How to educate students for the future?

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Abstract - Technologies, especially ICT are the most pervasive force influencing human lives today. Computers and electronic devices are mostly considered ICTs, but technologies in general involve much more. Most of technologies nowadays consist of four main components: hardware, software, brainware and know – how. All of these components are equally important. The investment efficiency into the modern technologies depends especially on the interest, motivation and education of their users. We are educating students for their future career opportunities that require such kind of knowledge and skills, which we as teachers may only predict nowadays. There is a question to be answered: “What should every educator extract from wisdom of the past and knowledge of the present for education needed in the future?”

The main goal of the article is to present and summarize our results of research of students’ informatics knowledge and ICT competencies via questionnaire and problem solving. We also describe experience in teaching, the body of knowledge and methods which we have implemented into the subject Informatics II in the first year of Bachelor study at the Faculty of Economics, Technical University, Košice.

Keywords – education; computer science/informatics; information and communication technology;

I. INTRODUCTION

Nowadays, we live in the Industry 4.0 era – era of the fourth industrial revolution. All fields of human lives, science disciplines, economies and industries are influenced by new technologies, that combine the physical, digital and biological worlds. These technologies give us huge opportunity, for example connecting billions of people to the web. The efficiency of business and organizations is drastically changing and improving. Now it is possible to help regenerate the natural environment through better asset management, and repair the damage previous industrial revolutions have caused [10].

The pace of change and innovation has intensified markedly: product life cycles and time for development are being compressed, services are becoming a larger proportion of economic output, computer power and capacity unprecedentedly increase and hardware prices to fall, data transmissions costs are decreasing, and ICT is expanding. The recent transformations in the world show us that knowledge has become a primary factor of success in the economy competitiveness. Also in the tertiary education it is necessary to re-examine the policies and assumptions in a rapidly changing environment [26], [25].

The way we work transforms fundamentally. Human tasks and jobs are replaced by automation and ‘thinking machines’. The skills that corporates, firms and organizations are looking for in their people are changing. All of us, and also businesses, organisations, governments etc. need to be prepared for a number of possible, even seemingly unlikely, outcomes. Some experts believe that artificial intelligence (AI) could create a new world where human abilities are amplified as machines help mankind process, analyse, and evaluate the abundance of data that creates today’s world. In this new world humans will spend more time engaged in high-level thinking, creativity, and decision-making [24].

Across advanced economies the debate about technological unemployment among economists has intensified. The decline of employment in routine intensive occupations and the impact of computerization on labour market outcomes is well-established and documenting in the literature [5].

Problem-solving skills are becoming very productive. We can see the substantial employment growth in occupations involving cognitive tasks where skilled labour has a comparative advantage, as well as the persistent increase in returns to education [2], [5].

Throughout all human history, technological progress has vastly shifted the composition of employment and significantly influenced education. How technological progress in the twenty-first century will impact on labour market, and subsequently education we will see. But we should be prepared, perceiving changes and trends.

II. CURRENT CHALLENGES FOR EDUCATION AND FOR EDUCATORS

Many disciplines which are taught and the way how they are taught are both stalked by the threat of obsolescence. Nowadays, graduates need the kind of education that enables them to participate actively in all areas of their lives, to use different types of thinking and attitudes as global citizens as well as economic actors to support ethical, sustainable development of their societies. The key message from the Europe 2020 strategy is: “we need more creative, flexible and entrepreneurial young people who are equipped for the challenges of today’s ever changing work environment” [4].

Human skills like creativity, thinking (logical, critical, computational), problem solving skills, leadership and empathy are now increasingly in demand. It is not just about science and technology. For educational institution it is necessary to identify the “knowledge and skills for the future” and start to concentrate on how to build them and how to use them alongside technology [24].
Education significantly develops human capital, and via human capital can support growth in two ways:

- first, by improving the capacity to absorb and adapt new technologies, which will affect short- to medium-term growth,
- second, by catalysing the technological advances that drive sustained long-term growth [17], [18].

As we can read in [25] tertiary (mostly university) education is more than the capstone of the traditional education pyramid. Universities are clearly a key part of all tertiary systems as a critical pillar of human development and a base for today’s lifelong-learning framework. Tertiary education provides not only the high-level skills necessary for every labour market but also the training essentials for teachers, doctors, nurses, civil servants, engineers, humanists, entrepreneurs, scientists, and myriad personnel. They are these trained individuals who develop the capacity and analytical skills that drive local economies, support civil society, teach children, lead effective governments, and make important decisions which affect entire societies.

The quality of education - teaching and learning - should be at the core of the needed higher education reform agenda. Based on our own experience it is necessary to focus on curricula that deliver relevant, up-to-date knowledge and skills, knowledge which is globally connected, which is useable in the labour market. Achieving this is not an easy task.

Undoubtedly, everyone agrees today, that higher education institutions should introduce and promote cross/trans and interdisciplinary approaches to teaching and learning. They are directly responsible for development of students’ depth of understanding and entrepreneurial and innovative mind-sets. Curricula should be developed and monitored through dialogue and partnerships among teaching staff, students, graduates and labour market actors, drawing on new methods of teaching and learning, so that students acquire relevant skills that enhance their employability [4].

Skills that the 21st century teachers are supposed to have to promote high quality learning, according to [4], are the ‘five Es’: education, experience, enthusiasm, ease, and eccentricity. A teacher’s knowledge base should not be restricted simply to his or her own subject, but must also include an understanding of learning theories and also how to incorporate them into practice. Teaching students well obviously implies that teachers produce up-to-date and good quality materials and supporting content for their lessons.

Students’ interest and motivation are important factors as well. While certain elements may be affected by the teacher, motivation and learning styles are completely individual. To ensure efficient knowledge transfer, teachers must be adapted to conditions such as group size, timing and duration of the lectures.

Despite the benefits, which are reflected in the multitude of resources that facilitate course realization, the main challenge for teachers who teach computer science and introductory programming courses is how to teach problem solving and develop critical and computational thinking by using algorithms. Polya in [14] observed problem-solving process through four stages: understanding the problem, solution planning, its execution and reflection on the results.

According to many authors personalization process in the modern educational systems has growing importance [12], [7].

III. IMPORTANCE OF COMPUTATIONAL THINKING AND PROBLEM SOLVING SKILLS

Students of the 21st century start using computer and ICT even before they first attend formal education. They are considered as digital natives and computer and ICT are parts of their everyday lives and they are significantly accustomed to many of computer’s functionalities because of playing computer games and using social media from a very early age [3].

Computational thinking is a new and much-needed part of literacy in the 21st century. It enables people to adjust computation to their needs.

Nowadays computer science and computational thinking is needed in all disciplines and professions beyond science and engineering. For example, computational economics and finance, computational social science, algorithmic medicine, computational archaeology, digital humanities, etc.

Computational thinking describes the mental activity in formulating a problem to admit a computational solution. It is a process involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent, by a human or machine, or more generally, by combinations of humans and machines [21].

Everyone should learn a little computational thinking because it can be applied in daily life. Due to advances in technology, especially computer science and ICT, universities have to change curricula to promote computational thinking to all students, not just computer science majors.

Computational thinking for everyone means being able to:

- understand the limitations and power of computer - computational tools and techniques,
- understand what parts and aspects of a problem are amenable to computation,
- evaluate the match between computational tools and techniques and a problem,
- apply or adapt a computational tool or technique to a new use,
- recognize an opportunity to use computation in a new way,
- apply computational strategies such as division and conquer in any domain [21], [22], [23].
Computational thinking for professionals – scientists and engineers, means to:

- being able to apply new computational methods to solving their problems,
- reformulate problems to be amenable to computational strategies,
- discover new “science” through analysis of large data,
- ask new questions that were not thought of or dared to ask because of scale, easily addressed computationally,
- explain problems and solutions in computational terms [21], [22], [23].

Nowadays, immediate task ahead is to better explain to non-computer scientists what it means computational thinking and the benefits of being able to think computationally. The educational benefits are mostly in transferring to any domain by enhancing and reinforcing intellectual skills. Computer scientists see the value of thinking abstractly, at multiple levels, abstracting to manage complexity, abstracting to deal with scale, etc. [21], [22], [23].

Problem solving skills are considered to be an important part of teaching and learning according to many authors, and our experience, too. Many researchers concluded that via problem solving method the participants not only received knowledge, but actively participated in the educational process - at the same time they learned, associated and organized value to their acquired knowledge, built abstract knowledge, and adopted a belief system and a personal worldview.

Problem solving method enables students to create a personalized learning environment and a majority of students have agreed that this kind of educational activities enabled them to feel more confident and engaged into the learning process.

Many students have learned to solve problems in other disciplines by memorizing formulas and procedures. They often do this without an in-depth understanding of the essence of concepts and problems. Since the computer science and programming are oriented to critical and computational thinking, problem solving, but also gaining practical skills, students often mistakenly believe that it can be mastered mainly by studying textbooks without intensive practicing. This can be prevented by providing frequent opportunities during regular classes as well as in order to solve practical and real problems.

Problem solving requires a variety of skills that students often do not ad hoc possess sufficiently: understanding the problem, knowledge transfer, reflective thinking and perseverance. The teacher should ask the students to predict the results of certain activities, set new tasks to address some of the procedures used in previous solutions etc.

IV. INFORMATIC EDUCATION AT THE FACULTY OF ECONOMICS TUKE

As teachers, we have been dealing with the problem of optimization and personalization our education in the subject Informatics II due to individual needs and knowledge base of different kinds of students to maximize development of their problem solving skills and computational thinking.

We are inspired by the social constructivist Vygotsky - [19] and constructionist Papert - [15] theoretical perception of the learning process. We are trying to apply pedagogical innovations in the forms of increased students’ active role, in construction of learning resources, and learning environment. It is a good basis for consideration and deeper investigation of learning personalization process affordances enabling a learner to create his/her personal learning, as we can read in [7].

There are some important attitudes and characteristics of modern education (mentioned in previous parts) that we try to implement and develop:

- computational thinking,
- software engineering,
- personalization of learning,
- problem solving skills.

Everyone, not just those who study major in computer science, can benefit from thinking like a computer scientist. Computational thinking is used in the design and analysis of problems and their solutions. The most important and high-level thought process in computational thinking is the abstraction process. Abstraction is used in defining patterns, generalizing from instances, and parameterization [21].

Software engineering provides a number of processes, models, methods and techniques, as well as tools and notations. It is an area of computing that defines systematic, and quantifiable approaches for the development, disciplined operation and maintenance of software. [6].

The inclusion of software engineering practices can help students gain insight into some of the challenges in real software projects: user requirements development, design and development of software, user interface design, testing, configuration management, etc.

We agree with authors [8], [11], that educational/learning process should be personalized. It is important to consider and follow the main characteristics/needs of the learners, i.e. prior knowledge, intellectual level, interests, goals, cognitive traits, learning behavioural type, and, finally, learning styles.

In determining both the content and the method of teaching Informatics II at our faculty, we consider an evaluation of the students’ knowledge base in the field of Computer science as a very important first step. At the beginning of their study, a questionnaire as a research tool has been used. We search for both the extent and content of compulsory education in the field of Computer science/Informatics at secondary schools. We have been
carrying out our research since 2003, of course, with the
necessary changes and modifications.

The sample of our research (in the mentioned period)
consists of all secondary school graduates who entered
their first year at Faculty of Economics Technical
University of Košice. In more than 95 % of cases students
in the studied sample are from the Eastern Slovakian
Region.

There are several parts in our questionnaire which
focus on different areas. Within the first part our students
are asked the questions like: What type of secondary
school did you attend? How many mandatory informatics
lessons per week did you get over at secondary school in
particular school years? In the second part of the
questionnaire we focus on students’ knowledge in the
field of basic terms of informatics, hardware architecture,
operation systems, text editors etc. In the third part we
want students to describe their experience in information
systems (IS). The questionnaire evaluation results since
2003 were published in detail in e.g. [16]. Figure 1
presents evaluation of questionnaire in average percentage
over the last three years.

One of the tasks of the questionnaire is: define and
describe user requirements for a simple information
system in a XY rental where we want to install new and
effective electronic IS based on modern ICT instead of
“old-styled/paper” one. We divided students’ solutions
into categories as follows:

- A – acceptable; it was possible to recognize user
  requirements, there were structure and hierarchy
  between requirements, there were some graphical
  expressions.
- B – mostly continuous text with effort to design
database tables or web site; partly incomplete.
- C – extensive continuous text with typical lack of
  exactness, structure, relationships; extent from ½
  sheet to 2 sheets.
- D – text - few sentences, max. ½ of sheet; totally
  unsatisfactory.
- E – no answer.

Figure 2 represents evaluation of users’ user
requirements in average percentage over the last three
years.

Based on the questionnaire evaluation, we can say
that the situation in the field of Informatics education at the
Slovak secondary school is unfavorable. Teaching is
flexible not enough for the requirements of the present, it
absolutely does not meet the modern trends. Education of
Computer science/Informatics at secondary schools is
focused on handling different packages of applications’
programs. There is a lack of understanding of basic terms,
of data processing, of modelling, of programing,
algorithm, etc. which implies that computer thinking and
problem solving skills are at a very low level. That is why
during the second semester (via the subject Informatics II)
students had to solve tasks involving basics of software
engineering, computational thinking, problem solving.

As a dominant method we use problem-oriented
project teaching, while we are using the functionality of
LMS Moodle environment [13]. We try to develop the
education with the potential to support our students by
personalizing learning process due to the individual
characteristics and needs. To achieve this, our system

![Figure 1](image1.png)  
Figure 1. Percentage of students (in average) who worked with the
terms, who worked in mentioned areas on secondary schools

![Figure 2](image2.png)  
Figure 2. Percentage of students (in average) - evaluation of user
requirements description
recommends learning materials, learning paths, consultations, teachers’ feedback and similar. The system presented mostly via recommended e-learning, activities and optional possibilities in a Moodle course provides personalization in the context of e-learning and learning by doing.

In this way of teaching/learning we are trying to transform the problem solving process into an active process of cognition. Our students are taking part in virtual projects of building IS in one of various types of virtual or real existing firms, companies or institutions to gain experience and skills via problem solving process. All our students find themselves in a position/role of IT executive such as Chief Information Officer (CIO) in ensuring continuous development and innovation of both IT applications and IT infrastructure. It offers us possibility for gamification of education that can motivate students to learn new concepts via game.

The recommended structure of the students’ projects corresponds to ARIS methodology and consists of four parts focusing on computer science fundamentals including creation of proper models, algorithms, processes, analysis of user requirements, abstraction, division of problems into the parts, software engineering, computational thinking and systematic approach. We teach our students to take into account as well social aspects, their experience and creativity.

In the first part of project students specify the core business process by text and a graphic model. It represents analysis of the business and its processes, creating a basis for process management, strategic factors and goals, challenges, possibilities to support management of IS and ICT in the enterprise. In this part students have to think about the basic business model, the model the functional and organizational structure of the business, the product model of business processes and their parameters, and the structure of applications to support the business.

In the second part students create requirements on the IS in a written form. They describe the IS functionality in the third part using UML use case diagram. The basis for the IS data model is a proposal of classes and their attributes created as UML class diagram. The last part is a proposal of tables and their relations in MS Access environment, where students deal with logical structure of the database system.

Development of user requirements project parts mean creating a logical concept of information system in the chosen firm/organization, which includes the structure of the information processes, the organizational structure, the basic structure of the application, IS procedures, role of users, requirements of hardware and network infrastructure, security requirements, possibilities of IS/ICT further development, documentation and staff training requirements, operation and continuous improvement of processes.

To create new modern information system via project of specifying users’ requirements, students have to think about how to differ from the others, what kind of innovations they should bring into their model of the main process of a chosen company. By using the method “learning-by-doing” they get knowledge of IS and its management together with experience on how to prepare the project proposals, how to communicate with others, how to present their ideas, design, suggestions. The ability of problem solving we consider as the most valuable skill.

V. DISCUSSION

The European Commission Science Hub has been promoting computational thinking as an important 21st century skill or competence. Computational thinking could be added to the traditional three Rs: reading, writing and arithmetic as an additional basic skill needed especially by university students. They will be better prepared to choose a future career. However, it’s impossible to predict exactly the skills that will be needed even five years from now. But educational institutions, their graduates as future employees/workers, firms and organizations need to be ready to adapt. It’s important to have a clear view of what the future, driven by the megatrends and our own actions, will look like.

The graduate who has received high quality education is more adaptable, assured, innovative, entrepreneurial and employable in the broadest sense of the term. The graduate who has received poor education has wasted a lot of his/her time and money and in a competitive job market is at a disadvantage. In many cases, poor education contributes to the high dropout rates and lack of student success [4, 20].

Providing education is not enough. What is important, and what generates a real return on investment, is learning and acquiring skills. Schooling without learning is a terrible waste of precious resources and of human potential [26].

Personalization is a more and more studied issue. Its advantage in terms of time and motivations widely proved in the context of e-learning courses. Course personalization basically means to understand student’s needs [11, 9].

VI. CONCLUSION

We developed a way of teaching to support development of students’ computational thinking and problem solving skills. Our education is based on modelling, simulation and on a well-known opinion that “no kind of teaching can replace the personal experience”. Students create interesting and relevant artefacts with the tools and techniques of computing and computer science, work with data using a variety of tools and techniques to better understand the many ways in which data is transformed into information and knowledge. Our education in the subject of Informatics II also includes examples of abstractions used in modelling the world, in managing complexity, and communication with people as well as with machines.

According to the Curriculum Guidelines for Undergraduate Degree Programs described in [1], our students are expected to demonstrate the following advanced user competencies:

MIPRO 2020/CE
• Professional knowledge - in formulating user requirements using the professional standards necessary for project managers.

• Technical knowledge - a basis for problem identification and analysis, verification, and documentation - an understanding of appropriate theories, models, and techniques.

• Teamwork - ability to work both individually and as part of a team to develop quality software artefacts.

• End-user Awareness - an understanding and appreciation of the importance of integration, effective work habits, leadership, and good communication with stakeholders.

• Design Solutions in Context - appropriate solutions in one or more application domains using approaches that integrate ethical, social, legal, and economic concerns.

• Perform Trade-Offs - finding acceptable compromises within the limitations of cost, time, knowledge, existing systems, and organizations.

To compete in the economy of the future, workers need strong basic skills and foundations for adaptability, creativity, and lifelong learning. Education raises human capital, productivity, incomes, employability, and economic growth [26]. But there are much more benefits of proper and modern education, which go far beyond monetary gains: education also makes people healthier and gives them more control over their lives. And it generates trust, boosts human and social capital, and brings prosperity.

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