Analysis of Different Approaches to the Development of Students' Calculation Thinking with the Help of Exact Sciences

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Abstract. This article talks about different approaches to the development of students' computational thinking with the help of specific sciences, the analysis of various definitions given to it, and the methodological foundations of developing computational thinking. Evolutionary stages of development of computer thinking, cognitive approaches to education, computational thinking are also presented. In the study of the science of "Digital control systems", its cognitive development was analyzed taking into account the possibilities.

Key words: calculation, thinking, cognitive, teaching, education, thinking, digital methods, computational thinking, computer thinking, teaching methodology.

The emergence and development of computer technology gave a strong impetus to the use of computing technology in almost all fields of science. In the modern world, it is practically standard to include the analysis of experimental data and the analysis of computational experiments along with theoretical research in scientific work. Entire scientific directions aimed at the professional use of computing techniques in scientific research have appeared: computational chemistry, computational physics, computational biology, neuroinformatics, bioinformatics, and others.

The concept of "calculation" can be seen not only as performing arithmetic operations, but also as a much broader concept, a way of thinking, a basis for any scientific research.

In order to further increase the competitiveness of the republic's economy through the widespread introduction of modern information technologies and the expansion of telecommunication networks in our republic, the decision of the President of the Republic of Uzbekistan dated April 20, 2020 "On measures for the widespread introduction of digital economy and electronic government" No. PQ-4699 was adopted . In the decision, one of the main tasks is defined as "the wide introduction of digital technologies at all stages of the education system, the improvement of the level of digital knowledge necessary for the modern economy, and the improvement of the educational infrastructure."

The report "Future of Work Skills 2020" published by "The Institute for the Future" (The Institute for the Future, Palo Alto, USA) lists mobile technologies as one of the ten basic skills that people who have achieved professional success should have.

To date, many foreign scientific and educational organizations are actively developing the concept of "mobile technologies". Including the US National Academy of Sciences, British Computer Society (BCS, The Chartered Institute for IT), International Society for Technology in Education (ISTE), Computer Science Teachers Association (CSTA), International non-profit Stanford Research Institute (SRI), Google Academy and others.

The subject of "Digital Management Systems" focuses on the formation of the culture of using high-level information technologies and a new scientific outlook of students in higher education institutions. The ability to think outside the box is important for professionals in any field, especially for students whose future careers are related to computer science, which is rapidly developing.

Therefore, studying science requires from students not only high-level mathematical training and professional knowledge of modern computer technologies, that is, specially developed thinking that allows easy transition from problem formulation to solution, and serves as an impetus for the formation of competence to create a problem-solving algorithm. The possibility of using digital control systems to solve scientific, technical, economic and other problems and their automation with the help of personal computers and mobile technologies is directed to a certain development environment.

Sometimes numerical control systems are not studied in the general course, but mathematical modeling, optimization methods are studied in separate elements, the same approach is recommended by the European Society for Engineering Education (SEFI) in the document "Computer Science for European Engineers Association".

Regardless of the field of study, the main forms of teaching in the study of "Digital control systems" are lectures and laboratory or practical exercises. Organizational, methodological and information tasks are conveyed to students through lectures.

It is in the lectures that the teacher reveals the conceptual apparatus of the science of "Digital control systems", gives a complete understanding of the science and shows its connection with other disciplines of professional training.

The active form of teaching is laboratory or practical training, which helps to strengthen students' theoretical knowledge, increase the effectiveness of teaching, and acquire professional skills.

Traditionally, great attention is paid to independent work of students. Independent work can be divided into the following types: traditional independent work of students outside of class, which is done independently at a convenient time for students; independent work during the lesson under the supervision of the teacher; information and communication independent work using information and mobile technologies.

A meaningful analysis of the science programs shows that the approaches to the teaching of "Digital control systems" for different areas of education differ significantly, especially in practical training. This shows how important the task is to the future engineer, and he should choose the most effective solution. In addition to studying the theory of digital control systems, it is an important task for future teachers to pay attention to the theory and methodology of teaching science, as well as the physical representation of the studied processes and phenomena.

For an expert in the field of computer science, the construction of the algorithm, the accuracy of the solution, the analysis of the effectiveness of the method and the limitations in its use play an important role.

According to V.S. Kornilov, digital management systems "help the expansion of students' worldview: they gain an understanding of the interpenetration and mutual enrichment of scientific methods, approaches and methods developed in different fields of knowledge" [2].

In the training of specialists in higher education institutions, there is a contradiction between the large amount of professional and general cultural information necessary for the professional activity of a future specialist in a certain field and the time limit allocated for obtaining higher education.

This contradiction can be overcome by introducing mobile technologies into the educational process together with the development of appropriate methodological support. That is, it is necessary to form a science information environment that allows students to work independently, as well as cognitive and research activities that develop computational thinking, practical and developing knowledge, based on the modern capabilities of mobile technologies.

In the second half of the 20th century, along with the development of computer technology, digital control systems for solving problems in mechanics, physics, chemistry, science and other fields of technology: endoscopic surgery, computer diagnostics, tomography, fusion reactors and many other areas familiar to the modern world began to develop rapidly.

Today, no field can be imagined without computer technology. The emergence of new algorithms for digital control systems, parallel computing, the use of neural networks, genetic algorithms, developments in the field of creating a quantum computer will bring new changes to this field. Computational thinking, along with theory and practice, became the main pillar of the thought process, with the help of formal operations on numbers, certain mathematical results were obtained.

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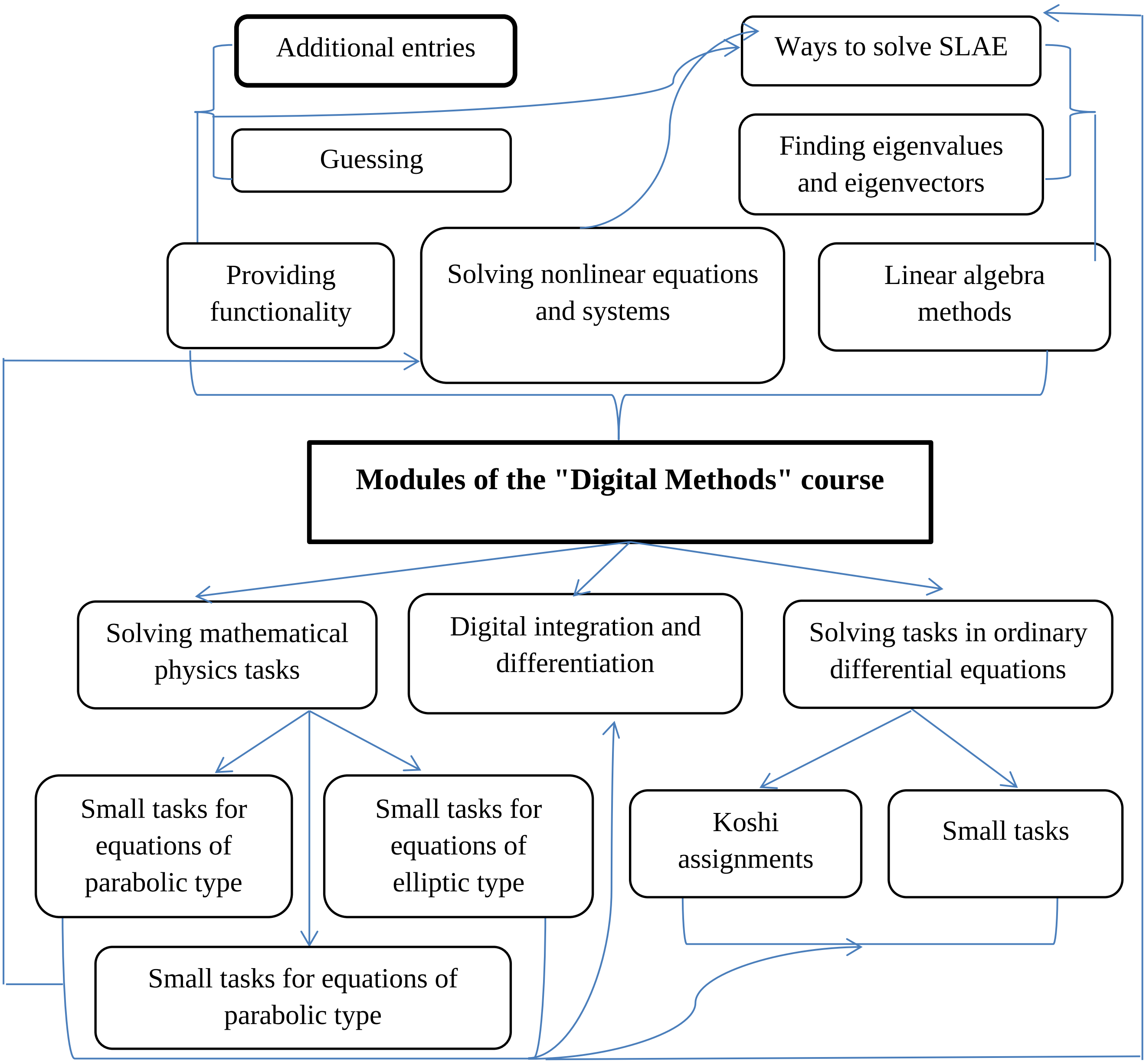
Nowadays, the science of "Digital control systems" is an important subject in the training of specialists in many fields, and the numerical analysis of mathematical models is an effective research tool in any practical development.

The ability to use digital control systems and automate them using personal computers to solve scientific, technical, economic and other problems is directed to a certain development environment. Algorithms and program text led to the introduction of textbooks with examples and brief information on the theory of applied methods. These publications are mainly intended for engineering students, but they are also useful for mathematicians in the practical application of Numerical Control Systems. Such textbooks often fail in the mathematical reasoning of ideas and the specifics of applying numerical control systems.

Sometimes numerical control systems are not studied in the general course, but higher mathematics, mathematical modeling, optimization methods are studied in separate elements in the study, the same approach recommended by the European Society for Engineering Education (SEFI) in the document "Mathematics for European Engineers".

The traditionally organized structure of the teaching material of the subject "Digital control systems" is shown in Figure 1, and the direction signs depicted in it show the connections between the studied topics. Usually, selected topics are included in the subject "Digital Control Systems" with varying degrees of detail, depending on the educational program.



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SLAE - systems of linear algebraic equations

Figure 1 - Modules of the discipline "Digital control systems".

The subject of "Digital control systems" is the main one in the training of teachers of mathematics, physics and informatics in technical universities, and it is focused on the formation of high-level mathematical calculation culture and scientific outlook of students. Textbooks for students of technical higher education institutions usually provide basic theoretical information on digital control systems for solving practical problems in a concise and accessible form, and problems are considered using various tools.

Regardless of the field of study, the main forms of teaching in the study of "Digital control systems" are lectures and laboratory or practical exercises. Organizational, methodological and information tasks are delivered to students through lectures. It is in the lectures that the teacher reveals the conceptual apparatus of the science of "Digital control systems", gives a complete understanding of the science and shows its connection with other disciplines of professional training. An active form of teaching is laboratory or practical training, which helps to strengthen students' theoretical knowledge, increase the effectiveness of teaching, and acquire professional skills.

Traditionally, great attention is paid to the independent work of students. Independent work can be divided into the following types: traditional independent work of students outside of class, which is done independently at a convenient time for students; independent work during the lesson under the supervision of the teacher; information and communication independent work using information technologies.

A meaningful analysis of the work programs shows that the approaches to the teaching of "Digital control systems" for different fields of study differ significantly, especially in practical training. This shows how important the task is for the future engineer, and he should choose the most effective solution. In addition to studying the theory of digital control systems, it is important for future engineers to pay attention to the theory and methodology of teaching science and the physical representation of the studied processes and phenomena [4]. For a specialist in the field of computational mathematics, the construction of the algorithm, the accuracy of the solution, the analysis of the efficiency of the method and the limitations in its use play an important role.

According to V.S. Kornilov and V.V. Belikov, digital management systems "help the expansion of students' worldview: they understand the interpenetration and mutual enrichment of scientific methods, approaches and methods developed in different fields of knowledge" [6]. In teaching science, "Numerical Control Systems" depends on the field of study, and almost all researchers agree that it is necessary to teach students not only to use numerical methods, but also to program them.

The analysis of work programs in different areas of education showed that, usually, the study of "Digital control systems" for one semester does not allow to study the features of Digital control systems and their implementation algorithms in sufficient depth. The lack of programming experience among students forces teachers to choose software that requires minimal time to learn or to look for other methodological approaches.

Thus, T.A. Stepanova [9] offers two "parallel teaching methods" that increase the role of independent work and create conditions for mastering the material in a short time.

The first approach involves structuring the subject area in such a way that individual subjects are divided into a certain number of equivalence classes. In this case, the assignments of one class can be distributed among students with the subsequent public protection of assignments. The second involves the creation of working mini-groups of students within the framework of the organization of project activities in solving one complex problem divided into separate independent stages.

To prepare future teachers, T.A. Stepanova and M.A. Lyashkolar [7] suggest the use of spreadsheets, simple error correction mechanism, formulas, the ability to programmatically determine mathematical relationships between values in a table, formatting and data display, powerful built-in functions, and spreadsheets that allow for quick and efficient data analysis in MS

Excel. The advantage of this approach is that no additional training is required, because students have the skills to work with spreadsheets in school computer science, and the graphical capabilities of Excel make it easy to visualize the process of calculations, compare relevant data series.

As a set of working tools for solving practical problems in the study of numerical control systems, specialized mathematical sets are increasingly used to activate the educational process. I. V. Belenkova follows the point of view that the use of specialized software (software) increases the professional information competence of future specialists, but the choice of software significantly changes the approaches to teaching the science of "Digital Control Systems" [3].

Each of the mathematical sets has its own characteristics. So, Maple is great for symbolic calculations (calculating limits, integrals, derivatives, simplifying algebraic expressions). MatLab is a matrix-oriented language that is effective in solving high-dimensional problems, such as solving systems of linear algebraic equations, including sparse matrix systems, symbolic mathematics, optimization methods, mathematical statistics, neural networks, etc. Mathematica considers itself "a universal system for mathematics on the computer" and allows you to implement traditional procedural and functional programming styles, as well as the style of transformation rules. I.V. Belenkova states that the MathCad package is the most effective from a methodological point of view for training engineers.

All these systems have good graphics capabilities, but like any commercial products, they also have a number of disadvantages:

- low adaptability to the special needs of individual users, closed development model, unavailability of source code;
- dependence on the software provider (expensive updates, new versions and extensions);
- vulnerability in areas not foreseen or planned by system developers and unnecessarily complex interface.

Choosing the right software is fundamental and determines the effectiveness and long-term support of students in their future research and education activities. Therefore, it is better for mathematics students to use general-purpose programming languages when studying Numerical Control Systems. Usually, students choose a programming language (Delphi, C++) that they learned in 1-2 years, Python is a popular programming language that allows mathematical ideas to be expressed with minimal programming effort and in a "mathematics-like" form. Python has a clear and simple syntax, a convenient interactive environment for rapid program development and debugging, and many extensions (modules) and applications for use in mathematics and engineering.

The study of numerical control systems is a mandatory subject for the study areas of automation and control of technological processes and production (by networks). It requires students to have a high level of mathematical training, professional knowledge of the fundamentals of computing theory and methodology, as well as modern knowledge of computer technologies. Two semesters are allocated for the study of science, in addition, in the curriculum of undergraduate and graduate students, there are many subjects that allow the student to deepen his knowledge in this field.

V.V. Belikov noted that in the training of specialists in automation and management of technological processes and production (on networks) "there is a contradiction between the large amount of professional and general cultural information necessary for the professional activity of a future graduate in a certain field and the time limit allocated for higher education" [5].

This contradiction can be overcome by introducing information technologies into the educational process together with the development of appropriate methodological support. G.M.Fedchenko and T.A.Stepanova agree that it is necessary to create a science information environment that allows practical, developing knowledge and research activities, as well as independent work of students, based on the modern possibilities of information and telecommunication technologies.

The use of mixed educational technologies makes it possible to expand the range of didactic tools based on the characteristics of the taught subject. Practitioners emphasize that three main aspects come to the fore when organizing mixed education in an educational institution:

- administrative, including the existence of a strategy for the development of e-learning strengthened by relevant regulatory and legal documents in the educational institution, the organization of professional development of professors and teachers in ICT, and the development of motivational mechanisms of encouragement and incentives;

- technological, programmatic and technical provision of educational process;

- aimed at developing methods for individual subjects based on pedagogical, information technologies, active and interactive teaching methods.

It is believed that e-learning technologies increase the rate of mastering educational material by 10-15%, to save up to 35-45% of teaching time, optimize the workload of professors by 30%, and generally improve the quality of lessons [8]. Despite the advantages of e-learning, it has a number of disadvantages compared to traditional face-to-face teaching. Advantages and disadvantages of traditional and electronic education are presented in Table 1.

Table 1

Advantages and disadvantages of traditional and electronic education

Traditional education	**E-learning**
Advantages	
The ability of the teacher to react instantly to the student's actions. Forming personal relationships with deep emotional interaction between the subjects of the educational process.	Ability to receive teacher feedback anywhere and anytime. Interactive interaction with electronic learning materials. Increasing the level of individualization through the use of various types of electronic resources. Use of Internet opportunities for wide communication. High involvement of students in the educational process.
Disadvantages	
Limiting the time of communication with the teacher. Lack of interaction with printed learning materials. Low level of personalization, same learning trajectory for all students. Limited communication options.	Teacher response delay in online communication. Indirect formation of personal relationships. Predefined options for the response of the electronic resource to the actions of the student.

In conclusion, the analysis of different approaches to the development of students' computational thinking with the help of concrete sciences shows that in many studies devoted to various educational technologies, its positive aspects are emphasized:

- every student will have the opportunity to acquire the necessary knowledge and skills in a convenient format;
- planning and understanding what needs training should meet and what results it will bring;
- provision of effective educational management tools;
- reducing the time and financial costs of training without losing the advantages of the traditional approach;
- enriching and complementing technologies and teaching methods;
- active social communication of students with each other and teachers;
- the presence of the teacher is almost constant;
- the possibility of teaching regardless of time and place;
- variety of didactic approaches;
- improving the quality of education (including through the use of more effective educational tools);

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- individual control over training;
- the natural development of modern work, organization of means of communication by students;
- the priority of the student's independent activity;
- organization of individual support for the educational activities of each student;
- organization of educational activities in groups;
- flexibility of the educational trajectory;
- Integrating educational and methodological online and offline reusable content.

This, in turn, helps future engineers to develop many intellectual abilities, such as creativity, technical thinking, computational thinking.

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