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Quo vadis, informatics education? – Towards a more up-to-date informatics education

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Abstract: Informatics education has been in a cul-de-sac for several years (not only in Hungary), being less and less able to meet the needs of the industry and higher education. In addition, the latest PISA survey shows that – to put it a little strongly – the majority of the x-, y- and z-generations are digital illiterates. The aim of this paper to examine what could be done in order to improve the situation.

Key words: Informatics, Hungarian National Core Curriculum (NAT), digital literacy, computer science, information technology

1. Problems in informatics education: past and present

Informatics education in the world was launched along three different strategies:

- Informatics as an independent school subject;
- Informatics integrated into many other school subjects (e.g. mathematics, science, literature);
- Informatics integrated into another specific school subject (e.g. only mathematics).

Informatics cannot be an independent school subject unless some basic material (computers) and intellectual (teachers, curriculum) requirements are met. That is the reason why only a few countries chose this path, and most of them failed, mainly because of the lack or shortage of qualified teachers; the latter presumably comes from the lack of informatics teacher trainings in universities from several countries all over Europe recently, at least based on their homepages.

The other two strategies could be launched in a way that it was not compulsory to immediately include informatics in other subjects, but it has become more and more widely used and integrated as the necessary conditions have gradually been met. The third strategy could naturally lead to the emergence of ICT as an independent subject (i.e. the realization of the first strategy), while this kind of transition is very difficult in the case of the second strategy due to the scatteredness of the informatics curriculum.

In Hungary informatics set its foot at the beginning of the 1980s within the framework of a school subject called technics. In 1983 informatics teacher training started with approximately 300 teachers graduating per year. After that it took about 15 years for informatics to be included in the first National Curriculum as an independent school subject; by then the material and intellectual conditions had already been established.

Europe has now a shortage of IT professionals [21]. In Hungary alone there are over than 22,000 open positions for IT professionals [20], while primary and secondary education only worsens the situation due to the reduction in the number of lessons for the informatics subject in the curriculum. A major problem of higher education is that it is not able to produce as many informatics graduates as the IT sector requires in order to maintain the current number of employees. The deficit cannot be explained by low wages since IT jobs are among the best paid ones in the labour market. A clear reason could be

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the lack of motivation. One can motivate in various ways, but undoubtedly public education is among the most effective ones.

Before 1980 informatics courses had been mostly theoretical, and it was so not only in Hungary. In the 80s the appearance of the first personal computers significantly redesigned the curriculum, and consequently until 1990 the main topic was computer science, especially programming and algorithmisation.

After 1990, taking advantage of IT opportunities, teaching digital literacy became a mass phenomenon. Instead of creating products, using ready-made products, as well as communication via such products, came to the foreground.

2. The recent past of informatics subject area

The Hungarian National Curriculum 2012 (NAT 2012) categorizes the informatics educational area as follows: [1]

1. The use of IT/ICT tools
2. Users' knowledge
    2.1. Creating electronic written and audio-visual documents
    2.2. Data management, data processing, information display
3. Problem solving with IT/ICT tools and methods
    3.1. Choosing the right methods and tools required to solve a problem
    3.2. Algorithmisation and data modelling
    3.3. Modelling simple processes
4. Infocommunication
    4.1. Searching for information, systems of communicating information,
    4.2. Communication based on information technology
    4.3. Media informatics
5. Information society
    5.1. Legal and ethical aspects of information management
    5.2. The role and use of e-services
6. Library informatics

The over-emphasis put on the management of application systems has definitely become outdated due to technological development, the socio-economic problems arisen in the meantime, and to modern curriculum theory research (computational thinking and competency-based curriculum).

It is a fundamental mistake to regard information technology as a simple practice, since information technology is science accessible for everyone. Juraj Hromkovic writes about it in a personal letter: *I hope that you do not want to do mistake the West Europe did 15 years ago and now try to repair. The education in ICT reduced to the skills (Word, Excel) is called a mess by the minister of education in England and they want to focus on teaching proper concepts of informatics and programming. The same way of thinking we observe in USA.*

Writing about Slovakian pathfinding in their paper "Informatics in Primary School. Principles and Experience", A. Blaho and L. Salanci illustrate informatics education in the entire public education as Figure 1 shows [2]:

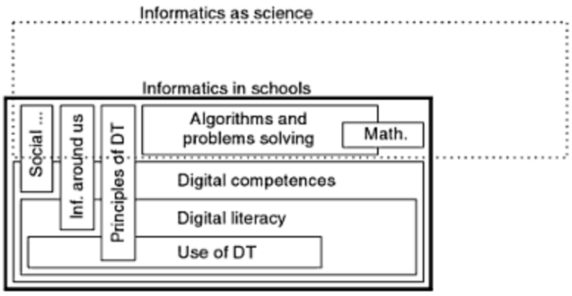

Figure 1. *Division of informatics in Andrej Blaho's paper*

There are many countries where informatics is divided into several topics including computer science, digital literacy, information technology etc [5–13,18,21]. ACM gives a recommendation for the first topic in a report dated from as early as 2003 [3]:

Recommended Grade Level

- *K–8 Level I—Foundations of Computer Science*
- *K–9 or 10 Level II—Computer Science In the Modern World*
- *K–10 or 11 Level III—Computer Science as Analysis and Design*
- *K–11 or 12 Level IV—Topics in Computer Science*

The ACM 2012 reports as follows [4]:

- *Computer science and the technologies it enables now lie at the heart of our economy, our daily lives, and scientific enterprise.*
- *The digital age has transformed the world and workforce, but education has fallen woefully behind in preparing students with the fundamental CS knowledge and skills they need for future success.*
- *To be a well-educated citizen as we move toward an ever-more computing-intensive world and to be prepared for the jobs of the 21st Century, students must have a deeper understanding of the fundamentals of computer science.*

It can be stated that informatics education has been gaining grounds at an international level. Although individual countries are going their own ways, the roads are clearly converging [5–13,21].

3. Recommendations for the informatics subject area by 2020

In 2013 the public education working group of Europe's leading universities and scientific societies adopted a crucial report on informatics education in primary and secondary education [14]:

Informatics education: ***Europe cannot afford to miss the boat***

Recommendation 1. All students should benefit from education in digital literacy, starting from an early age and mastering the basic concepts by age 12. Digital literacy education should emphasize not only skills but also the principles and practices of using them effectively and ethically.

Recommendation 2. All students should benefit from education in informatics as an independent scientific subject, studied both for its intrinsic intellectual and educational value and for its applications to other disciplines.

Recommendation 3. A large-scale teacher training program should urgently be started. To bootstrap the process in the short term, creative solutions should be developed involving school teachers paired with experts from academ-ia and industry.

Recommendation 4. The definition of informatics curricula should rely on the considerable body of existing work on the topic and the specific recommendations of the present report (section 4).

From the point of view of curriculum theory, a subject can be studied on the basis of its terminology. If there is a strong correlation between the concepts, the curriculum can be taught in one subject.

Relying on international experience, successful informatics education also requires a substantial number of classes: one class a week (each year) in grades 1 to 6, two classes per week in grades 7 to 10, and in grades 11 and 12 one class per week.

Based on the above (plus considering other logical additional information as well as market demand) the topics of the informatics school subject, as well as their weight and depth, can be determined. Our recommendations plan to build informatics curricula around the following three topic areas, the importance of which and their close interaction we have been emphasizing for over 30 years. Thus, informatics should stand on the following three legs:

- **Digital literacy**: word processing, data visualization, presentation, music editing, web editing, image editing, an-imation, user interfaces, info-communication, information society services, history of informatics, legal, ethical, safety, psychological, social issues etc.,
- **Computer Science**: algorithmisation, data modelling, database management, spreadsheet management, prob-lem solving, programming languages, architectures, operating systems, predictability, formal languages and au-tomata, possibilities and limitations of computer-based problem solving etc.,
- **Information technology**: large databases, industrial and economic application of data tables, robotics, simula-tion, web and mobile development, GIS, financial applications, internet of things etc.

3.1. Digital literacy

Probably it is digital literacy the importance of which we need not talk about. Nevertheless, it might be worth a few thoughts. One of the latest PISA surveys shows that the majority of the x-, y- and z-generations is digital illiterate [22]. The reason for this is that there are many schools and courses where the management of specific application systems is taught instead of application teaching, and students spend their time quite uselessly chatting on Facebook, or communicating unnecessary information instead of intelligently using social networks.

What matters most in this field is not the ability to professionally handle devices (although it does not hurt either), but to create meaningful "documents" with their help (the word *document* is used here in the most general sense), so that their use will facilitate students' daily work, recreation or entertainment etc.

We believe that it is important to approach computer usage from the problem side, where the question is the possibility of using a general-purpose program that is being tested for problem-solving. First students need to recognize whether the problem or any parts of it can be solved by IT tools. Then they will have to select the most suitable tool(s) or device(s). If such a tool does not exist, they will have to create it (programming). If they are to use several tools, they will also have to solve the problem of information transfer among them. If they do not know any of the tools to be used for solving the problem, they will have to be able to familiarise with them by reading the documentation.

As technology appears increasingly in our lives we have to show how to use it in the right way. Technology can serve as a very useful tool in education, work and everyday life, but sometimes it can be self-serving and time-consuming. Students need to know the social, psychological and medical consequences of the right and excessive use of IT technology.

3.2. Computer science

Acquiring the basics of computer science is essential not only for students who are planning to go into IT, but it is vi-tal for everyone. Without them, we cannot understand how the modern digital world works, or we will not feel "at home" in the modern information society.

In everyday life including school, we keep carrying out algorithms, planning sequences of activities or infor-mation flow, filling in data structures e.g. questionnaires, forms or have other people complete them, then we draw conclusions from the data, and it is absolutely up to us how and for what purpose we use the information obtained; it means that only those will understand this world who are aware of the basics of these activities. The understand-ing of the world around us develops through modelling. Algorithmisation, data modelling and programming can be good tools for developing modelling skills and training logical thinking. The necessity of formalisation requires pre-cise, rigorous thinking.

In the beginning algorithmisation is not about computer implementation. The executor of an algorithm is often the person who creates and interprets it. Only after this can we entrust an automaton, a computer to execute a precisely formulated algorithm. Here, however, we need a fundamental change in our approach. While you yourself implement an algorithm, you typically analyse real-world objects and carry out operations on them. In contrast, the first step towards computer-like (i.e. algorithmic) thinking, as well as towards implementing computer algorithms, is describing objects of the world by data (and entering them into the computer). The second step is that the computer – using these data – will calculate something. The third step is to draw conclusions about the real world from the calculated results.

If an algorithm is executed by a computer, we, of course, need to be familiar with the necessary tools (eg. programming languages).

The technical development of computers is extremely rapid and users are required to have an ever-deeper understanding of physical phenomena. However, the operating principle can be understood with no difficulty; to achieve this, we can make use of knowledge of automata and formal languages, as well as theoretical computer science and computer architectures.

3.3. Information Technology

Digital literacy and computer science are not enough for us in today's world, not only because of the needs of the IT labour market. You should understand and experience the opportunities offered by information technologies as well as their usefulness. The earlier you start paying close attention to this, the more success you can achieve. Of course, we must deal with technologies that students of a given age group are interested in, and motivate them to deeper understand informatics.

We regard robotics as one of the most important areas, which starting with programming apps of robot toys for preschool children can take students – by the end of their secondary education – to industrial automation as well as computer aided measurement and control. First, students only control a robot, then they will write a program for it, and next they will make the program depend on the state of sensors. This can be followed by programming autonomous robots, which are then placed in decision-making situations (e.g. How to go round an obstacle?) that they can resolve relying on their program, and finally, the robots can learn during the problem-solving process.

Sometimes programming a robot can be realized in a low-level environment – depending on the specific robot platform. This low-level manipulation appears in the constructing and programming of small electronical devices (Raspberry Pi, Arduino) with sensors and feedback mechanism, and which can be turned into internet enabled de-vices generating a huge amount of data. This area can motivate technical-minded students to control these devices and to process the generated data with their own programs.

Computer simulation of various real-world phenomena can play a similar role. Due to the development of in-formation technology, simulation models might offer promising solutions in areas where it is impossible to use other means and/or direct observation. At school simulation helps learning and understanding the real world, whereas in the real world it often contributes to planning and forecasting. Teaching the basics of simulation within the frame-work of informatics has been an age-old topic in Hungarian primary and secondary education; the first interna-tional reports on it were published in 1985. [15–17]

The areas students are extremely interested in include web and mobile apps, and the methods and technology of their preparation. These platforms have some advantages over classical environments:

they are ubiquitous – anyone anytime can access them from anywhere –, have social aspects, and represent modern and familiar environments. Students need not only use but understand and control these platforms. In technological development a new trend has emerged, which, after providing useful tools, lays the "last programming step" into the hands of users.

4. Considerations to move informatics education forward

Today the shares of the three areas (digital literacy—computer science—information technology) in Hungary are 80-10-10%, respectively. The attainable rates could be today: 50—30—20%, or 40—40—20%; and for groups with a higher number of informatics lessons, the rate could be 20—40—40% or 20—50—30% depending on the objectives of the course. Consequently, the outdated structure we have today needs to be fundamentally changed.

In order to design a new informatics curriculum, we should reconsider the contents of current informatics curricula, and restructure them in accordance with modern curriculum concepts and research on methodology. In addition, each new curriculum and methodological concept has to be tested.

We believe that this can only be carried out effectively if it is scientifically well-founded, the same way as it has been implemented in Britain. Please find below a quotation from the Foreword of ”Shut down or restart?: The way forward for computing in UK schools”, a paper by the President of the Royal Society [18], which served as a basis for renewing the British National Curriculum: *”This report analyses the current state of Computing education in schools and sets out a way forward for improving on the present situation. With support from the Royal Academy of Engineering and others the Royal Society has used its ‘convening’ role to bring together a wide range of dis-tinguished Computer Scientists and stakeholders to explore problems and propose solutions. Computing is of enormous importance to the economy, and the role of Computer Science as a discipline itself and as an ‘underpin-ning’ subject across science and engineering is growing rapidly. This alone is motivation enough, but as this re-port shows, the arguments for reforming Computing education are not purely utilitarian. It is becoming increas-ingly clear that studying Computer Science provides a ‘way of thinking’ in the same way that mathematics does, and that there are therefore strong educational arguments for taking a careful look at how and when we introduce young people to the subject.”*

5. Conclusion

We believe that informatics is much more than being just one of the school subjects! Regarding the importance of – good – informatics, Avi Cohen & Bruria Haberman defined five languages in an article [19]:

The languages that we recommend to acquire are as follows:

- *our language (mother tongue),*
- *their language (an elective international foreign language),*
- *a language of science (mathematics),*
- *a language of art and body,*
- *and a language of technology (Computer Science).*

The traditional curriculum of a young school subject, which does not boast hundreds of years of history, can become outdated very quickly – even if it was modern and cutting-edge 10 years ago – if it is not adjusted continually, or not supported by appropriate scientific background. Therefore, the entire informatics education needs to be reconsidered relying on the latest scientific achievements in methodology.

Our recommendations try to reestablish the informatics curriculum, restoring the balance between the abstract knowledges (like problem solving, algorithmic and computational thinking) and the practical skills needed for everyday work (e.g. digital literacy). In order to achieve this, the ratios between the aforementioned three areas of informatics education need to be changed in a more balanced way, and – along with this – the number of informatics lesson per week also should be increased to give space for the larger amount of educational content.

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