R. S. Mansfield and T. V. Busse, D. W. MacKinnon [26] D. N. Jackson and J. P. Rushton [11], G. J. Feist [8] (personality traits in scientific creativity).

There are a lot of factors that contribute to scientific thinking development such as 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, which are mainly related to the external environment). There are factors that include natural development of scientific thinking and are closely related to psychological developmental aspects and elements that consist of artificial intervention in development of scientific thinking and represent an infrastructure of scientific thinking forming. In our opinion these can be divided in three main units: *operational side*, *intellectual aspect* and *personality components*.

At first, a highly capable science student, in order to advance in scientific thinking has to possess specific personality qualities. Therefore, in case of scientific creativity, R. S. Mansfield and T. V. Busse summarized the existing findings and concluded that six personality and motivational variables have consistently been shown to correlate with success in science and proposed a model consisting of four entities: autonomy, personal flexibility and openness to new experiences, as well as aesthetic sensitivity, that helps the “creator” both to set and change constraints; and commitment to work and need for professional recognition are essential for the process of elaboration and verification [26, p. 232].

D. N. Jackson and J. P. Rushton have found other important personality characteristics associated with scientific creativity that include low sociability, aggressiveness, dominance, and introversion [26, p. 232].

The same conclusion was found in another study dedicated to the personality of scientists. It was argued, that scientists are less sociable, outgoing, affiliative, gregarious, and expressive; in short, they are less extraverted, less stable, less assertive, anxious, and more emotionally reactive; gloomy, and cynical; immersed with their own thoughts, and unaffiliated; pessimistic but more open to new (and sometimes radical) ideas, willing to experiment, and inclined to seek out variety and novel experiences.

J. W. Lounsbury and others investigated the personality traits of scientists versus nonscientists and their relationship with career satisfaction. They concluded that scientists tend to be more pessimistic and they were also distinguished by lower levels of assertiveness. Scientists scored lower on conscientiousness than nonscientists, but at the same they have such characteristics as time tough – mindedness, introversion and openness [8, 15].

According to G. Feist, relative to nonscientists, scientists are confident, secure, conventional, dominant, skeptical and disciplined. G. Feist has concluded that openness is one of the clearest factors differentiating scientists from nonscientists [8, p. 294].

There are manifold practical implications of openness being a key trait for scientists. First, openness has relevance for career planning, both for students contemplating majoring in science in school, and for individuals who are thinking about becoming a scientist [15, p. 53]. Based on the previous studies, it can be concluded that psychologists still need research focused on the field of science that include a broad range of topics related to students' scientific thinking and formation. For a student to be considered as a potentially highly able scientific thinker, as a scientific creator, these particularities should be inherent.

R. J. Sternberg postulates that new scientific discoveries require the disposition or preference for engaging but also involves intellectual abilities, knowledge, and motivation, as does the problem solving capacity. He characterizes these dispositions as "thinking styles" [25].

D. W. MacKinnon highlighted the problem of most studies that are retrospective more as creative and are focused on problem solving attempts that finally are successful. Because the less able scientific thinkers try to copy, not to create with the desire of something new, or he cannot do it as well as highly able scientific thinker. The scientist posits, as far as this stage is concerned, psychologists need a better understanding of the cognitive and motivational processes involved [26, p. 238].

To support the idea of personality qualities of university students that are in process of their professional training, it was outlined the psychological portrait of university student with high level of scientific thinking based on a research made in different faculties and universities from Republic of Moldova [21].

As it can be seen, a student with high level of scientific thinking is characterized through high implication in research action and collective implication in an inquiry doing; is able to impose its own point of view; to acts quickly and takes risks efficiently; is self-confident, optimistic, energetic; prefers variation and diversion; has an ability to get into the essence of the problem; is tolerant and understanding; manifests independence in action, self-criticism; is willing to experiment. Compared to deliberate scientific thinkers, young scientists that are still in process of scientific and professional development are prone to be: more affiliative, optimistic, tolerant and understanding. But in both cases the important common element is openness that creates conditions to different perspectives, ideas, people, and situations, and disposal to a wide range of thoughts, feelings, and new scientific problem-solving strategies. The disposition of openness involves first and foremost a response style of approach or avoidance of new ideas, people, or situations [8, p.300].

Figure1.

The psychological portrait of the student with high level of scientific thinking [21, p.150]

Finally, it can be mentioned that there are certain personality traits that favor the development of students' scientific thinking and at the same time the lack of these personality traits or, more precisely, their negative polarity create remarkable shortcomings to persevere in scientific thinking skills. Therefore, a good young scientific thinker will always have the boldness to face the obstacles, which will allow him or her to persevere in work and will seek to meet new people to exchange experience, being permanently ready to learn something new [21].

Another issue in forming scientific thinking is related to operational side. Operational component means how students think, what it is involved in problem solving, how they finally act. This component demonstrates the ability to integrate information and concepts into existing knowledge base, sees connections between science and other disciplines, supports thinking with logical reasoning, the ability to make judgements using criteria and standards, the ability to apply what is learned to new situations, makes generalizations and assumptions based on data. Most of these skills are related to the ability to think critically and logically. From the functional perspective of scientific thinking, critical and logical thinking appear to be operational components of scientific thinking. Critical thinking is in immediate proximity to scientific thinking, constituting the precursor it, thus creating the necessary conditions for its further development. In this case we can mention that the critical thinking structure is very similar to that of scientific thinking [16, 21].

M. Demirel M and B. Gücüm, argue that in order to have a high level of scientific thinking, it has to be formed from the initial training stage and then developed through continuous training. But this is not possible without a high level of critical thinking, creative and research and problem solving skills [3].

According to J. S. Woolley the common false strategies used by undergraduate students lead to critical failures in using scientific reasoning [29].

The last factor implied in scientific thinking development is intellectual one and supposes extensive scientific knowledge based in science and ability to relate that knowledge base to new problems and topics, problems view in a scientific manner, understanding and applying advanced scientific vocabulary, persistence in the pursuit of science knowledge or solving a problem, experiencing the world as structured by causal connections between phenomena, understanding, explanation and beliefs about the nature of knowledge and knowing [6, 7].

Sufficient content knowledge is necessary to reason and think critically and scientifically. According to Alexander's Model of Domain Learning [1], students need to move toward the proficiency stage of knowledge development before they have sufficient knowledge with which to reason critically [6, p 25].

3. RESULTS AND DISCUSSION

The present paper involves the construction of the concept of "scientific thinking" derived from the conceptualizations of different authors like K. Dunbar, C. Zimmerman, D. Kuhn, C. Mango and others in order to facilitate the process of scientific thinking development in university students, the ability to think adaptively and reason about complex of scientific problems that requires weighing issues and arguments and considering alternative points of views. Even if a teacher or a trainer provides the appropriate environment to support scientific thinking and reasoning, students often lack the requisite background knowledge and skills to do so effectively.

Figure 2.

Theoretical scientific thinking model: ST-scientific thinking; CT-critical thinking; LT-logical thinking; I-intelligence; OS-organizational skills; CS-communicative skills

According to presented theoretical model, the scientific thinking can be developed only if specific conditions and principals are respected. At first, there are some components that cannot be neglected. These components are strongly related with every part of scientific thinking starting with: scientific knowledge, skills, capacity of reasoning and understanding, metacognition, and ending with scientific methods.

All factors are interdependent. The critical thinking as the operational component is in direct proximity to scientific thinking, being the basic operational component that assures the good functioning of scientific thinking. At the base of the model stay personality peculiarities that form a solid base consists from attitudes, beliefs, orientation.

4. REFERENCES

- [1] Alexander P. A., Jetton T. L., & Kulikowich J. M. Interrelationship of knowledge, interest, and recall: Assessing a model of domain learning. *Journal of Educational Psychology*, 87, 1995. pp. 559-575.
- [2] Bruner J. *The Process of Education*. Cambridge, MA: Harvard University Press. 1960. p. 93
- [3] Demirel M, Gücüm B. Scientific thinking skills of prospective teachers. 1st International Conference on Education and New Learning Technologies 6-8 July, 2009. Barcelona. p. 3834-3844.
- [4] Dewey J. *How we think*. New York: Mineola. Dover Publications, 1997. 240 p.
- [5] Dimova Y., Kalina Kamarska K. Rediscovering John Dewey's model of learning through reflective inquiry Problems of education in the 21st Century Vol. 63, 2015. pp. 29-39. http://www.scientiasocialis.lt/pec/files/pdf/vol63/29-39.Dimova_Vol.63.pdf [2018-04-28].
- [6] Eric M. Anderman, Gale M. Sinatra. The Challenges of Teaching and Learning about Science in the 21st Century: Exploring the Abilities and Constraints of Adolescent Learners. https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_072608.pdf [2018-04-28].
- [7] Faye J. *The nature of scientific thinking*. Palgrave Macmillan, London, 2014. 333 p. DOI 10.1057/9781137389831
- [8] 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
- [9] Hall B. Tandon R. Tremblay C. *Strengthening Community University Research Partnerships: Global Perspectives*; University of Victoria: Victoria, BC, Canada, 2015
- [10] 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.
- [11] Jackson D.N., Rushton J.P. *Scientific excellence: origins and assessment*. Newbury Park, Calif: Sage Publications; 1987. 381 p.
- [12] Klahr D., Li Ju. *The Psychology of Scientific Thinking: Implications for Science Teaching and Learning*. Teaching Science in the 21st Century. National Science Teachers Association and National Science Educational Leadership Association. NSTA Press. 2006. https://www.researchgate.net/publication/228379207_The_psychology_of_scientific_thinking_Implications_for_science_teaching_and_learning
- [13] Klempe S.H. The Aspect of Subjectivity in Scientific Thinking - Where Did It Actually Come From?. Preprints 2017, 2017090147 doi:10.20944/preprints201709.0147.v1
- [14] 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
- [15] Lounsbury J.W, Foster N, Patel H, Carmody P, Gibson L.W, Stairs D.R. An investigation of the personality traits of scientists versus nonscientists and their relationship with career satisfaction: Relationship of personality traits and career satisfaction of scientists and nonscientists. *R&D Management*. 2012; 42 (1): 47-59. <https://doi.org/10.1111/j.1467-9310.2011.00665.x>.
 - [16] Magno C. A Measure for Scientific Thinking. *The International Journal of Educational and Psychological Assessment*. December 2010, Vol. 6(1) pp. 71-86
 - [17] National Research Council. *Exploring the Intersection of Science Education and 21st Century Skills: A Workshop Summary*. Washington, DC: The National Academies Press. 2010. <https://doi.org/10.17226/12771>
 - [18] National Science Foundation.. *Fondations Volume 2: A monograph for professionals in science, mathematics, and technology education*. 2000. Retrieved from: <http://www.nsf.gov/pubs/2000/nsf99148/start.htm>.
 - [19] Patrașcu D. *Tehnologii educaționale*. Chișinău: Î.S.F.E.P „Tipogr. Centrală”, 2005. 704 p.
 - [20] Pecore J. L. From Kilpatrick’s Project Method to Project-Based Learning. *International Handbook Of Progressive Education*, 2015 pp. 155-171.
 - [21] Sanduleac, S. *Formarea gândirii științifice la studenții din învățământul universitar*. Red. șt. Racu Jana. (Monografie). Chișinău. Ed. Garomont Studio. 2017. 231 p.
 - [22] 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.
 - [23] Schauble L. The development of scientific reasoning in knowledge-rich contexts. *Developmental Psychology*, 32, 1996. pp. 102-119.
 - [24] Scifos L. *Repere psihopedagogice ale competenței investigaționale: Autoref. tezei dr. ped.* Chișinău 2007. 28 p.
 - [25] Sternberg R. J. *Thinking Styles*. New York, NY: Cambridge University Press.1997.180 p.
 - [26] Stumpf H. Scientific Creativity: A Short Overview. *Educational Psychology Review*. 1995. 7(3). pp. 225-241. <https://doi.org/10.1007/BF02213372>.
 - [27] 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>
 - [28] White W.F. (Ed.). *Participatory action research*. Newbury Park, CA: Sage. 1991. 247 p.
 - [29] Woolley J.S., Deal A.M., Green J., Hattenbruck F., Kurtz S.A., Park T.K.H., et al. Undergraduate students demonstrate common false scientific reasoning strategies. *Thinking Skills and Creativity*. 2018, 27. pp. 101-113. <https://doi.org/10.1016/j.tsc.2017.12.004>.
 - [30] Zimmerman C. The development of scientific thinking skills in elementary and middle school. *Developmental Review*, 27, 2007. pp. 172–223.
 - [31] Gershunsky B. Computerization in education: problems and perspective. *M. Pedagogy*, 1987. p. 264.
 - [32] Guzeev V. *Planning of Educational Results and Educational Technology*. M.: Populalry Education, 2000, p. 240.
 - [33] Pahomova N. *Method of the educational project in educational institutions: A Handbook for teachers and students of pedagogical universities*. Moscow: ARCTI, 2005. p. 112.
 - [34] Poddyakov A. *Research behavior: strategies of knowledge, assistance, opposition, conflict*. M.: Erebus; Third edition, corrected. and additional. 2006. p.372
 - [35] Smolyaninova O. *Case - the method of teaching students*. <http://ipps.sfu-kras.ru/sites/ipps.institute.sfu-kras.ru/files/publications/57.pdf>.