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ALGORITHMIC THINKING IN HIGHER EDUCATION: DETERMINING OBSERVABLE AND MEASURABLE CONTENT

Abstract. Nowadays algorithmic thinking, as a key demand and the main requirement of technology-based society, extensively expands outwards the computer science area and rapidly becomes a meaningful instrumentality for effective realization of any information activities with or without ICT. This instrumentality creates new opportunities and possibilities for improvement of the effectiveness of any educational professional activities in the higher education context by creating problem-solving algorithms completely within the ICT area, as well as non-ICT-based algorithms that provide clear technological step-by-step instructions for solving a diversity of educational problems.

Although attention to algorithmic thinking as scientific phenomenon is increasing, the studies aimed at determining the algorithmic thinking content in observable and measurable statements have not been conducted yet and its great potential is still undiscovered.

The purpose of this study is to identify, clarify, and categorize algorithmic thinking content in observable and measurable knowledge, skills, and abilities statements (KSAs).

The study is a mixed-methods type of development research carried out in 4 stages: 1) extraction of the KSA statements from the extant scientific literature related to algorithmic thinking; 2) design of The Algorithmic Thinking Content Survey (ATCS) based on the five steps Universal Sequence of an Algorithm Development (USAD); 3) administration of the ATCS on a wide variety of educational professionals (N = 117); 4) data analysis aimed to obtain the content of algorithmic thinking in observable and measurable KSA statements.

The design of the ATCS is also based on algorithmic thinking as a complex phenomenon that integrates five types of thinking: abstract, logical, figurative, conceptual, and constructive.

The administration of the ATCS involved 117 experts – educational professionals (11 professors who teach courses concerning algorithms and computer science, 23 practicing teachers of informatics, 35 students in the 3rd year of Informatics teacher training program, and 48 master

students of informatics). Expert validation of algorithmic thinking content in knowledge, skills, and abilities statements was obtained through the Likert scale.
One hundred KSA statements of algorithmic thinking content were obtained (32 statements of knowledge, 38 statements of skills, and 30 statements of abilities).

Keywords: ICT; higher education; algorithmic thinking; measurable and observable algorithmic thinking content; KSA statements.

1. INTRODUCTION

The problem statement. Algorithmic thinking is a new demand of a technology-based society that creates many opportunities for every professional to enhance the quality and optimize any information activities. Even though algorithmic thinking is one of the core concepts of the ICT sphere, it is a versatile and indispensable instrumentality for creating problem-solving algorithms far beyond the computer science area. In the context of higher education professional activities, algorithmic thinking unfolds the benefits of using algorithms for better solutions to everyday routines and tasks based on a person’s strengths, beliefs, perceptions, and needs both with and without the use of ICT.

However, bringing algorithmic thinking into higher education professional activities requires clarifying and categorizing its content in observable and measurable statements.

Analysis of recent studies and publications. A targeted literature review suggests that the problem of algorithmic thinking has been widely researched.

Previous research examines the role of algorithmic thinking in education: algorithmic thinking as one the most important ICT competencies (L. Zsakó, Szlávi) [1]; the importance of students’ algorithmic thinking skill improvement (M. Hrubý) [2]; semantic aspects of algorithmic thinking (M. Kovalchuk) [3].

A growing body of researchers continues to investigate the problem of encouraging, forming, and developing algorithmic thinking in computer science context: R. Tadevosyan, O. Shevchuk [4], G. Geda, Cs. Bíró [5], V. Vdovenko [6], M. Kovalchuk, A. Voievoda, E. Prozor [7], J. Quaicoe, M. Laanpere, K. Pata, N. Hoić-Božić, R. Rõbtšenkov [8], S. Chuechote, A. Nokkaew, A, Phongsasithorn, P. Laosinchai [9], J. Hromkovič, T. Kohn, D. Komm, G. Serafini [10], J. Mezak, P. Papak [11], D. Gonda, V. Duriš, A. Tirpáková, G. Pavlovicová [12]. The results obtained by authors [4] - [12] cover the following aspects: a possible way to develop algorithmic thinking; formation of algorithmic thinking of junior schoolchildren at computer science lessons; algorithmic thinking as a meaningful component of cognitive competencies of the future engineer; games for learning algorithmic thinking projects; algorithmic thinking development through the “sorted” digital game; examples of algorithmic thinking in programming education; learning scenarios and encouraging algorithmic thinking; teaching algorithms to develop the algorithmic thinking of the informatics students.

There are few studies on algorithmic thinking development without a computer: encouraging algorithmic thinking without a computer (B. Burton) [13], algorithmic thinking skills without computers for prospective computer science teachers (Ç. Güler) [14], algorithmic thinking as a new dimension of learning in higher education (M. Byrka, A. Sushchenko, A. Svatiev, V. Mazin, O. Veritov) [15], and prospective directions of research on the problem of algorithmic thinking (M. Byrka [16]).

However, research on identifying algorithmic thinking content in observable and measurable statements both with and without the use of ICT is still lacking.

The study goal is to identify, clarify, and categorize algorithmic thinking content in observable and measurable knowledge, skills, and abilities statements (KSA statements).

2. THE THEORETICAL BACKGROUND

The study is based on the following theoretical research: "The Universal Sequence of an Algorithm Development" [15], "The Model of Algorithmic Thinking" [15], and "The Knowledge, Skills, and Abilities Framework" [17]-[18].

2.1. The Universal Sequence of an Algorithm Development and the Model of Algorithmic Thinking

The study uses the Universal Sequence of an Algorithm Development (USAD), developed and adapted to higher education by M. Byrka, A. Sushchenko, A. Svatiev, V. Mazin, and O. Veritov [15]. The sequence is also an algorithm settled for solving problems in any subject in and beyond the ICT area.

The suggested USAD consists of 5 steps: 1) clear formulation of expected results that should be obtained after solving a problem; 2) determination of all properties of the problem and detailing constraints of resources (time, logistics, finances, etc.); 3) selection and sequence determination of main actions that are necessary to solve the problem; 4) implementation of this sequence of actions considering all properties and constraints of the problem; 5) comparison of the obtained results with the desired ones, and, if necessary, adjustment of the sequence of the set of defined actions [15].

Based on the USAD, algorithmic thinking is considered an integrated complex that includes other simple types of thinking: abstract, logical, and figurative thinking, as well as conceptual thinking and constructive thinking. The *abstract thinking* and *conceptual thinking* are required *to perform steps one* and *two* of the proposed universal sequence of algorithm development (clear formulation of expected results that should be obtained after solving a problem, determining all properties of the problem, and detailing constraints of resources (time, logistics, finances, etc.). The *logical, constructive*, and *figurative thinking* should be applied *to perform step three* (selection and sequence determination of main actions that are necessary to solve the problem). The conceptual, logical, constructive, and *figurative thinking* are required *to execute step four* (implementation of this sequence of actions considering all properties and constraints of the problem) and *step five* (comparison of the obtained results with the desired ones, and, if necessary, adjustment of the sequence of the set of defined actions) [15].

2.2. The Knowledge, Skills, and Abilities Framework

The Knowledge, Skills, and Abilities (KSA) framework [17-18] is a series of narrative statements that determines the successful performance of an educational professional in algorithmic thinking activities by performing the Universal Sequence of an Algorithm Development (fig. 1).

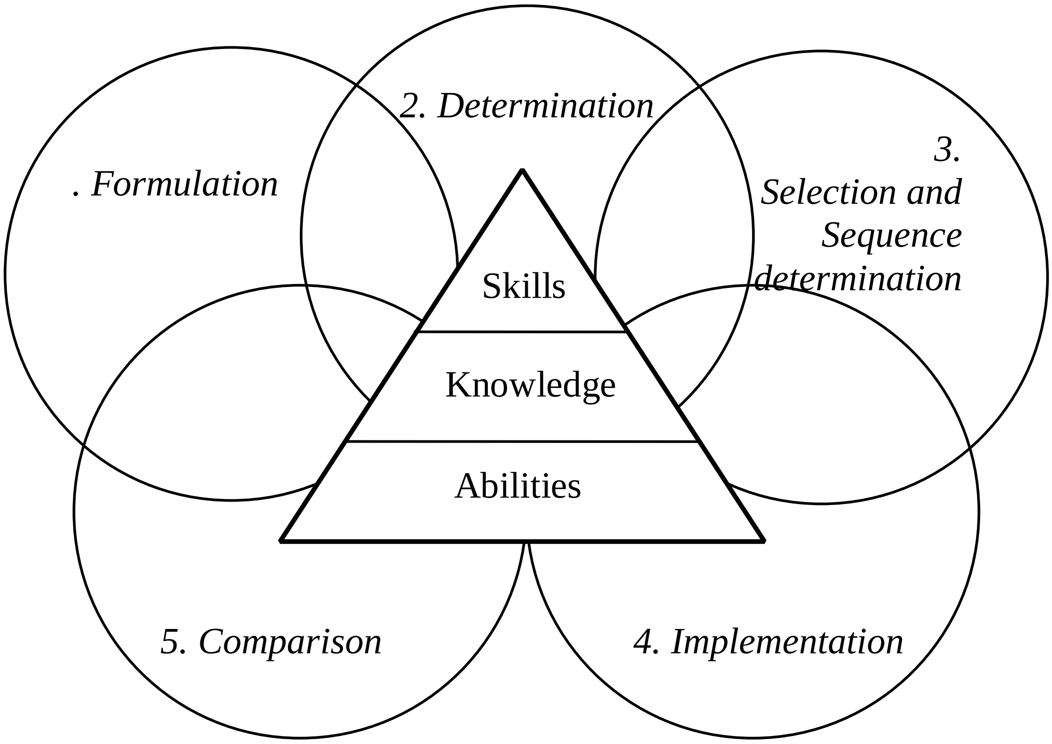

Figure 1. Interrelations between Knowledge, Skills and Abilities statements and Universal Sequence of an Algorithm Development

Knowledge as a person's cognitive characteristic contains the next three categories: 1) *propositional knowledge* or *declarative knowledge*, that refers to "an understanding or familiarity of facts and/or of objects"; 2) *procedural knowledge*, which is knowledge of "how to do something", and 3) *knowledge by acquaintance*, or *strategic knowledge*, or *conditional knowledge* that refers to "when and why to apply different procedures, use specific approaches or make certain choices, which comes from deep familiarity" (N. Waights Hickman) [19]. J. Hlavac considers *knowledge* as a term that encompasses cognitive attributes that refer to "a person's familiarity with" and "capability of doing something". Also, the author is certain that knowledge does not require demonstration or application in a tangible or observable sense [18].

Thus, in the KSA framework, *knowledge* refers to the body of declarative, procedural and strategic knowledge that an educational professional should know at the time of applying algorithmic thinking and building an algorithm. In knowledge domain, algorithmic thinking focuses on conceptual strategic comprehension of educational professional activities, theoretical and practical understanding of how to resolve possible problems, algorithm theory and involves all above mentioned three categories of knowledge.

Skills are reasonably based on a person's knowledge. J. Hlavac considers a skill as "either a demonstration of procedural knowledge or the capability to demonstrate procedural knowledge". Consequently, skills are "almost always something observable and measurable", "usually involve a person's interaction with stimuli and/or other people", and "result from training, i.e. a process of learning and acquisition of proficiencies, including training that may be self-directed" [18, p. 31]. In our opinion, *skills*, as the next element in the KSA framework, should be based on all three knowledge categories with *the main focus on the use of procedural knowledge*, which is most important for algorithms development because of its strong dependence on conditions of resolving a particular problem.

Thus, *skills* are the educational professional's observable and measurable capabilities in actual application of declarative, procedural and strategic knowledge for resolving a particular problem by using means of abstract, logical, figurative, conceptual, and constructive thinking incorporated in the USAD.

Abilities, as the last element in the KSA framework, refer to "the power or capacity to act or to do certain things in a particular way" (J. Hlavac) [18, p. 31]. Although abilities are frequently confused with skills, they are the intrinsic features, innate traits, or talents that a person brings into solving a problem, and they "refer to performing something in a wide variety of senses – physical, mental, financial, moral, etc." (J. Hlavac) [18, p. 31]. The abilities as intrinsic features match a person's qualities and inclinations (M. Byrka et al.) [20, p. 228]. Along with that, abilities attain a "ranking" function, which means if someone can do something well, they have the abilities required to do it (J. Ladwig, A. McPherson) [21]. However, abilities are "not the result of formal training or instruction" (J. Hlavac) [18, p. 31], therefore they can be improved rather by observation and feedback in the course of a particular person's activities [22].

Thus, *abilities* are cognitive aptitudes that present the educational power to apply algorithmic thinking knowledge and skills simultaneously in order to develop an algorithm in an observable behavior. Among abilities are the intrinsic thinking features, innate traits and talents that the educational professional brings to an algorithm development activity.

Consequently, *the KSA framework of an algorithm development* refers to all knowledge, skills and abilities used together to perform the USAD and due to its features *can be aligned to the person's competence in developing algorithms*.

3. RESEARCH METHODS

This study employed a mixed-methods research design involving the application of both qualitative and quantitative approaches. As for this study case, a qualitative research approach and an extant literature analysis helped the researchers to gain insights into the definition of algorithmic thinking content. Expert validation of obtained qualitative data as a quantitative procedure contributed to clarifying and categorizing the content of algorithmic thinking in observable and measurable knowledge, skills, and abilities statements.

The experimental base of research included Yuriy Fedkovych Chernivtsi National University and Poltava V.G. Korolenko National Pedagogical University. These higher educational institutions provide educational programs and disciplines which have explicit or implicit application of algorithmic thinking and train future educational professionals, and offer courses in algorithms and computer science in their curricula (Programming Languages, Data Analytics, Algorithm Design and Development, Advanced-Data Structures, Programming Foundations: Algorithms, Computer Science Fundamentals, Machine Learning, Mobile App Development, Internet of Things etc.).

To define algorithmic thinking content in measurable KSA statements, we analyzed the corpus of scientific publications from September 2023 to March 2024 from Scopus abstract and citation database, Web of Science Core Collection citation database, and web sites of Scientific Periodicals of Ukraine. The obtained data, in Algorithmic Thinking Content Survey, were arranged and grouped by five steps of the universal sequence of an algorithm development and knowledge, skills, and abilities domains.

To capture the various KSA statements of algorithmic thinking content in the survey we selected eight relevant keywords used by scholars: (a) algorithm development, (b) algorithmic thinking, (c) algorithmic thinking content, (d) abstract thinking, (e) logical thinking, (f) figurative thinking, (g) conceptual thinking and (h) constructive thinking.

To assess the appropriateness of the obtained KSA statements, the Algorithmic Thinking Content Survey uses 5-point Likert-type scale (-2 – "Absolutely inappropriate", -1 –

“Inappropriate”, 0 – “Neither Agree nor Disagree”, 1 – “Appropriate”, 2 – “Absolutely appropriate”).

In total, 117 participants who are considered as practicing or prospective educational professionals took part in this study. The survey involved 11 professors, who teach courses in algorithms and computer science, 23 practicing teachers of informatics from Chernivtsi region, 35 Informatics students of the 3-4 years of study, and 48 Master’s students of informatics from Yuriy Fedkovych Chernivtsi National University and Poltava V.G. Korolenko National Pedagogical University.

To obtain the content of algorithmic thinking in observable and measurable knowledge, skills, and abilities statements, we performed data analysis of the ATCS results: (1) sorting in descending order; (2) discarding 10% of items which received the lowest scores of the appropriateness; (3) merging the statements grouped by five steps of the USAD in knowledge, skills, and abilities domains; (4) avoiding duplication of derived results. As a result, *one hundred KSA statements* of algorithmic thinking content were obtained (32 statements of knowledge, 38 statements of skills, and 30 statements of abilities).

The research was carried out in 4 stages: 1) extraction and merging of the knowledge, skills, and abilities statements from the extant literature related to algorithmic thinking definition; 2) design of the Algorithmic Thinking Content Survey (ATCS) based on the 5 steps Universal Sequence of an Algorithm Development; 3) administration of the ATCS on a wide-variety of educational professionals (N = 117); 4) data analysis aimed to obtain the content of algorithmic thinking in observable and measurable knowledge, skills, and abilities statements.

4. THE FINDINGS AND DISCUSSION

4.1. The Algorithmic Thinking Content Survey

Table 1 presents the Algorithmic Thinking Content Survey questions arranged alphabetically and grouped by five steps of the Universal Sequence of an Algorithm Development and KSA statements (“knowledge of/understanding of”, “skills to”, and “abilities to”).

Table 1

The Algorithmic Thinking Content Survey structure and content

Knowledge of/understanding of	**Skills**	**Abilities**
1) clear formulation of expected results that should be obtained after solving a problem		
a problem subject area how to do a generalization how to do a result formulation how to do an abstraction how to do an analogy modeling principles regularities of a problem specifics of a problem	being accurate and seeking accuracy being clear and seeking clarity decision making identifying regularities of a problem identifying specifics of a problem making abstractions making analogies making generalizations	ability to define the expected final results ability to define the intermediate results ability to take the best possible decision abstract thinking conceptual thinking critical reasoning ability to exercise imagination ability to gain insight
2) determination of all properties of the problem, and detailing constraints of resources (time, logistics, finances, etc.)		
a problem subject area how to define a limitation how to do a generalization how to do an abstraction	being accurate and seeking accuracy being clear and seeking clarity being detail oriented	ability to isolate and select the main challenges of a problem ability to see the problem entirely

how to do an analogy how to identify a problem how to plan how to reflect problem-solving strategies regularities of a problem specifics of a problem	decision making identifying constraints identifying necessary resources identifying of a problem identifying peculiarities of a problem identifying regularities of a problem making abstractions making analogies making generalizations making plans making reflection	ability to take into account a variety of properties of the problem abstract thinking conceptual thinking
3) selection and sequence determination of main actions that are necessary to solve the problem		
a problem limitation a problem subject area a problem's spatial and parametric inner relationships algorithmic thinking concepts and their application to a problem algorithms theory how to do a deduction how to do a formalization how to do a generalization how to do an abstraction how to do an analogy how to analyze how to do an induction how to plan how to reflect problem-solving strategies the basic algorithmic structures the basic steps of an algorithm the specifics of algorithmic constructions the technology of step-by-step solution of the problem	analyzing perspectives applying the operational components of algorithmic thinking comprehensively in a holistic process of solving various problems being accurate and seeking accuracy being clear and seeking clarity being detail oriented building a sequence of actions building complex algorithms based on simple ones building logical statements building sequences of actions building simple algorithms creativity decision making deductive reasoning dividing tasks into successive interconnected blocks identifying constraints identifying necessary resources inductive reasoning making abstraction making analogies making generalizations making plans operating inductive and deductive reasoning in building an algorithm planning appropriately planning of final goal planning of intermediate results planning of the actions planning the structure of actions necessary to achieve a goal with a fixed set of tools problem-solving skills producing sequential and logical solutions to a problem reflection solving various kinds of problems involving the preparation of an action plan for their resolution structuring of the actions	ability to apply policies and procedures and use available resources ability to construct algorithms that take into account all the requirements for their development ability to express solution step by step ability to find optimal solution to a problem ability to generate new ways of viewing a situation that are outside the boundaries of standard conventions ability to invent ability to manage personal mental activity consciously ability to provide a general solution plan for a problem ability to provide the basic steps of an algorithm ability to research, analyze and critically review information ability to think in steps ability to apply sequential rules to problem-solving attention (span, selectivity and concentration) constructive thinking figurative thinking logical thinking

	taking into account a variety of constraints of resources using algorithm structures competently and effectively using the method of formalization	
4) implementation of this sequence of actions considering all properties and constraints of the problem		
algorithm comprehension algorithms theory limitations of a problem problem-solving strategies regularities of a problem specifics of a problem the operations that should lead to the sequence and execution of these tasks the problem subject area	being accurate and seeking accuracy being detail oriented following certain patterns implementing the steps of an algorithm independently solving problems independently	ability to complete assigned sequence with a high level of accuracy ability to implement all steps of an algorithm without hesitation ability to maintain composure under pressure ability to work independently with minimum supervision ability to work well under pressure and meet tight deadlines ability to work with algorithms conceptual thinking constructive thinking figurative thinking logical thinking
5) comparison of the obtained results with the desired ones, and, if necessary, adjustment of the sequence of or the set of defined actions		
accuracy algorithm comprehension efficiency expected intermediate and final results that should be obtained after solving a problem how to analyze how to do a comparing how to do a deduction how to do an induction how to reflect limitations of a problem systems analysis the problem subject area understanding of all properties of the problem, and detailing constraints of resources (time, logistics, finances, etc.)	analyzing errors analyzing perspectives being accurate and seeking accuracy being detail oriented building logical statements decision making examining algorithms making comparations presenting data recognizing errors and solving problems to make improvements summarizing data systems analysis	ability to check the solution for accuracy and efficiency ability to evaluate the effectiveness of your actions ability to monitor your own thinking ability to recognize errors ability to research, analyze and critically review information ability to respond appropriately to feedback ability to shift priorities ability to update algorithms taking into account all challenges and find an optimal solution to a problem conceptual thinking constructive thinking deductive reasoning figurative thinking inductive reasoning logical thinking

4.2. Knowledge statements domain

The data analysis resulted in 32 observable and measurable statements of knowledge of the algorithmic thinking content both with and without the use of ICT.

Knowledge of/understanding of: a problem subject area; regularities of a problem; specifics of a problem; limitations of a problem; the basic algorithmic structures; the specifics of algorithmic constructions; the basic steps of an algorithm; a problem's spatial and parametric inner relations; algorithm comprehension; accuracy; efficiency; expected intermediate and final results that should be obtained after solving a problem; understanding of all properties of the problem, and detailing constraints of resources (time, logistics, finances, etc.) were considered as observable and measurable statements of *propositional knowledge* of the knowledge statements domain of the algorithmic thinking content.

Knowledge of/understanding of: how to do an analogy; how to analyze; how to do an induction; how to do a deduction; how to do a generalization; how to do an abstraction; how to do a formalization; how to formulate results; how to reflect; how to plan; how to define a limitation; and how to do a comparing were considered as observable and measurable statements of *procedural knowledge* of the knowledge statements domain of the algorithmic thinking content.

Knowledge of/understanding of: systems analysis; algorithms theory; the technology of step-by-step solution of the problem; algorithmic thinking concepts and their application to a problem; the operations that should lead to the sequence and execution of these tasks; modeling principles; and problem-solving strategies were considered as observable and measurable statements of *strategic knowledge* of the knowledge statements domain of the algorithmic thinking content.

The findings demonstrate the importance of knowledge requirements for developing an algorithm, which concerns both knowledge of all aspects of the problem solved and understanding of actions aimed at algorithm comprehension.

4.3. Skills statements domain

Data analysis resulted in 38 observable and measurable statements of skills of the algorithmic thinking content.

Skills in: making analogies; making abstractions; making generalizations; identifying regularities of a problem; identifying peculiarities of a problem; making comparations; being accurate and seeking accuracy; being clear and seeking clarity; being detail oriented; analyzing errors; analyzing perspectives; decision making; systems analysis; identifying necessary resources; identifying constraints; recognizing errors and solving problems to make improvements; examining algorithms; summarizing data; presenting data; problem-solving skills; creativity; analyzing perspectives; structuring of the actions; making plans; operating inductive and deductive reasoning in building an algorithm; producing sequential and logical solutions to a problem; building logical statements; planning the structure of actions necessary to achieve a goal with a fixed set of tools; building a sequence of actions; applying the operational components of algorithmic thinking comprehensively in a holistic process of solving various problems; dividing tasks into successive interconnected blocks; taking into account a variety of constraints of resources of a problem; using algorithm structures competently and effectively; building simple algorithms; building complex algorithms based on simple ones; following certain patterns; implementing the steps of an algorithm independently; and solving problems independently were defined as observable and measurable statements of the skills statements domain of the algorithmic thinking content.

This list shows the continued application of the defined above statements of propositional, procedural, and strategic knowledge for successful and effective development of an algorithm.

4.4. Abilities statements domain

Data analysis resulted in 30 observable and measurable statements of abilities.

Abilities to: do critical reasoning; gain insight; exercise imagination; take the best possible decision; define the intermediate results; define the expected final results; see the problem entirely; take into account a variety of properties of the problem; isolate and select the main challenges of a problem; invent; think in steps; use sequential rules to problem-solving; find an optimal solution to a problem; manage personal mental activity consciously; express solution step by step; research, analyze and critically review information; construct an algorithm that takes into account all the requirements for its development; provide the basic steps of an algorithm; apply policies and procedures and use available resources; work with algorithms; implement all steps of an algorithm without hesitation; complete assigned sequence with a high level of accuracy; work independently with minimum supervision; monitor your own thinking; recognize errors; check the solution for accuracy and efficiency; research, analyze and critically review information; respond appropriately to feedback; evaluate the effectiveness of your actions; update the algorithm taking into account all challenges and find an optimal solution to a problem rated as observable and measurable statements of the abilities statements domain of the algorithmic thinking content.

Developing an algorithm is consistent with multiple abilities that emphasize the necessity of using the above defined knowledge and skills statements and creates the proper foundation of algorithmic thinking content in observable and measurable KSA statements.

5. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

The study created a framework of algorithmic thinking content in one hundred observable and measurable KSA statements (32 statements of knowledge, 38 statements of skills, and 30 statements of abilities) for both with and without the use of ICT. It was developed by analyzing recent scientific publications and building Algorithmic Thinking Content Survey in the ICT area and beyond it, then validated through a 5-point Likert-type scale used to assess the appropriateness of the obtained KSA statements.

This research as a complex mixed-methods study has several limitations that should be acknowledged. For instance, the algorithmic thinking KSA statements were collected over a short time period (from September 2023 to March 2024) and analysis of the scientific publications was performed only for publications in education and pedagogy areas. Therefore, the obtained research results may not be generalized to other areas. In order to reduce this limitation, the future research should expand study areas. Additionally, the study is limited to 117 participants considered as practicing or prospective educational professionals and engaged 11 professors, teaching courses in algorithms and computer science, 23 practicing teachers of informatics from Chernivtsi region, 35 Informatics students of the 3-4 years of study, and 48 Master's students of informatics from two Ukrainian universities. Consequently, the study results obtained cannot be generalized to all educational professionals. In order to reduce this limitation, future research should be performed on an enlarged sample including international experts in the field of education by applying the Delphi Method to further validate the obtained Algorithmic Thinking content in the KSA statements.

Despite all limitations, these findings might be applicable for describing algorithmic thinking content in KSA statements both in the ICT area and wide beyond it, and can provide a profound basis for prospective studies aimed to design an instrument of its level assessment, as well as for development of algorithmic thinking of ICT and non-ICT area educational professionals.

Specifically, understanding the content of algorithmic thinking could contribute to the cultivation of an educational professional's ability to use algorithms in everyday routine with or without use of ICT. With the emerging trends of technology-based society, algorithmic thinking is becoming a key for professional success when performing any complex activities, repeated day by day or systematically both in the ICT area and far beyond it.

This study also benefits faculty in designing courses and curricula to prepare their students for using algorithmic thinking in their future professional activities in the education field, as well as for improvement of their learning process effectiveness with or without use of ICT.

Future research could focus on the use of the identified framework of KSA statements of the Algorithmic Thinking Content for the development of informative-diagnostic instruments aimed to assess an educational professional's algorithmic thinking level.

AUTHORS' CONTRIBUTION

The authors contributed to the writing of the article are as follows: Marian Byrka and Andrii Sushchenko conducted the scientific research, substantiated its main conceptual idea and organized writing of the paper; Volodymyr Luchko, Galina Perun, and Victoria Luchko contributed to the implementation of the research: extraction and merging of the KSA statements from the extant literature related to algorithmic thinking definition, administration of the ATCS, analysis of its results and to writing of the paper.

All authors have participated in discussing the research results, providing critical feedback and approving the final version of the paper.

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АЛГОРИТМІЧНЕ МИСЛЕННЯ У ВИЩІЙ ОСВІТІ: ВИЗНАЧЕННЯ СПОСТЕРЕЖУВАНИХ І ВИМІРЮВАНИХ ПОКАЗНИКІВ ЗМІСТУ

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Анотація. Алгоритмічне мислення як ключова потреба та головна вимога технологічного суспільства нині екстенсивно поширюється за межі ІКТ-галузі та швидко набуває статусу значущого інструмента, необхідного для ефективної реалізації будь-якої інформаційної діяльності як з використанням ІКТ, так без їх використання. Цей інструментарій створює нові можливості та перспективи для підвищення ефективності будь-якого виду професійної освітньої діяльності у вищій освіті як шляхом розробки алгоритмів для вирішення проблем, що повністю належать до сфери ІКТ, так і алгоритмів без використання ІКТ, які надають чіткі технологічні покрокові інструкції для вирішення різноманітних освітніх проблем.

Попри те, що увага до алгоритмічного мислення як наукового феномену зростає, досліджень, спрямованих на визначення змісту алгоритмічного мислення в спостережуваних і вимірюваних характеристиках, ще не проводилось, а його величезний потенціал ще не розкритий.

Метою цього дослідження є виявлення, уточнення та категоризація змісту алгоритмічного мислення у спостережуваних і вимірюваних характеристиках: знання, уміння та здібності.

Проведене дослідження поєднує кількісні та якісні методи і було реалізовано в 4 етапи: 1) аналіз існуючих наукових джерел з проблеми алгоритмічного мислення з метою виокремлення сукупності характеристик (знань, умінь та здібностей), які використовуються для його визначення; 2) розробка опитувальника для визначення змісту алгоритмічного мислення, який базується на основі п’ятикрокової універсальної послідовності розробки алгоритму; 3) проведення опитування серед широкого спектра освітян (N = 117); 4) аналіз даних з метою отримання змісту алгоритмічного мислення у спостережуваних і вимірюваних характеристиках: знання, уміння та здібності.

Розроблений опитувальник також базується на розгляді алгоритмічного мислення як складного явища, що інтегрує п’ять типів мислення: абстрактне, логічне, образне, концептуальне та конструктивне.

Опитування здійснювалось із залученням 117 експертів-освітян (11 викладачів, які читають курси з алгоритмів та інформатики, 23 практикуючих учителів інформатики, 35 студентів 3-4 курсів підготовки вчителів інформатики та 48 магістрів з інформатики). Експертна оцінка сукупності спостережуваних і вимірюваних характеристик змісту алгоритмічного мислення відбувалась за допомогою шкали Лайкерта.

У результаті отримано сто спостережуваних і вимірюваних показників змісту алгоритмічного мислення (32 показники знань, 38 показників умінь та 30 показників здібностей).

Ключові слова: ІКТ; вища освіта; алгоритмічне мислення; спостережуваний і вимірюваний зміст алгоритмічного мислення; знання, уміння та здібності.