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Pedagogical and Psychological Characteristics of Developing Students' Scientific Literacy Based on PISA International Assessment Program Requirements

Gulchehra Zokirjon qizi Rahmonova

3rd Year Doctoral Student at A. Avloniy National Institute of Pedagogical Skills, Uzbekistan

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Abstract: This article discusses the factors influencing students' scientific literacy and the pedagogical-psychological characteristics of shaping scientific literacy.

Keywords: Natural sciences, experiment, factor, law, phenomenon, curriculum, laboratory, textbook, exact sciences, excursion.

Introduction: Currently, the task of developing students' scientific literacy in natural sciences has become one of the urgent issues facing educators. Solving the problem of developing students' ability to apply the knowledge and skills acquired in various fields at school and outside of school in life is a result of the new educational principles expected from schools. The fundamental innovation in this lies, first and foremost, in a new approach to pedagogical thinking, where there is a new attitude toward the results of knowledge that ensure well-being in life and are demonstrated through the ability to solve life's problems constructively. In traditional education, emphasis was placed on students' memorization abilities, but now there is a demand to develop students' skills to independently acquire knowledge and use the knowledge acquired to solve real-life problems. As a result, the ability to solve educational problems based on acquired knowledge

and facts, or the ability to act in real-life situations, is formed. The world, which is constantly evolving, requires us to form more scientifically literate individuals to address the global changes humanity is facing.

Scientifically literate individuals will be able to explain and potentially mitigate scientific and global issues and make rational decisions. Understanding issues such as global warming, loss of biodiversity, evolution, the impact of genetic research, and many other topics in the context of sustainable development is crucial, if not essential, for personal participation. Moreover, the modern economy is primarily based on science and technology, and we need technically literate citizens capable of solving complex problems. These challenges stem from internal factors (students' readiness in STEM subjects, process skills, conducting scientific research, and implementing scientific projects) and external factors, such as the insufficient preparation conditions provided by teachers and schools, which do not contribute to the development of scientific literacy.

In order for every person to live well and make rational decisions in problematic situations, they must be scientifically literate. Furthermore, scientific literacy is also important in the workplace. Today, many jobs require highly skilled personnel, and the ability to think creatively and make quick, rational decisions is an essential indicator. Understanding science and its processes contributes significantly to developing these skills. Therefore, scientific literacy is considered the primary goal of studying science in various parts of the world. Many countries are investing significant resources to train scientifically and technologically literate professionals. This is also helping to prepare employees who can compete with other nations. Regardless of the level of education, every citizen must possess the concepts of scientific literacy. Students can only achieve high results under the guidance of a qualified teacher. Furthermore, sufficient study time and modern educational resources are also of great importance.

In-depth study of processes in natural sciences further develops students' skills and competencies, such as observation, drawing conclusions, conducting experiments, and research. These are considered the core or the essence of learning sciences. By establishing interactive communication among students, their activity can be enhanced. In this process, students describe objects and phenomena through surveys, ask questions, form explanations, and explain their interpretations using the knowledge gained. As a result, students identify their assumptions, learn critical and logical thinking, and acquire the skills to search for alternative solutions.

Scientific literacy is the ability to develop scientific and critical thinking and make rational decisions based on the knowledge acquired. Scientific literacy leads to understanding the importance of education and science in contributing to social development and leads individuals to value science. The concept of scientific literacy has a broad meaning, and there are two different perspectives in its interpretation. The first group of scholars considers understanding content (the main concepts of science) to be a fundamental component of scientific literacy. Moreover, the representatives of this group believe that scientific literacy also plays an important role in acquiring life skills. The second group emphasizes that scientific literacy is equally important not only for those who are specialists in science or who have chosen science-related fields but also for everyone. Given the importance of scientific literacy, preparing students for scientific literacy is one of the main goals in any educational reform.

Scientific literacy allows for identifying national problems and solving them at the local level. A literate society can assess the quality and reliability of scientific information based on the sources and methods used, as well as develop the skill of drawing conclusions based on scientific evidence. Scientific literacy is an essential skill that every individual must possess to improve the quality of life and embrace the development of science and technology. Therefore, it is crucial to teach scientific literacy to students from a young age for the future generation. This process starts with creating an educational environment that helps raise scientifically literate individuals.

Today, the main task of education is to ensure that students acquire the skills necessary for a prosperous life in society, both in the present and future. For this, students must first develop creative thinking skills. Creative thinking helps them adapt to the rapidly developing world. In general, today's students are expected to work in fields that may not even exist at present, solving new problems through new technologies. Creative thinking allows the resolution of increasingly complex local and global issues based on unconventional approaches. Teaching scientific literacy in schools is not easy, although it is one of the most essential indicators in education during the current industrialization period. This research is aimed at analyzing the level of students' scientific literacy abilities and the obstacles they face in school. Observations revealed that, in addition to explaining phenomena scientifically, students in every school are not well-developed in their abilities to design and assess scientific research, analyze data and scientific evidence.

The existence of these obstacles hinders students' ability to understand scientific literacy.

Natural sciences are a branch of knowledge that believes the world is governed by natural laws and studies it rationally. The methodology of natural sciences differs from that of social and exact sciences. Natural sciences include subjects such as astronomy, physics, geography, chemistry, and biology. In the methodology of natural science teaching, various forms of organizing the educational process are defined. These include lessons, which are the main form of teaching, along with excursions, homework, extracurricular activities, and optional extracurricular lessons. These forms together create a system of teaching natural sciences.

The famous methodologist Yu.K. Babansky, based on his research, states: "Misjudging a principle, as well as granting excessive privileges—absolutizing—is also not possible. The success of the educational process is ensured by applying all didactic principles in interconnection and to the necessary extent." A person's special characteristics and comprehensive development cannot be achieved without focusing on their pedagogical and psychological thinking, as well as their professional innovative activity. The term "method" generally refers to the path the educator takes to achieve a certain goal. In the educational process, specific methods are used. The teaching methods are based on organizing and managing the cognitive activity of students, ensuring cooperation between the educator and students. These methods lead the entire educational process at all stages, and are often used in combination, with visual methods frequently performing the role of a locomotive function.

The main form of teaching is the lesson, which plays a linking role and occupies a leading position in teaching. Lessons, excursions, homework, extracurricular work, and extracurricular activities together ensure the achievement of general educational goals set for teaching natural sciences, helping students master the learning material and analyze the results obtained. Guidelines for teaching science in the 21st century require viewing subjects like physics, geography, biology, and chemistry as abstract or natural sciences together. Topics like Newtonian mechanics and Maxwell's laws have been removed from textbooks or replaced with subjects like "Light and Energy" [Jordan, 2009] or "Energy Sources and Their Use" [Miller, 2011]. In Poland, as part of the reform of the school curriculum called "Curriculum Fundamentals," biology, physics, chemistry, and geography were removed from secondary education and replaced with a general science course [Men, 2008]. Humanities subjects are taught to all students who have chosen this field as their specialty. The new program, adopted in 2007, did not have textbooks created in advance, and no special teacher training sessions were organized at universities. In 2012, considering the urgency of incorporating new curricula into schools, the Ministry allowed teachers of any subject to teach the entire course. As a result, there was a need to explore interdisciplinary directions, such as physics and geography, physics and chemistry, and geography and history. The Department of "Physics Didactics" at Nicolaus Copernicus University in Torun is recognized as a pioneer center for interactive didactics. They used simple objects, which we might consider "toys," in experiments conducted in school lessons. The method of teaching physics introduced in Poland for the first time (Karwas, 1998) actually brought unexpected results and led to gradual growth up to national science centers. If we imagine the Earth as a large experimental field, the universe is even larger. Geophysical phenomena include optics (rainbows, halos, blue sky, mirages, etc.), thermodynamics (weather, ocean currents, volcanoes, etc.), mechanics (Earth's orbit, interaction of Earth and the Moon, flattened globe, mountain formations), radioactivity (age determination, radioactive energy balance), and more. The Earth obeys the laws of physics like laboratory experiments. Several physical laws govern processes in the atmosphere, hydrosphere, and lithosphere. Additionally, events in the Earth-Sun-Moon system are explained using physical equations. These equations can be simplified by separating vertical and horizontal coordinates [Peixoto & Oort, 1984]. According to the first estimate, the mathematics behind Earth's phenomena is not complex. We use these theoretical indicators in describing geophysics through simple experiments. When determining the shape and age of the Earth, we also refer to physical laws. It is now widely known that the Earth is elliptical in shape. This question was already posed by Nicolaus Copernicus, who asked why water doesn't fall from the spherical Earth. Copernicus used Aristotle's reasoning – "because water is heavy, it fills the gaps in the ground." After Newton, the correct answer was found to be due to the central force of gravity [2].

In secondary schools, science laboratories have always been an essential part of science education. They help students to think independently, explore new ideas, and draw conclusions. Furthermore, students acquire intellectual and independent working skills needed to solve real-world problems. Hofstein and Lunetta (2004) emphasized the uniqueness of laboratory work in science education, stating that research had not yet identified the most effective teaching situations from the perspective of laboratory learning. In laboratory

lessons, students mainly participate passively. The goals and methods applied in the laboratory are usually chosen by the teacher. Student participation is primarily limited to following the teacher's instructions and the guidelines provided in the laboratory notebook. Therefore, it is not surprising that students lack planning skills and methods for conducting experiments. This raises the following question: “How can we ensure that students are active in the laboratory?” Several factors could influence this. In our research, participation is defined as the time spent by students completing tasks in the science laboratory. Considering this definition, several factors related to teaching, the teacher, and the students' characteristics that could affect their participation in the laboratory have been identified. In terms of teaching, it can be said that laboratory sessions are mostly conducted in small groups. However, this grouping can be detrimental to participation, as students are often not monitored by the teacher. Additionally, behavior rules in the laboratory are not strictly enforced, and the level of student engagement tends to be slow. Considering the lack of guidance in the laboratory, students’ preparation for the laboratory could be crucial in enhancing their participation. Therefore, discussions that take students' conceptions of the phenomena being studied into account, and which help create new knowledge, could alter their participation in laboratory activities.

Research has shown that the results of learning acquisition are also influenced by the personal characteristics of students, including their gender. Boys' participation in laboratory activities is different from that of girls. When boys and girls work together as a team, girls tend to participate less in the laboratory, with boys playing the primary role in using equipment and conducting experiments. Taking these factors into account, an experiment was conducted at "Canada High School" in France. A total of 102 students (60 girls and 42 boys) were selected for the study. The students were divided into four groups. Two teachers, one with many years of experience and one new to the profession, voluntarily tested their teaching strategies with their respective groups. To evaluate participation, the "Tobin" observation network was used. According to this network, students' participation in laboratory activities was assessed based on the following categories: attention, recall of facts, data collection, understanding, determining quantities, planning, generalizing, cognitive non-activities, and off-task activities. The new teacher held a discussion before the laboratory session, while the second teacher conducted the laboratory in a traditional manner. The results showed that student participation in one laboratory session differed from another. This difference could be explained by preparation for the laboratory, the tasks required of the students during the session, and the fact that the girls in the two groups participated differently than the boys. If tasks related to planning and generalizing were requested during the laboratory, the results of high-achieving students could differ from those of average students.

The use of Virtual Laboratories plays a significant conceptual role in developing students' scientific literacy. A Virtual Laboratory is a software and hardware complex that allows conducting experiments in the classroom that are not directly related to real-life setups or can be conducted in their absence. Virtual laboratories refer to two types of hardware and software systems: the first type includes remote laboratories, which consist of laboratory equipment that can be accessed remotely; the second type consists of virtual laboratories, which allow the simulation of real laboratory experiments.

Using Virtual Laboratories in laboratory lessons offers several advantages. In particular, it provides interactivity, the possibility of conducting experiments independently through computer technology in certain locations, an understanding of biological phenomena and processes at both micro and macro levels, modeling, and the completion of independent tasks via the Internet from a distance. Virtual laboratories also allow observing phenomena occurring in living organisms that are invisible to the human eye [2].

CONCLUSION

The research revealed several factors affecting student participation in laboratory activities. It was found that students' academic achievements do not significantly affect their participation in laboratory work. Identifying these factors and relationships helps us better understand and improve student participation in laboratory sessions. Determining the conditions that encourage students to engage in true scientific approaches, and thus mastering the scientific skills intended in the secondary school curriculum, is necessary for future research.

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