Professional orientation as a component in the formation of algorithmic culture among information technology students

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ABSTRACT: This study investigated the formation of an algorithmic culture of information technology (IT) students in the process of professional training. Within the framework of this study, the structural components of algorithmic culture have been identified. The indicators of professional orientation as a component in the formation of algorithmic culture are disclosed in the article. The level of professional orientation among information technology students of is also demonstrated. A diagnostic map has been developed, which made it possible to conduct an appropriate analysis through ranking and questioning. The results of the study to determine the level of professional orientation as a component in the formation of an algorithmic culture made it possible to identify the average level of professional orientation among information technology students. The authors conclude that most of the students seek to realise themselves in the modern information society as highly qualified IT specialists, understanding the demand for their specialisation in the labour market, but are not sufficiently aware of the importance of algorithmic culture for future professional activities.

Keywords: Algorithmic culture, algorithmic thinking style, algorithmic activity, information technology professional orientation

INTRODUCTION

The formation of an algorithmic culture of information technology (IT) students as the basis of their information culture is a prerequisite for their preparation for future professional activities in the modern conditions of digitalisation and the IT market. Modern information specialists have to develop, choose and use effective and optimal algorithms for solving problems for the implementation of professional activities. The training of highly qualified IT specialists with a developed culture of thinking is one of the strategic guidelines for the modernisation of higher education. The algorithmic culture of a student acts as one of the important components of his/her general culture, without which it is impossible to interact in the modern information society.

LITERATURE REVIEW

The importance of the algorithmic culture of a modern specialist is emphasised in several studies including, Tracy and Carmichael [1], Sunday, et al [2], and Malik et al [3]. Striphas defines the conceptual conditions for the emergence of the *algorithmic culture* concept and determines a new meaning for this term in the modern conditions of digital technology development [4]. The author identifies three main components that are related to the algorithmic culture: information, a person and an algorithm, while emphasising the development of systems for processing large amounts of data and their impact on the algorithmic culture of a modern IT specialist [4]. Dourish claims that modern civilisation is a civilisation of algorithms, with algorithms managing key moments of human life and society [5]. The author also considers algorithmic culture as a lens for studying the modern digital culture of IT specialists [5].

According to Surowik, the algorithmic culture of a student has integrative properties that contribute to the universalisation of the qualities of a future IT specialist [6]. The higher the level of algorithmic culture, the more guarantees of the correctness of the decisions made [6]. In a study by Hutchinson, algorithmic culture is defined as a form of digital mediation in automated multimedia systems [7]. The issue of forming an algorithmic culture of students' thinking was considered by Hromkovič et al [8]. According to the authors, algorithmic thinking and problem-solving strategies are the main principles of computer science. Programming education should reflect this and emphasise various aspects of these principles rather than focus on the syntactical details of a particular programming language. The same authors identified three main aspects of algorithmic thinking as goals for a programming curriculum: the concept of a formal language for expressing algorithms; abstraction and automation for translating proven strategies into new instances; and the limits of practical computability [8].

Pak et al revealed that the development of multidimensional algorithmic thinking should be carried out through the use of mental algorithmic maps for various thinking styles, mental and empirical tasks, as well as kinaesthetic simulators [9]. According to the authors, such learning tools include all channels of perception and greatly contribute to the understanding and better assimilation of the subject *Algorithmisation and Programming* [9].

Significant aspects of the formation of a culture of thinking of students, necessary for their familiarisation with mental activity, were considered by Gushchin [10], and Sarsekeeva et al [11]. Khaliullina in her study determined that the development of a culture of thinking depends on the orientation of students' thinking towards processing the received educational information, their subjective attitude to tasks and mastery of logical operations [12].

The work of Balkin concerns the conditions for the formation of an algorithmic culture of students based on the information approach [13]. According to the author, the level of formation of an algorithmic culture depends on the volume and time of algorithmic activity, which consists in the implementation of modelling, systematisation, structuring of information, on the development and awareness of the algorithmic nature of any human information activity in the context of the development of digital infrastructure [13]. Milková in her study described the use of a developed multimedia application for the formation of an algorithmic culture [14]. The author presented an application designed to intensify self-training of students in subjects that develop algorithmic thinking and the advantages of its application [14].

The issue of forming an algorithmic culture of students in the conditions of distance learning was considered in the work of Varzhavinova and Irkhin [15]. The authors revealed the content and technological essence of the formation of algorithmic culture among students in a university setting; a methodology is presented that includes diagnostic, constructive, activity and evaluation stages of the formation process. Tararina et al describe distance learning conditions that contribute to the development of the ability to use various sources of information to search for solution algorithms, and their implementation in various situations [16]. Humbataliev and Babaeva determined the stages of the formation of algorithmic culture and revealed the interaction of algorithmic activity with learning activity [17]. The authors emphasised the importance of the algorithmic direction of education in solving the problem of interdisciplinary communication and specialisation of students [17].

The problem of developing algorithmic culture and computational thinking in programming courses was discussed in by several authors [18-21]. For the successful formation of algorithmic culture, a methodology for step-by-step training in solving multi-level professionally oriented problems is proposed, and the content of the activities of the teacher and student when studying programming disciplines is presented. It is critical to move beyond traditional teaching methods and explore the experiences and reflections of mathematics students as they are introduced to programming and computational thinking [22].

The influence of software visualisation on the development of the algorithmic culture of future Web application developers was considered by Jaimez-González and Castillo-Cortes [23]. According to the authors, visualising algorithms through animation allows students to better understand basic programming concepts, such as declaring variables, assigning values to variables, using control structures and calling functions with parameters.

Thus, the above literature review shows that the concepts of algorithmic culture, algorithmic style of thinking and the direction of the formation of algorithmic culture are in the centre of attention of scientists all around the world, and are considered one of the most significant problems of professional training of IT specialists. However, there is a paucity in research on the issue of professional orientation as a component in the formation of the algorithmic culture of IT students. For the successful formation of the algorithmic culture of students, it is necessary to understand the requirements of the profession in the conditions of the development of the information society, recognise the need for algorithmic knowledge and skills and the role of algorithmic activity in the general system of professional activity, and to realise the importance of algorithmisation in solving professionally oriented tasks.

The purpose of this study was to identify the level of professional orientation of IT students as a component in the formation of their algorithmic culture in the educational environment of *E.A. Buketov* Karaganda State University, Kazakhstan.

MATERIALS AND METHODS

Within the framework of the problem under study, the concept of *algorithmic culture* is the key one. The concept of algorithmic culture has been defined in various sources as:

- a set of specific ideas, skills and abilities associated with the concept of an algorithm, forms and methods of its recording;
- the basis of computer literacy;
- a complex of personal qualities and a certain level of algorithmic thinking, which provide an understanding of the role of algorithms in a variety of activities;
- the ability to describe an algorithm using certain means and methods of description - for example, using a flowchart;
- knowledge of the main types of algorithmic processes;
- a systemic education, characterised by a certain level of development of algorithmic values, knowledge and skills that allow mastering the basics of professional activity algorithmisation, and reflects the way of self-organisation of activity in the information society;

- a systemic and dynamic formation, characterised by a certain level of development of algorithmic thinking, awareness of the common components of algorithmisation and manifested in various forms of algorithmic activity, prompted by the need-motivated sphere.

The analysis of various approaches to the essence of algorithmic culture allowed the authors of this article to identify the following structural components of the algorithmic culture of information technology students: professional orientation of the future IT specialist; possession of algorithmic knowledge; possession of means and methods for describing algorithms; creative activity in solving professionally oriented tasks. The key to a successful and effective formation of the algorithmic culture of students is their motivation for learning and their professional orientation. In accordance with the goal of this study, the authors intended to identify the level of professional orientation of IT students as one of the components of their algorithmic culture. For this purpose, they have developed a diagnostic card (Table 1), which allowed them to conduct an appropriate analysis through ranking and questioning.

Table 1: Diagnostic card for IT students.

Speciality _____ Course _____		
No.	Questions	Answers
1	Do you take part in programming competitions, exhibitions of software projects?	Yes (no) _____ Your achievements
2	In your opinion, what requirements does the information society put forward for IT specialists?	
3	What area of information technology are you going to work in? Mark your choice.	☐ programmer ☐ database administrator ☐ web designer ☐ network administrator ☐ systems engineer
4	What special knowledge (skills) will you need in your future professional activity? Please rank the options.	☐ mathematical ☐ algorithmic ☐ physical ☐ technical
5	What special knowledge (skills) do you feel you lack in order to solve professionally oriented problems? Mark your choice.	☐ mathematical ☐ algorithmic ☐ physical ☐ technical
6	Why did you choose this specialty?	
7	What is most important, in your opinion, for the compilation of computer programs?	
8	What role does algorithmic culture play in your professional activity? Mark your choice.	☐ nothing ☐ significant ☐ insignificant ☐ very significant ☐ relative
9	Rate your level of algorithmic training on a 10-point scale (0-none; 9-very high)	_____ points
10	Do you have an algorithmic thinking style?	Yes (no)_____
11	Will your professional activity be related to algorithmic activity?	Yes (no)_____
12	In case of difficulties in compiling solution algorithms, would you be looking for an answer:	☐ on one's own ☐ teachers ☐ the Internet ☐ books ☐ friends
13	Is knowledge of classical algorithms necessary for solving problems?	☐ yes, it always helps ☐ yes, it will come in handy ☐ no, not worth the time ☐ no, cannot always find a ready-made solution ☐ no, they have no practical value
14	What programming language, in your opinion, should be taught in the first year when studying algorithmisation?	☐ Basic ☐ Pascal ☐ C/C++ ☐ Python ☐ Java ☐ another _____
15	Did you consciously choose this specialty, understanding its importance in the modern information society? Justify your answer.	

The professional orientation of the future IT specialist was determined by the following indicators: a positive attitude towards the future profession; knowledge and understanding of the requirements of the profession for algorithmic knowledge and skills; awareness of the importance of algorithmisation for solving professionally oriented tasks; the presence of cognitive interest in the search for new algorithms for solving problems; understanding the role of algorithmic activity in the overall system of professional activity. Correlation of these indicators with the questions of the diagnostic card is presented in Table 2.

Table 2: Correlation of the indicators with the diagnostic questions.

Indicators of professional orientation	Question number on the diagnostic card
Positive attitude towards future profession	3, 6, 15
Knowledge and understanding of the requirements of the profession for algorithmic knowledge and skills	2, 4, 5, 8, 13, 14
Awareness of the importance of algorithmisation for solving professionally oriented problems	2, 3, 7, 9, 10
The presence of cognitive interest in the search for new algorithms for solving problems	1, 12
Understanding the role of algorithmic activity in the overall system of professional activity	5, 8, 9, 11

The study was conducted in the 2022-2023 academic year among students of the following information technology specialties: 5B070300/6B06103 - *Information Systems*; 5B060200/ 6B06101 - *Computer Science*; 5B070500/6B06104 - *Mathematical and Computer Modelling* of *E.A. Buketov* Karaganda State University, Kazakhstan. Data were collected from a survey in which 209 students were involved: 1st year - 54; 2nd course - 53; 3rd course - 50; 4th course - 52.

A systematic approach to the study allowed the authors to carry out the investigation holistically, and on that basis to identify the relationship between the structural elements ensuring integrity.

RESEARCH RESULTS

The survey data were analysed first. The number of respondents (209) can be considered statistically justified, and their assessment of various aspects of the phenomenon under study (algorithmic culture, algorithmic training) as reflecting their own opinion. The diagnostic validity of the study was ensured by a number of cross-cutting questions, sufficient awareness of the surveyed students in various characteristics of the topic under study, their knowledge, experience and intuition for *a priori* assessment of the factors proposed by them.

The analysis of the answers to question 1 by students of the 1st and 2nd courses showed that the majority of the students (98%) were not fond of programming, and respectively, demonstrated no interest in studying algorithmisation, and only 1% of the students surveyed participated in olympiads. Among 3rd- and 4th-year students, the analysis showed that the number of participants in programming competitions increases to 5%, including 4% of participants at the regional level, 1% at the republican level, and the number of participants in exhibitions of software projects is up to 15% of students, of which 12% are students who participated in events at the university level, 2% at the regional and 1% at the national level.

The analysis of the answers to question 2 revealed that students define the following requirements for information specialists: development of information resources, development of software and its use, development of telecommunications and networks, and the protection of information. The analysis of the answers to question 3 among students of all courses showed that students' choice of the IT sphere of their future professional activity is approximately the same (Figure 1).

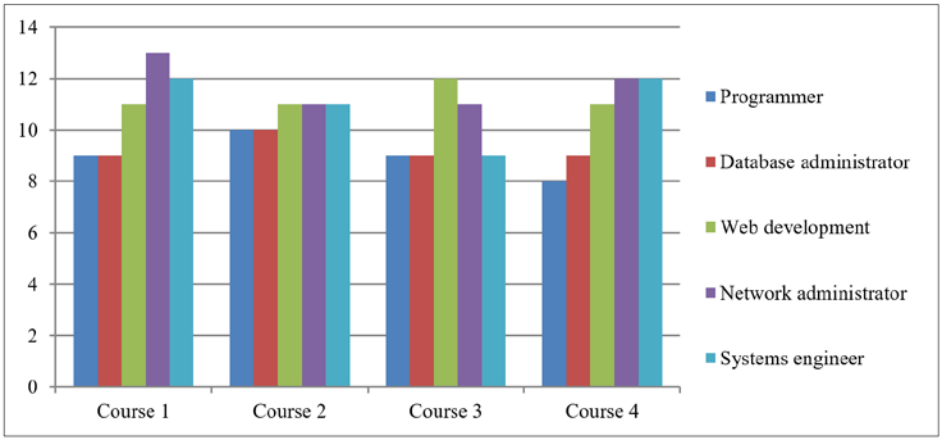

Figure 1: Choice of IT speciality by students.

According to the analysis of the answers to questions 4-8 and 11, there is a slight positive trend in understanding the importance of algorithmic culture for the future profession among graduate students, but in general it is not at a high enough level (Figure 2). Almost all students of the 1st, 2nd and 3rd courses in response to questions 9 and 10, rated their algorithmic training at a low level (less than 5 points out of 9), and graduate students - a little higher, as a result of writing diploma projects. The analysis of the answers to question 12 suggests that the majority of the students (82%) do not seek to independently find a solution to problems by developing an algorithm, but turn to various sources: the Internet - 35%, teachers - 14%, books - 4%, friends - 29%.

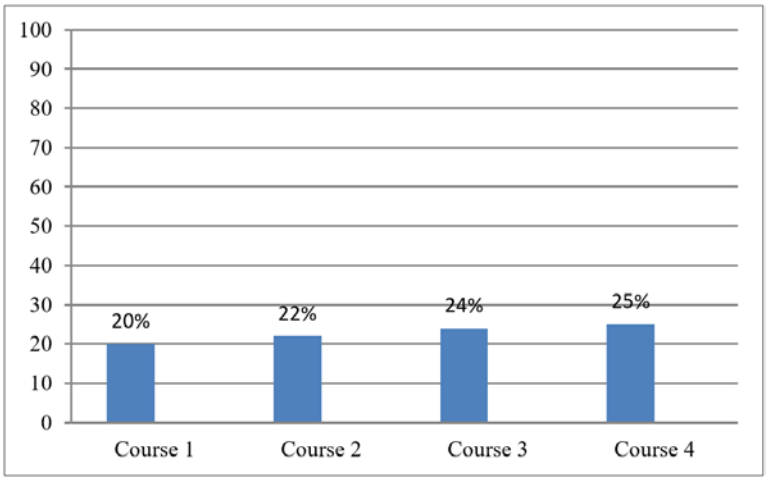

Figure 2: Awareness of the importance of algorithmic culture among students by training courses.

When analysing the answers to question 13, it was revealed that only 25% of the students note the importance of classical algorithms in solving problems. The analysis of the answers to question 14 showed that the majority of the students (81%) understand the importance of learning high-level algorithmic languages (C/C++ and Python) and their application for the implementation of algorithms. The analysis of the answers to question 15 showed that 94% of the students understand the demand for specialists in their field by the information society.

A general analysis of the answers suggests that students understand the requirements of the information society for IT specialists, but do not fully understand the algorithmic component of professional training, underestimate the role of algorithmic activity in the overall system of professional activity, and have insufficient understanding of the importance of algorithmic culture for solving professionally oriented tasks.

It was also revealed during practical and laboratory classes in programming and also through observing students' work in solving professionally oriented problems that there is practically no cognitive interest in finding new algorithms for solving problems, and that most students do not seek to independently find algorithms for solving problems, but refer to various sources, which is also confirmed by the results of the survey. The main reason for this, in the authors' opinion, is the low level of mathematical training and the lack of an algorithmic style of thinking. There is also a low cognitive activity in the development of various means of implementing algorithms. The level of professional orientation was determined on the basis of a set of developed indicators.

Mathematical processing of statistical data of the conducted survey and observation of students' work in the process of solving professionally oriented tasks in programming made it possible to group students according to the levels of professional orientation in accordance with the indicators. The results are presented in Table 3.

Table 3: Grouping of students by levels of professional orientation considering the diagnostic card.

Levels	Courses							
	1st course		2nd course		3rd course		4the course	
	%	Number of students	%	Number of students	%	Number of students	%	Number of students
Low	35.2	19	32.1	17	30.0	15	23.1	12
Average	37.0	20	41.5	22	38.0	19	42.3	22
High	27.8	15	26.4	14	32.0	16	34.6	18

The analysis of the study results made it possible to determine that the professional orientation of students of information specialties is at an average level, while the level of professional orientation of senior students is slightly higher than that of students in the 1st and 2nd year of their study. This is explained, in the authors' opinion, by the volume of obtained algorithmic skills and abilities in practical programming classes and during professional practices. Most of the students strive to realise themselves in the modern information society as highly qualified IT

specialists, understanding the demand for their specialisation in the labour market, but they are not sufficiently aware of the importance of algorithmic culture for their future professional activities.

In the authors' opinion, in order to increase the level of professional orientation and the successful formation of an algorithmic culture of students, it is necessary that in programming aimed at solving professionally oriented problems students' attention is focused on the algorithmisation of computational processes, and independent research to develop algorithms for solving problems. In this case, the study of programming languages should be an accompanying, and not the main task of the course. When solving problems and studying new algorithms, students accumulate quantitative algorithmic knowledge, which contributes to a better understanding of the role of algorithmisation, thereby increasing the level of their professional orientation. An independent search for algorithms for solving problems creates the basis for an individual style of future professional activity.

DISCUSSION AND CONCLUSIONS

The analysis of the conducted research allows the authors to point out that the formation of an algorithmic culture among university students is relevant for researchers across the globe, and that the algorithmic culture of information technology students should be part of the general culture of every IT specialist.

The results of the study to determine the level of professional orientation as a component in the formation of algorithmic culture enable to identify the average level of professional orientation among information technology students. It should be noted that senior students have a slightly higher level of professional orientation than students in the 1st and 2nd year of study. This is due, in the authors' opinion, to a large volume of completed practical tasks in programming, solving professionally oriented tasks and gaining practical programming experience during professional practices.

The conducted survey suggests that the majority of students do not fully realise the importance of algorithmic culture for their future professional activities. In general, according to the results of the survey, it can be stated that students of the 1st to 4th course are interested in realising themselves in the modern information society as highly qualified IT specialists, but at the same time they do not pay due attention to their algorithmic culture.

The authors also note the need to teach students to independently search for algorithms for solving professionally oriented problems in order to increase the level of professional orientation and form their algorithmic culture.

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