THE RELATIONSHIP BETWEEN DIGITAL, MATHEMATICAL AND LANGUISTIC LITERACY IN PROGRAMMING EDUCATION: RESEARCH AND CONCLUSIONS

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Abstract. *The article explores the interrelationship between digital, mathematical and linguistic literacy among programming teachers. The presented results and conclusions are based on a conducted study, according to which the successful assimilation of knowledge and construction of the target digital competences is closely related to a high level of mathematical and linguistic literacy. The research proves the interdependence of digital, mathematical and linguistic literacy and the need for an integrated approach both in the process of teacher qualification and in student learning.*

Key words: Digital Competences, Mathematical and Linguistic Literacy.

Introduction

In the modern digital world, programming has become one of the most important key skills, requires knowledge and competencies across various literacies [1]. Digital, mathematical and linguistic literacy are the three main pillars that form the basis for successful programming training, each of which contributes in a different way. On one hand, digital literacy develops the necessary skills related to the application of ICT technologies and approaches to creating digital content; mathematical literacy creates an appropriate environment for building logical and analytical thinking [2], while linguistic literacy supports the understanding and creation of correct, clear, readable and well-structured code.

The interrelationship between these three types of literacy is particularly important in teaching students programming [3]. For example, creating an algorithm for solving a specific programming problem requires mathematical thinking, coding this algorithm requires a certain level of digital competence, while the clarity and readability of the written code, as well as the interaction between team members, is largely associated with the features of linguistic literacy.

The article examines the integration of these key literacies in programming education in Bulgarian schools.

Motivation and related works

The integration of digital, mathematical and linguistic literacy provides the basic framework for effective programming education. These literacies, although specific in nature, complement each other in the learning process to achieve the main goal – for learners to acquire a comprehensive understanding of programming principles, strategies for solving various practical tasks and problems, and the development of communication skills that are key to this field.

Digital literacy encompasses the ability to effectively use and navigate digital tools, platforms and resources. In programming education, this literacy is associated with knowledge of programming environments (IDEs), control systems and debugging tools; understanding the structure and syntax of programming languages, as well as knowledge and skills to integrate different software tools for problem solving, communication and collaboration.

Digital literacy allows students to adapt to the rapidly changing world of emerging technologies and to explore computational thinking skills that are key to building the digital competencies standardized by the DigComp 2.2 [4].

Mathematical literacy refers to the ability of people to use mathematical concepts, skills, and tools in a variety of contexts to solve real-world problems and make informed decisions. It includes not only basic mathematical principles, but also the ability to analyze data. Mathematical literacy includes: the ability to understand and interpret mathematical ideas and principles; the ability to use mathematical skills to solve real-world problems and tasks; critical thinking; the ability to communicate mathematical ideas and solutions in understandable language, etc.

Programming requires logical reasoning, perception and management of abstract entities, quantitative analysis, modeling of real-world objects and interactions, which are essential components of mathematical literacy. Knowledge of discrete mathematics (e.g., graph theory, set theory) is critical for understanding complex programming concepts that require a higher level of abstraction and formalization in processing data structures.

Mathematical literacy prepares students of all grades and forms of learning to solve problems systematically, which in turn is a fundamental skill in programming.

A significant number of studies discuss the difference between literacy and competence [5]. Virkus in [6] makes a thorough analysis of the concept of information literacy and defines it as an important competence of the 21st century. The author analyzes different, contradictory concepts and definitions of the concept of "Information Literacy". He accepts the view that information literacy can be viewed in three perspectives as general basic functional skills, as social practices and as transformative skills, which complement each other. For good analysis of information, it is necessary to have a system of algorithmic thinking built, which is best implemented through mathematical skills and competences. Adopting this statement, we specify that by Mathematical Literacy we understand the knowledge and skills for the practical use of mathematics in everyday life, and Mathematical Competence encompasses a wide range of skills and abilities related to their independent, creative and combinative use. It is for this reason that we will talk here about literacy as the first step towards competence. Anna-Lena Godhe in [6] analyzes Digital Literacies or Digital Competence: Conceptualizations in Nordic Curricula. The author answers the question of whether digital literacy and digital competence are the same thing. According to her, the terms digital literacy and digital competence are used interchangeably, especially in policy documents on education and the digitalization of education systems and teaching.

In order to have good mathematical literacy, it is important to note that students need to have good general literacy and especially the ability to master their native language. The ability to reading comprehension, to describe well-connected and logically correct conclusions, to analyze a text is important. The opposite statement is even stronger: if a student does not understand the texts of the tasks, then he will not be able to solve them. Linguistic literacy refers to a person's ability to understand, use and communicate with the means of written speech in a language. It encompasses the skills of correct spelling, grammar, punctuation and understanding of what is written. Language proficiency and literacy are important for successful communication and understanding of information in different areas of life.

Programming requires much more than just coding. It involves un-

derstanding abstract concepts and good language literacy. In programming training, this literacy enables understanding programming terminology and syntax, which are a unique combination of programming language and human-readable logic; writing clear and easy-to-read code; skills in developing descriptions, comments, and software documentation, which ensures the long-term usability of the software, etc.

The interrelationships between literacy skills are fundamental to teaching students how to program. Mathematical literacy interacts with digital literacy by providing the logical basis for designing and understanding algorithms and computational models. Linguistic literacy underpins human-computer interaction and enables the solution of a variety of programming problems. Native language and communication are essential for understanding mathematical concepts, posing problems, formulating strategies, and expressing results. Although mathematics uses symbols and formulas that have their own linguistic structure, understanding mathematical ideas requires the ability to express and understand the language in which mathematics is presented.

Digital literacy relies on both mathematical and linguistic skills to create software products that are functional, efficient, and easy to use. For example, if a practical programming problem needs to be solved, students must interpret (linguistic literacy) the problem description, develop an algorithm for the solution (mathematical literacy), and code it using some programming tools and environments (digital literacy).

Results and discussions

In recent years, systematic research has been conducted in Bulgaria on the approaches to building and the interrelationship between different types of literacies and competencies in programming education in Bulgarian schools [7]. The different forms of literacies – linguistic, informational, visual and others – are interconnected and have their own essence and importance (Fig. 1). Each of them represents specific skills and knowledge that are necessary for successful functioning and communication in the respective field. So, although it is possible for a person to be relatively good at mathematics but not to be fluent in their native language, strong linguistic literacy is important for the successful understanding and use of mathematics. Native language literacy and mathematical literacy are two different but interrelated concepts. Literacy and mathematical liter-

acy are interrelated because the mastery of written and oral expression is important for the communication of mathematical ideas and results.

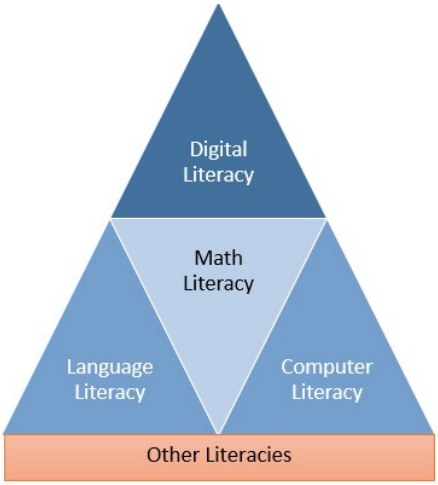

Figure 1. Interaction between main literacies in programming education in school

A good understanding of mathematical terminology and the correct use of mathematical language are also part of mathematical literacy [8]. General literacy and mathematical literacy are developed and improved through education, practice and experience. Mathematics education can help people develop their mathematical skills and literacy, which ultimately helps them understand and analyze information related to mathematics and apply it in real-world situations [9]. However, the development of other forms of literacy, such as linguistic literacy or social literacy, does not necessarily require strong mathematical knowledge. Each form of literacy has its own specific features and significance in the context in which it is used. A study conducted among students and teachers in our country found that there is a strong relationship between digital, computer and mathematical literacy. Digital and computer literacy is a person's ability to use computers and technologies to access, process and communicate information. This includes skills in working with computer programs and applications, skills in searching and evaluating information online, basic knowledge of cybersecurity and data protection, as well as understanding basic concepts in the field of information technology. Teachers share that the basic relationships and logical structures are based on their mathematical knowledge and they are fundamental for their good preparation and confidence in their computer literacy. The relationship between computer literacy and mathematical literacy is undeniable, but what is the degree of this dependence. It turns out that good mathematical literacy can be

useful in understanding the basic concepts in computer science and programming. Mathematics plays an important role in computer science and programming, as they use algorithms, logical operations and mathematical models to solve problems and analyze data. Understanding algebraic and geometric concepts, logical operations and basic mathematical principles can be useful in programming and solving problems in the field of computer science. Many of the primary programming tasks are precisely mathematical. To a large extent, in the 1970s, the first programming teachers in our country were mathematicians.

After analyzing the curricula, we can identify some specific areas where mathematical literacy is important for computer literacy such as:

- Algorithms and Data Structures: To understand and implement effective algorithms and data structures in computer science, an understanding of mathematical concepts such as iterations, recursion, matrices, lists, and others is required.
- Cryptography: Cryptography is based on mathematical principles and algorithms that enable the security of data and communications. Understanding the mathematical foundations of cryptography is important for understanding and applying various cryptographic methods and systems.
- Machine Learning and Artificial Intelligence: Mathematical foundations such as linear algebra, probabilistic models, and statistics play an important role in the development and application of machine learning and artificial intelligence algorithms. Understanding these mathematical concepts allows people to understand and develop models that are based on data and can predict or solve problems.
- Graphics Programming and Computer Graphics: To understand and use computer graphics techniques and algorithms, including visualization, object modeling, and image processing, knowledge and understanding of mathematical concepts such as trigonometry, linear algebra, and geometry are required.
- Data Analysis and Statistics: Computer literacy also includes skills in data processing and analysis. Understanding mathematical concepts in the field of statistics, as well as skills in information extraction and data visualization, are important for effectively working

with large volumes of data and making informed decisions.

There is also a direct connection between mathematical literacy and digital literacy. Digital literacy refers to a person's ability to use technologies related to digital devices and the Internet to communicate, search for information, create, and process data. It includes skills in working with computer programs, social media, email, online communication, and much more. Mathematical literacy is important for digital literacy for the following reasons:

- Understanding data and statistics: To be digitally literate, we need to be able to interpret data and statistical information, which are often presented in digital format. Mathematical literacy helps us understand and interpret the numbers, graphs, and tabular data that we encounter in the digital environment.

- Analyzing and solving problems: Digital literacy requires the ability to analyze and solve problems that arise in the digital environment. Mathematical literacy provides us with the logical and analytical skills that are necessary to achieve this goal. Solving problems and formulating mathematical models and algorithms can be useful in addressing digital challenges.

- Coding and programming: All types of programming, from basic to advanced, involve mathematical concepts and logical thinking. Mathematical literacy is important for understanding the concepts of variables, operations, conditional expressions and many others used in programming.

The self-assessment of the digital literacy of 129 computer science teachers in our country found their low confidence in their preparation, which is due to the fact that technology and programming are developing at a fairly high pace. The interest and newness of knowledge among students and their motivation to engage in coding and creating software products have increased significantly. Business and the labor market have increased the requirements that do not always correspond to the curricula and programs. The teaching profession is faced with rapidly changing requirements that require a new, broader and more advanced set of competencies than before. The ubiquity of digital devices and applications requires teachers to develop their digital competence.

Conclusions

In conclusion, it can be said that the development of any of the literacy skills requires a systematic approach. They are interconnected and the development of mathematical is key to supporting the development of the others. Each of the competencies needs to be developed during the training in each lesson and in mutual connection, and not as isolated ones.

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