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Educational Trends in Computing - Blockchain concept

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Abstract: *The paper presents the development of educational activities in the field of computing. Professional associations, primarily the ACM (Association for Computing Machinery) and the CS IEEE (Computer Society Institute of Electrical and Electronics Engineers) have recognized the need to define an educational framework at the level of computing. Over the last four decades, the working groups formed by these two associations have been submitting reports setting out recommendations regarding the structure and content of education in this field. Through these reports, the development of computing and its division into recognizable and complete areas can be followed. In addition to global changes in computing education, there have been structural changes within certain areas. It also required the identification of new knowledge necessary to meet all the requirements required by the widespread use of computers in the life of modern human. An important aspect of modern computing, above all its application is the protection of information that is processed. One of the latest approaches in data protection is the use of the blockchain concept. Accordingly, the paper gives an overview of the educational aspects of blockchain technology.*

Keywords: *blockchain, computing curriculum, cybersecurity, data science, education*

1. INTRODUCTION

Technological advances in the field of computer hardware have influenced changes in the field of computer applications as well as the development of software support necessary to put computer hardware into operation. The better hardware performance of modern computers has led to an unprecedented expansion of the field of application of computers. On the other hand, it influenced the development of specialized programming languages adapted to different fields of application. Also, there have been adjustments from the aspect of application of other components of system software, primarily operating systems.

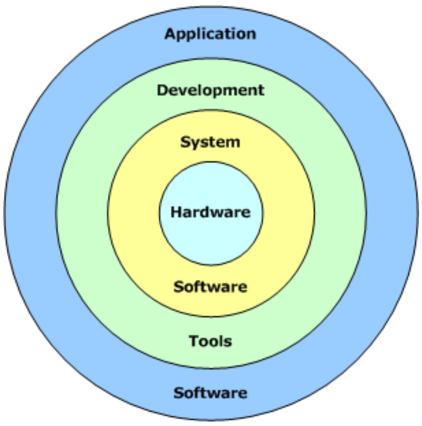

Figure 1. *Computer system model based on concentric circles*

There is no need to emphasize the scope and variety of application software. However, it should be pointed out that with the rapid development of computing came the development of a whole new field within it, and these are tools for hardware and software development. The structure of the computer system using the known model of concentric circles now looks like in Fig. 1.

The proliferation of computer applications and the frameworks in which applications run have imposed additional demands on changes in computing education. Applications in the field of artificial intelligence, data analysis, etc. have especially contributed to this. The use of computers in the conditions of a global computer network such as the Internet has fully actualized the aspect of distributed data processing. Since various transactions take place in this way, the problem of trust in the correctness of their execution has arisen. About ten years ago, the digital currency Bitcoin appeared, which introduced many innovations in the field of digital transactions, especially finance. The use of this digital currency is based on a new concept of databases that are realized on distributed and interconnected blocks (blockchain).

The subject of this paper is to present some new trends in computer education. Within the analysis that will be presented, special attention will be paid to the correlation between new trends in computing and appropriate educational content.

2. THE STRUCTURE OF COMPUTER EDUCATION

More than three decades ago, two renowned professional associations ACM (Association for Computing Machinery) and Computer Society within the IEEE (Institute of Electrical and Electronics Engineers) jointly began to present their vision of computing education to the professional public. In the document "Curriculum ‘68" [1], computer science was introduced for the first time as a special discipline. The discipline was divided into three areas, which corresponded to Keenan's definition of computing [2]. These areas were: Information Structures and Processes, Data processing systems, and Methodologies.

It is important to note that this document emphasizes algorithmic thinking, which should be clearly distinguished from the concept of programming. The document was criticized for neglecting the training of staff in the field of commercial data processing. And there have been cases where some of the recommended courses have been included in curricula in other areas. The situation in undergraduate studies was somewhat worse, as only 14 faculties offered classes with elements of recommended courses.

The document was innovated in 1978 and contained recommendations that are common to all undergraduate courses. Recommendations are given through topics and courses at primary and secondary level of computer education. Also, a set of elective courses was considered with the aim of completing the program of basic computing studies [3]. According to this document, the goals of computer education are: the ability to write programs, understanding the basic computer architecture, acquire knowledge in the use of appropriate tools, training for independent and team work and creating a basis for continuing education in this field. Also, the proposal of the new curriculum contained a course that treated the relationship between computers and the community.

2.1 A new look at computing

In 1981, the CS IEEE and ACM established the Computer Science Accreditation Board (CSAB). The task of this Committee was to define the criteria for certification of curricula in the field of computing.

At the same time, there was criticism of Curriculum '78. The main shortcoming was considered to be that the principles on which computing is based were not adequately founded through it. On the other hand, the consortium wanted to propose a relatively compact curriculum that could be implemented at smaller faculties. The core of their proposal consisted of six courses: algorithms, programming, data structures, computer organization, theory of computing, and programming languages [4], [5].

2.2 Joint forces

In the mid-1980s, the ACM cooperated with the CS IEEE, within which a Task Force was formed. Primarily, it was necessary to show that computing is more than programming. During the eighties, there was a turning point in computer technology. Primarily in the technology for making components and computer applications. It also required changes in computer education. In 1988, the working group presented the document "Computing as a discipline", [6]. The duality in computing is pointed out, i.e. division into computer science and computer engineering. Computing is further divided into nine sub-areas: algorithms and data structures; programming languages; computer architecture; numerical and symbolic calculation; software methodologies and engineering; databases and information systems; artificial intelligence and robotics; human-computer interaction.

In Computing Curricula 91 (CC91) computing is divided into eleven areas. In relation to the 1988 report, two areas were added: an introduction to programming and the social, ethical and professional aspects of computing. In addition to the structuring of computing in the sub-areas, the criteria for the formation of the curriculum have been defined. The criteria reflected the obligation, complexity, efficiency and level of abstraction that knowledge within the courses carries with it. Within CC91, twelve sets of courses are presented which illustrate the use of knowledge units for the formation of curricula.

2.3 A step forward

At the end of 1998, the CS IEEE and ACM formed a new working group with the aim of making a new report on the structure of the Computing Curricula 2001 [7]. The task of the working group was to review the development of computing in the previous decade on the basis of CC91 and define appropriate recommendations. In the previous decade or two, computing has changed almost dramatically. At the same time, the framework of computing has expanded so much that it is no longer possible to consider it as a single discipline.

The working group for CC2001 defined a set of 14 areas that include basic knowledge related to computer science at the level of undergraduate studies: These areas are: discrete structures; basics of programming; algorithms; computer architecture and organization; operating systems; networking; human-computer interaction; computer graphics and visual computing; intelligent systems; information management;

social and professional aspects; software engineering; computer science.

From the aspect of pedagogy, the courses are divided into the following six groups: introductory topics and courses; accompanying topics and courses; computer core; professional practice; advanced studies and undergraduate research; computing through the curriculum.

In defining recommendations regarding the structure of computer education in the near future, the working group took into account the technical and cultural changes that occurred in the previous period, especially in the previous decade. Technical and technological advances over the past decade have increased the importance of many programming topics such as: the World Wide Web and its applications; Network technologies, especially those based on TCP / IP; Graphics and multimedia; Object-oriented programming, etc.

It has already been mentioned that computer education has also been affected by changes in the cultural and sociological framework in which that education takes place. At the same time, technological changes have influenced changes in pedagogical aspects, but also in general the culture of computer education. It was with the entry of computer technology into cultural and economic trends that the battle was won for computing to become an academic discipline [6].

2.4 Final structure

The speed with which computing developed influenced the ACM and IEEE CS working group to offer the public a new document with guidelines related to defining curricula within computing after only five years. This document was named Computing Curricula 2005 (CC2005), [8].

The development of microcomputers marked the separation of computer science as a special discipline. The relationship between the mentioned areas within computing is shown in Fig. 2. The distance between the areas indicates how closely their successors cooperated with each other.

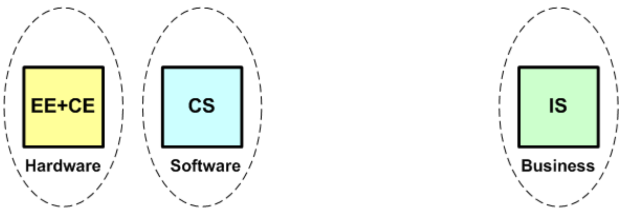

Figure 2. *Offer of educational areas within computing before the nineties*

During the 1990s, computer engineering consolidated its status thanks to the great expansion of integrated circuit-based devices. Thanks to the training for integrated circuit design jobs and their programming, a large number of students decided to study computer engineering during this decade.

Software engineering originated as a subfield within computer science. However, as computing has been increasingly used to solve a wide range of complex problems, the development of appropriate software has become increasingly important. As early as 1968, the concept of software engineering was introduced.

In the 1960s, it was observed that computers could be of great use to support the needs of the business world, such as accounting systems, payment systems, inventory systems, etc. On the other hand, in the early 1990s, networked personal computers became widely available.

During the 1990s, networked computers became the information backbone of various organizations. However, possible problems in the computer infrastructure created limitations in terms of efficient working performance. This initiated the creation of another area within computer education, information technology. At the turn of the century, the educational structure of computing could be divided as shown in Fig. 3. Dotted lines give areas connected in clusters according to the primary activity for which students are trained.

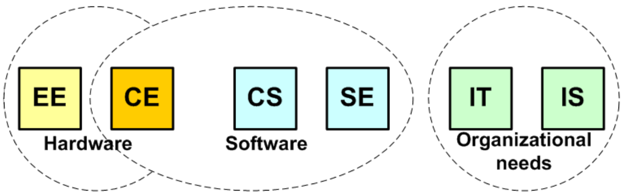

Figure 3. *Offer of educational areas within computer science at the beginning of the XXI century*

The advent of CC2005 marked a major milestone in computer education. It defined the structure of education at three levels - hardware development, software development and computer applications, primarily for business purposes.

3. NEW TRENDS IN COMPUTER EDUCATION

After the appearance of CC2005, the joint working group of ACM and IEEE CS in the following period was engaged in the development of curricula in certain areas of computer science. This is how the documents Computer Science 2013, Software Engineering 2014, Computer Engineering 2016 and Information Technology 2017 were created. The beginning of the new century was marked by data processing that could practically not be imagined outside the context of computer networking. In that period, the Internet did not become just a basic communication infrastructure in data exchange. At the same time, it became the basic computer platform for data processing. With the globalization of economic and business flows and processes, the Internet has proven to be an ideal platform for efficient support of all the needs of modern human in all aspects of his work and living environment.

In the beginning of 2020, the joint working group of ACM and CS IEEE published a document called Computing Curricula 2020 [9], which presented the principles for defining computer curricula in the future. Compared to the previous general report, CC2020 also contains a curriculum proposal for two new areas, Cybersecurity and Data Science.

3.1 Cybersecurity

Cybersecurity is a typical example of how computing is evolving with an increasing emphasis on multidisciplinarity. Therefore, the curricula for certain areas are increasingly interconnected. The proposal and recommendations related to this area of computing were first published in the Cybersecurity Curricula 2017 report (CSEC2017) [10]. This document highlights the importance of security in eight areas: data, software, components, connection, system, human, organization, and society.

It is important to note that the report indicates that in terms of cybersecurity there is a wide range of jobs that graduates can perform. Therefore, it is necessary that the curriculum in this area allows graduates to acquire knowledge and skills in public affairs, trade, management, research, software development, operations in the field of IT security and organizational structure of the company.

3.2 Data Science

Data science is a new field in computing that is directly related to data analysis and engineering. A possible definition of data science is that it is "A set of basic principles for extracting knowledge from data ... including principles, processes, and techniques for understanding phenomena using automated data analysis" [11].

ACM carried out the first activities in this field during 2015. In February and December 2019, the working group prepared drafts of two reports marked as DS202x [12], [13]. The second report paid special attention to the competencies acquired through education in the field of data science. Accordingly, the basic knowledge is defined for gaining the required competences. This knowledge includes: computer basics; data acquisition and management; data storage and management; privacy, security and data integrity; machine learning; data mining; analysis and presentation; professional aspects.

4. BLOCKCHAIN CONCEPT

The blockchain concept was firstly introduced in 2008 paper of Satoshi Nakamoto [14], along with the Bitcoin cryptocurrency. The main point in the paper is to form a peer-to-peer system for money transfer, without any need for a third party or the middleman. The entire transaction between two parties is encrypted and secure. This is ensured by creating an environment in which every node doesn't have significant reason to compromise or attack the network.

A block in the blockchain is the collection of transactions [15]. When enough transactions are collected, the new block in the blockchain is formed. As an incentive for validating transactions, a special group of nodes called miners is rewarded when each block is created. The key security property of the blockchain is the cryptographically linked blocks. Each block contains the Hash function of the previous block, so if an attacker would like to compromise the blockchain, he would have to change all Hash signatures of all previous blocks, which is not likely possible [16].

Consensus mechanism in a blockchain is a set of rules that determine which nodes can be used as a transaction verifiers [17]. The consensus mechanisms mostly used today are: Proof of Work (PoW), Proof of Stake (PoS), Delegated Proof of Stake (DPoS) and Practical Byzantine Fault Tolerance (PBFT) [18]. Proof of Work is based on purely physical work that validators have to perform in validating transactions. This physical work is based on the heavy computational tasks that require lots of processing power to finish [14]. Proof of Stake is more energy conserving and is based on the amount of digital currency the validators hold. The more currency they hold, they are likely to become validators and contribute to the network. However, this can lead to the centralization of the network [19]. Delegated Proof of Stake is created to somewhat improve original Proof of Stake algorithm. In DPoS, the validators are not chosen based on their currency holdings, but on the elections that is performed throughout the network [20]. Practical Byzantine Fault Tolerance is a consensus mechanism that uses three phases in block creation. In each phase, a node would proceed to the next phase if it receives more than 2/3 votes from other blockchain members [21].

Since its adoption, the blockchain has been used in many industries and applications, such as: digital identity providers, voting systems, banking and financial industry, supply chains, social inclusion, E-government, healthcare, energy, education, etc. [22], [23].

5. CONTEMPORARY EXPERIENCES IN BLOCKCHAIN EDUCATION

Blockchain technology has been in its infancy for as long as half a decade. Since it promises to solve many socio-technical problems in areas such as finance, trade, ICT security, etc. further research in this area is needed. On the other hand, there is a great lack of experts specialized in this field. Although many companies have an understanding of the potential of blockchain technology, they face a lack of appropriate experts. Even when there are attempts to introduce educational courses for this area, they are more limited to the so-called cryptocurrencies, such as Bitcoin, and less to the blockchain technology itself. And it is precisely in this technology that this potential lies, which unfortunately has not yet been sufficiently explored. On the other hand, educational courses related to blockchain technology are mostly found at the master level of education. Also, the current educational orientation when it comes to blockchain technology goes towards creating a critical mass of professionals with practical competencies for the development and implementation of products and services based on blockchain technology.

Of course, the emergence of new technologies provides space for ideas for its application in education. One of the directions in the development of education is aimed at the fastest possible transformation in terms of incorporating new knowledge into curricula. Special attention is paid to the applications of blockchain technology from the aspect of security factors of education [24].

It is interesting that the courses in which students are introduced to blockchain technology are more common in universities, which are not among the leading schools when it comes to computing. Also, blockchain-related courses are more often found in business schools than those that are technically oriented. Interestingly, many authors try to observe blockchain technology through already existing areas of computing, such as software design, algorithms and data structures, and distributed computing [25], [26].

6. CONCLUSION

The development and application of computers have created the need to train appropriate professionals. If we analyze the development of computer education more carefully, it can be noticed that it was actualized with the beginnings of the commercial application of computers. Due to that, the framework of computer education has shifted from the preparation of experts for computer design to the preparation for concrete application. The initial steps in computer education mostly were identified with the institution where it was realized.

Beginning in the 1970s, working groups formed by the ACM and CS IEEE associations presented their thoughts to the public through reports called Computing Curricula (CC). The reports were created as a result of research, which tried to determine the necessary structure and content of the curricula of basic studies in the field of computing.

With the expansion of the application of computers, it became clear that the education of computer experts cannot be realized through a single curriculum, but that it is necessary to diversify computing as a discipline into more compact units. In this way, students interested in the field of computing were offered a certain type of specialization from the very beginning of their studies. Despite the division of computing into certain areas, we must not ignore the fact that there is a smaller or higher level of overlap between them, which also has an impact on the structure of computer education. The draft of the latest CC2020 report looks at computing through seven areas: Computer Science, Computer Engineering, Software Engineering, Information Systems, Information Technology, Cybersecurity and Data Science.

In addition to the structural approach, the mentioned CC reports also provide recommendations regarding the content of the courses through which the necessary knowledge is acquired in each of the considered areas. The structure and content of the recommended curricula are defined with the aim of monitoring trends in the development of computing and appropriate education. In order to emphasize the importance of certain trends in computing, in the paper is shown the way of incorporating new technologies into educational practice on the example of blockchain.

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