D-STEAM LABORATORY DESIGN: A SYSTEM-ALGORITHMIC MODEL FOR PROGRAMMING COMPETENCY DEVELOPMENT

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Today, the development of algorithmic and programming competencies has become one of the priority areas in the educational environment. Recent studies indicate that the formation of algorithmic thinking significantly increases the effectiveness of programming education [1–2]. The reviewed research also demonstrates that interdisciplinary integration based on the STEAM approach enhances learners' competencies in problem modeling, systems thinking, and the development of creative solutions [3–4]. Furthermore, educational processes organized through robotics, virtual laboratories, and interactive coding environments have been shown to produce high results in strengthening algorithmic skills [5].

However, these studies do not sufficiently address the comprehensive development of algorithmic and programming competencies specifically through a systemic-algorithmic model implemented within a STEAM laboratory platform. Research conducted by scholars in Kazakhstan, Uzbekistan, and Russia has primarily focused on developing the theoretical foundations for introducing STEAM and STEM technologies, highlighting interdisciplinary integration, project-based learning, and the use of digital tools as key factors [6–7]. The effectiveness of innovative pedagogical technologies, modular instruction, and digital platforms in teaching programming has also been substantiated [8–9]. Nevertheless, a specialized STEAM laboratory model ensuring the holistic integration of mathematics, engineering, technology, arts, and natural sciences has not yet been sufficiently developed [10].

Taking these considerations into account, the proposed D-STEAM laboratory is designed based on a systemic-algorithmic approach, integrating theoretical knowledge, practical programming, modeling, and creative design elements within a unified platform[11]. This model aims at the comprehensive development of learners' algorithmic thinking, problem decomposition skills, efficient coding abilities, and interdisciplinary project development competencies[12].

The D-STEAM laboratory is organized according to a three-stage systemic-algorithmic model.

At the first stage, students acquire an understanding of the concept of algorithms and their fundamental structures (sequence, branching, iteration). They learn to solve problems step by step using flowcharts and pseudocode. Particular emphasis is placed on problem decomposition, identifying logical relationships, and developing optimal solution strategies.

At the second stage, depending on their interests and level of preparation, students choose one of the programming languages such as Python, Java, PHP, or C++, and learn to transform algorithms into actual code. This stage includes mastering syntax, data

structures, functions, object-oriented programming (when necessary), as well as testing and debugging processes in a gradual and systematic manner.

At the third stage, students complete practice-oriented projects based on STEAM integration and real-life problems. The projects are divided into three levels of complexity: three basic projects (calculation and visual modeling tasks), three intermediate projects (programs focused on data processing and modeling), and three advanced projects (integrative projects aimed at solving complex real-world problems). Each project incorporates elements of mathematics, engineering, technology, arts, and natural sciences.

The assessment system is criterion-based, with each project evaluated according to specific components: (1) the logical structure and correctness of the algorithm; (2) the syntactic and functional accuracy of the program code; (3) the validity and efficiency of the problem-solving approach; and (4) the level of interdisciplinary integration within the STEAM framework. This multi-criteria assessment system enables a comprehensive evaluation of students' technical skills, systems thinking, and interdisciplinary competencies.

Thus, the development and implementation of the D-STEAM laboratory represent an innovative mechanism for improving programming competencies in the context of digital education, possessing both scientific and practical significance.

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