DEVELOPING KEY COMPETENCIES THROUGH SCIENTIFIC LITERACY IN 4TH GRADE

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Abstract

The article provides an overview of existing methods and approaches for developing key competencies in fourth-grade students through scientific literacy. In the contemporary educational context, scientific literacy is a fundamental element of comprehensive education, offering a foundation for understanding the world around us and stimulating critical thinking and problem-solving skills. The authors analyze various pedagogical approaches and strategies that can be applied in the learning process to achieve effective acquisition of scientific knowledge and skills. Emphasis is placed on the essence and importance of scientific literacy, outlining the connection between scientific literacy and other key competencies such as communication, collaboration, and creativity. The article offers an overview of the diversity of teaching methods in primary school science, including experimental activities, project-based learning, and the use of interactive technologies. The integration of scientific literacy into the curricula for subjects such as "Man and Nature" and foreign language - English is explored to create an interdisciplinary approach to learning. The role of the teacher in the process of developing scientific literacy is analyzed, along with methods for assessing the level of scientific literacy among students and providing constructive feedback to support their development. The authors of the article present practical applications of the discussed ideas and guidelines for future research in the field of scientific literacy and its impact on the overall educational development of students in the early grades.

Keywords: s*cientific literacy, key competencies, interdisciplinary learning, primary education*

INTRODUCTION

Scientific literacy represents a fundamental element in the process of developing key competencies among students at the primary education level. It provides foundational knowledge about natural and social phenomena while simultaneously fostering critical thinking, analytical processing, and information synthesis skills. Through scientific literacy, students acquire the ability to formulate scientific questions, use empirical evidence, and draw logically justified conclusions. Additionally, it stimulates cognitive curiosity and intensifies interest in scientific knowledge, leading to increased academic motivation and engagement. Scientific literacy also encourages the development of social skills, such as teamwork, effective communication, and sharing ideas, which contributes to building collective intelligence. In this way, it plays a crucial role in preparing adaptive and competent individuals capable of addressing the dynamic challenges of the modern world and contributing to its development.

1. THE ESSENCE OF SCIENTIFIC LITERACY AND ITS RELATIONSHIP WITH KEY COMPETENCIES

Scientific literacy represents a multidisciplinary concept that encompasses the ability of individuals to understand, interpret, and apply scientific knowledge and methods in everyday life. It is not limited to the acquisition of discipline-specific knowledge but also includes the development of critical thinking, analytical skills for processing information, and the ability to make informed decisions. According to the National Research Council (2012), scientific literacy involves not only understanding fundamental scientific concepts and principles but also the ability to apply them in various contexts and real-life situations.

The key competencies defined in the European Framework for Key Competences for Lifelong Learning encompass skills such as learning, communication in one's native and foreign languages, social and civic competencies, entrepreneurship, and digital literacy. Scientific literacy interacts synergistically with these competencies by providing a conceptual foundation for understanding the complex interrelationships in the modern world (European Commission, 2006).

In the context of globalization and accelerating technological development, scientific literacy gains particular importance. The ability to analyze scientific data and interpret it is essential for making informed decisions on key social, economic, and environmental issues. As emphasized by the American Association for the Advancement of Science (AAAS, 1993), „scientific literacy is a fundamental goal of education, enabling citizens to participate actively and knowledgeably in a democratic society".

In the process of developing key competencies, which are essential for the personal and professional growth of students, scientific literacy plays a central role. These competencies include:

- **Critical thinking and problem-solving:** Scientific literacy encourage students to ask questions, seek evidence, and draw well-founded conclusions. This develops their critical thinking skills and ability to solve complex problems (Bybee, 2010).
- **Communication skills:** Through participation in scientific projects and discussions, students learn to present their ideas clearly and persuasively, which is fundamental for effective communication (National Research Council (NRC), 2012).
- **Teamwork:** Many scientific tasks require collaboration and coordination among team members. This develops skills for working in groups and sharing responsibilities (Pellegrino et al., 2001).
- **Creativity and innovation:** Scientific literacy stimulates creative thinking and innovation by encouraging students to explore new ideas and solutions (European Commission, 2019).
- **Digital literacy:** In the modern world, scientific literacy often involves the use of digital tools and technologies for collecting, analyzing, and presenting data (UNESCO, 2015).

Scientific literacy represents a fundamental component of the educational process, which not only enriches knowledge and skills in the scientific field but also contributes to the development of key competencies. It prepares students to navigate the complexities of the modern world and make informed decisions based on scientific facts and principles.

2. THEORIES AND MODELS FOR THE DEVELOPMENT OF SCIENTIFIC LITERACY.

The development of scientific literacy is the subject of numerous theories and models that aim to describe and explain the process of acquiring, applying, and evaluating scientific knowledge by individuals. These theories emphasize various aspects of scientific literacy, including cognitive, social, and contextual factors.

Social Theories: The social constructivist theory of learning, for example, emphasizes the importance of interaction among students and their peers. Vygotsky (1978) argues that „learning is a social process", meaning that students develop their scientific literacy through collaborative work and the exchange of ideas with others. This interaction is essential for building understanding and applying scientific concepts.

Cognitive Models: Cognitive models of scientific literacy focus on the role of mental processes in the acquisition of scientific concepts. The model of „Scientific Literacy and Critical Thinking" by R. A. Duschl and colleagues (2007) emphasizes the need to integrate critical thinking into science education. According to them, „scientific literacy requires not only knowledge but also the ability to analyze information and evaluate evidence".

Assessment Models: The model for assessing scientific literacy, proposed by the National Assessment of Educational Progress (NAEP), provides a structured framework for measuring students' scientific literacy. This model includes three main components: knowledge of scientific facts and concepts, skills

for applying scientific methods, and the ability to evaluate scientific arguments. According to NAEP (2018), „scientific literacy is not only knowledge but also the ability to apply that knowledge in the context of the real world".

Integrated Models: Integrated models, such as the „Scientific Literacy and Sustainable Development" model (UNESCO, 2017), link scientific literacy to global challenges, such as sustainable development and environmental conservation. This model emphasizes the need to develop critical thinking and problem-solving skills related to real-world situations.

The presented perspectives on models for the development of scientific literacy highlight its complex and multifaceted nature, viewing it not only as a set of knowledge but also as a set of skills and abilities to apply this knowledge in various contexts. Here are some key aspects that can be summarized:

1. ***Integration of knowledge and skills:*** According to the models analyzed above, scientific literacy involves not only the acquisition of scientific facts and concepts but also skills for applying scientific methods, developing critical thinking, analyzing information, and evaluating evidence. This defines scientific literacy as a dynamic process that requires the application of theoretical preparedness and practical skills.
2. ***Social context:*** The analyzed models emphasize the importance of the social and contextual aspects of scientific literacy. Interaction with others, as well as the application of scientific knowledge in real-life situations, are key to the development of scientific literacy. This includes both social interaction (according to the social constructivist approach) and the ability to apply knowledge in global and local contexts (as in models for sustainable development).
3. ***Critical thinking and problem-solving:*** A common point among all the analyzed models is the emphasis on the importance of critical thinking and problem-solving skills. Scientific literacy is not limited to the passive acquisition of information but requires active participation in analyzing, evaluating, and applying knowledge.
4. ***Indicators for assessment and measuring progress in scientific literacy:*** The models described above include components for assessing scientific literacy, which shows that it can be measured and analyzed through precisely defined criteria and standards. This highlights the need for clear criteria and standards for evaluating scientific literacy.

From the models analyzed by the authors, it is evident that scientific literacy is in synergy with real-world challenges (sustainable development, environmental conservation, and social issues). Scientific literacy should be defined not as an isolated academic competence but in close connection with the practical application of knowledge in everyday life. From the analysis conducted, it can be summarized that scientific literacy is a multifaceted process that integrates knowledge, skills, and values, and is aimed at developing critical thinking, social interaction, and the ability to solve real-world problems. It is both individually and collectively significant, fostering scientific literacy within the environment and microclimate of the classroom.

3. MAIN METHODS FOR FORMING KEY COMPETENCIES THROUGH SCIENTIFIC LITERACY

Project-based learning is a methodology for organizing educational activities through the execution of projects. According to S. Chakrova, „in project-based learning, pedagogical goals are focused on forming behavioral models and attitudes towards self-directed learning, goal setting, planning, and implementing one's own ideas, as well as building personal qualities and attitudes towards communicative, civic, digital, and other competencies" (Chakrova, 2022, p. 107). This method is oriented towards activities and goals that can be both in school and out-of-school settings and usually have social, civic, or personal orientations. The main characteristics of project-based learning include a high level of autonomy and freedom for students in setting goals and their work, the possibility of establishing interdisciplinary connections, and encouraging initiative. The role of the teacher is supportive, with students planning activities and generating ideas independently. This method allows

for more „mistakes“ and encounters with difficulties during the work process, providing opportunities for acquiring knowledge and experience.

Educational experiments play an important role in forming key competencies and scientific literacy among students. They provide a practical context that supports the development of various skills and abilities needed for successful realization in the modern world. Among the most widely applicable types of experiments in natural science education are the demonstration experiment, the laboratory experiment, and the individual experiment.

Experimental methods in the educational process play a key role in developing cognitive, practical, and social skills in learners. Each type of experiment brings specific advantages and contributes to the formation of scientific literacy and critical thinking. Below are presented the main aspects of the three types of experiments - demonstration, laboratory, and individual:

- *Demonstration Experiment*

The demonstration experiment provides an opportunity for visual observation and analysis of scientific processes, which stimulates the development of critical thinking and the ability to focus on details. Through active participation in discussions and interpretation of observed phenomena, students improve their verbal communication and argumentation skills. This method also contributes to the formation and enhancement of scientific literacy by facilitating the assimilation of theoretical concepts and their application in practice.

- *Laboratory Experiment*

The laboratory experiment is aimed at developing practical skills, including working with scientific instruments and materials. It encourages collective interaction, supporting the formation of group work skills, collaboration, and effective communication. Integrating the laboratory experiment into problem-based learning stimulates creativity and the ability to solve complex tasks. Additionally, adhering to strict safety rules during experimental activities promotes responsible behavior and discipline, which is essential for successfully conducting scientific research.

- *Individual Experiment*

The individual experiment encourages the independence and initiative of learners by engaging them in research tasks that require planning and managing time and resources. Analyzing the obtained results and formulating conclusions supports the development of self-reflection and self-assessment. Moreover, by incorporating ecological aspects into the experiments, it lays the foundation for forming environmental awareness and commitment to sustainable development and nature conservation.

These three types of experiments contribute to the overall development of students by combining theoretical knowledge with practical skills and encouraging active participation in the scientific process.

Interactive technologies and digital resources significantly enrich the learning process, providing new opportunities for interaction between students and teachers and creating a new educational environment. Research by Hattie (2009) and Kirkwood & Price (2013) shows that these technologies not only facilitate access to information but also encourage active student participation. Platforms such as Teams and Google Classroom offer interactive tools for managing the learning process. Educational games and applications like Kahoot!, Quizizz, and Quizlet contribute with their software capabilities, making learning more fun and motivating for students. Virtual laboratories and simulations support the understanding of complex scientific concepts and develop students' research and problem-solving skills. Interactive technologies such as virtual and augmented reality (VR and AR) provide opportunities for simulating scientific phenomena, which increases student motivation and performance according to Merchant et al. (2014). Also, „virtual and augmented reality (VR/AR) offer opportunities to create interactive and engaging learning experiences“ (Mishkova-Yotova, Peneva, 2024, p. 511). Electronic books and interactive textbooks offer multimedia educational content and game-based learning, encouraging active student participation in the learning process.

To form key competencies through scientific literacy, it is necessary for teachers to encourage students to ask questions and explore using interactive technologies and digital resources. Applying the integral

approach leads to the formation of integrative educational paradigms, through which key competencies are acquired and scientific literacy is built. This approach combines knowledge of sciences, foreign languages, technology, and mathematics, connecting them to real-life problems. It allows teachers to go beyond subject-specific teaching and show students how to solve problem tasks using knowledge from different fields. Integrative knowledge is based on the principles of unification, synthesis, and hierarchy of information, leading to higher quality education. Through the integral approach, repetitions in subjects are prevented, and more time is provided for exploring new areas.

4. PRACTICAL EXAMPLES AND CASE STUDIES

Forming key competencies underlying scientific literacy begins in the early stages of secondary education and continues to develop in subsequent upper stages. Integrating various subjects into the process of forming scientific literacy can be achieved through diverse methods, including: discussing specific content, writing reports, keeping records, writing letters to politicians, educational institutions, public leaders, media outlets, internet platforms, developing projects, conducting surveys, attempts, and experiments (fig. 1).

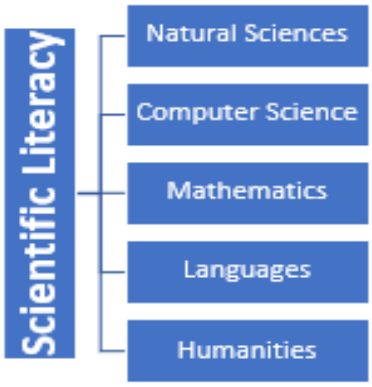

Fig. 1. Academic subjects integrated into the process of developing scientific literacy

Source: the authors

Natural Sciences:

- Investigation of water pollution and purification
- Study of the physical and chemical properties of water
- Study of the impact of climate change on water resources
- Analysis of the water cycle and its components
- Research on global warming processes and their impact on the hydrosphere and atmosphere
- Methods for sampling aquatic bodies
- Conducting laboratory and field experiments

Computer Science:

- Working with electronic spreadsheets for data analysis
- Creating graphs and charts using specialized software
- Designing visual materials such as signs, posters, flyers, templates, logos, and other informational carriers

- Conducting scientific research with the help of computer technologies
- Using interactive websites for presenting results and collaboration

Mathematics:

- Interpretation of diagrams and graphs
- Measuring volumes and capacities
- Application of coordinate systems in various contexts
- Working with maps, symbols, and keys for cartographic purposes

Languages:

- Writing poetry and essays
- Using signs and letters in communication
- Participating in debates and discussions
- Compiling newsletters and informational publications

Humanities:

- Geography of rivers, lakes, seas, and oceans
- Organizing campaigns to raise public awareness about water resources

5. CONCLUSIONS AND SUMMARY

Scientific literacy is a fundamental element in the educational process, playing a key role in shaping key competencies in students at the primary education level. It not only enriches students' knowledge in the fields of natural and social sciences but also develops critical thinking, analytical skills, and the ability to synthesize information. Through scientific literacy, students acquire the skills to formulate scientific questions, use empirical evidence, and reach logically justified conclusions. It stimulates cognitive curiosity and learning motivation, while simultaneously encouraging the development of social skills such as teamwork, effective communication, and sharing ideas.

The understanding of scientific literacy as a multidisciplinary concept encompasses the ability of individuals to comprehend, interpret, and apply scientific knowledge in everyday life. It is not limited to the acquisition of scientific facts but also includes the development of critical thinking, analytical skills, and the ability to make informed decisions. Scientific literacy interacts synergistically with the key competencies defined in the European Framework for Lifelong Learning, providing a conceptual basis for understanding the complex interrelationships in the modern world. In the context of globalization and technological advancement, scientific literacy is essential for making informed decisions on key social, economic, and environmental issues.

Research on scientific literacy is the subject of various theories and models that emphasize cognitive, social, and contextual aspects. The social-constructivist approach highlights the importance of interaction among students for building scientific knowledge, while cognitive models focus on the role of critical thinking and analytical skills. Integrated models, such as the UNESCO model for scientific literacy and sustainable development, link scientific literacy to global challenges, including sustainable development and environmental conservation.

In educational practice, project-based learning, educational experiments, and interactive technologies are among the primary methods for developing key competencies and building scientific literacy. Project-based learning fosters independence, critical thinking, and teamwork skills, while educational experiments (demonstrative, laboratory, and individual) provide a practical context for the development of scientific skills and abilities. Interactive technologies and digital resources significantly enrich the learning process by offering new opportunities for interaction and active participation of students. The

integrated approach, which combines knowledge from various fields, enables students to solve complex problems and apply scientific knowledge in real-life situations.

In the field of natural sciences, for example, students can investigate water pollution or the impact of climate change on water resources. In computer science, they can use software for data analysis and creating visual materials, while in mathematics, they can interpret charts and graphs. Language and humanities disciplines also play an important role by encouraging writing, debates, and organizing campaigns to raise public awareness.

From everything discussed so far, we have reached the following conclusions:

1. Scientific literacy is fundamental to the development of key competencies in students, fostering critical thinking, analytical skills, and problem-solving abilities.
2. The integration of knowledge and skills is essential for scientific literacy, which requires not only the acquisition of scientific facts but also the application of scientific methods in real-life situations.
3. Social context and interaction are crucial for the development of scientific literacy, promoting teamwork and effective communication.
4. Critical thinking and problem-solving are defining aspects of scientific literacy, which requires active participation in analyzing and evaluating information.
5. Interactive technologies and digital resources significantly contribute to the development of scientific literacy by providing new opportunities for learning and interaction.
6. The integrated approach in education enables students to apply scientific knowledge in real-world contexts and address complex issues related to sustainable development and environmental conservation.

In conclusion, scientific literacy is crucial for preparing students to tackle the challenges of the modern world. It equips young people to become active, informed, and responsible citizens capable of contributing to societal development and well-being.

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