# The Education Column

by


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# Informatics – New Basic Subject

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**Abstract**

Informatics, as Computer Science is called in Europe, has become a leading science. It is high time that it be adopted as a basic subject in schools like mathematics or physics. We discuss in this article some recent developments in Europe concerning informatics in schools.

## 1 Computers have been invented for *computing!*

The first computers were calculating machines designed to solve engineering problems faster and with fewer errors. Consider for instance two typical representatives of computer pioneers:

1. Howard Aiken (1900-1973), a physicist, who encountered a system of differential equations during his PhD studies in 1939 which could not be solved analytically. He therefore needed to compute a numerical approximation, a tedious work by hand calculations.

   > *He envisioned an electro-mechanical computing device that could do much of the tedious work for him. This computer was originally called the ASCC (Automatic Sequence Controlled Calculator) and later renamed Harvard Mark I. With engineering, construction, and funding from IBM, the machine was completed and installed at Harvard in February, 1944.*[1]

2. Konrad Zuse (1910-1995), civil engineer, had to solve linear equations for static calculations. This tedious calculations motivated him to think about constructing a machine to do this work. Unlike Aiken he did not look for a sponsor but installed 1936 a workshop for constructing a computer in the living room of his parents! [8]

[1] `http://en.wikipedia.org/wiki/Howard_H._Aiken`

*His greatest achievement was the world's first programmable computer; the functional program-controlled Turing-complete Z3 became operational in May 1941. Thanks to this machine and its predecessors, Zuse has often been regarded as the inventor of the modern computer.*[2]

# 2 From Numerical Computing to Information Processing

After World War II the interest in developing and using computers grew. Pioneers in several countries started to built their own machines: in USA, in the UK and also in Switzerland and in Germany. ETH Zürich built 1950-1956 the ERMETH, TUM the Technical University in Munich developed 1952-1956 the PERM. Heinz Rutishauser (ETH) and Friedrich L. Bauer (TUM) developed together with GAMM[3] and ACM[4] members ALGOL60 [2, 3]. ALGOL60 was focussed on numerical calculations. It can be considered as the "Latin of the programming languages" since many features of ALGOL60 have been inherited into modern programming languages.

Computers are not only fast calculators, capable of performing millions of operations per second, but have also the capability to store vast amounts of data, coded as bit-strings. Manipulating such data by storing and retrieving information, sorting and interpreting their contents required new programming languages and finally changed the calculating machines to information processing agents. George Forsythe, the founder of the Computer science Department in Stanford and one of the fathers of Silicon Valley wrote already in 1963 [4]:

> *Machine-held strings of binary digits can simulate a great many kinds of things, of which numbers are just one kind. For example,* they can simulate automobiles on a freeway, chess pieces, electrons in a box, musical notes, Russian words, patterns on a paper, human cells, colors, electrical circuits, and so on. *To think of a computer as made up essentially of numbers is simply a carryover from the successful use of mathematical analysis in studying models*
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> ...
>
> Enough is known already of the diverse applications of computing for us to recognize the birth of a coherent body of technique, which I call computer science.

[2] `http://en.wikipedia.org/wiki/Konrad_Zuse`

[3] International Association of Applied Mathematics and Mechanics `https://www.gamm-ev.de/`

[4] Association for Computing Machinery `https://www.acm.org/`

Today, some 50 years later, *computers determine our lives*, we indeed live in a *digital world*. All our communication by cell-phone, e-mail, sms, through social networks is digital and based on computers. We are writing using text-processing programs and spreadsheets and use presentation tools for our lectures. Books are available as electronic files: the *Digital Book Index*, for instance, provides links to more than 165'000 full-text digital books from more than 1'800 commercial and non-commercial publishers, universities, and various private sites. More than 140'000 of these books, texts, and documents are available free[5]. Also the way we store music has changed. Vinyl records have been replaced, music is digitized and a memory stick can store the music of a whole former collection of records. Radio and television have also been digitized. It became possible to listen or watch missed emissions on the Internet. The video portal *YouTube* added another dimension by providing a platform for uploading digital files and making available everybody's own videos. Photography has changed completely: software has replaced chemically processed films. Finally, search machines have revolutionized the way we acquire our information – *Wikipedia* has become our encyclopedia, libraries and archives are digitized and became accessible on-line.

# 3 CS Education in Switzerland

In spite of the impressive digital revolution, computer science was for a long time not recognized by academia as a new basic science in Switzerland. It took years till the pressure from industry was large enough to convince the ETH management to finally introduce 1981 a curriculum for computer science studies at ETH.

In schools the computer was first seen as calculator. Pocket calculators replaced gradually the slide rule. It was only with the advent of the personal computer (PC) around 1984 that those responsible for education showed interest to introduce computers in schools. Committees were formed to develop teaching material and to study how to integrate computer science as a new subject in the STEM-oriented tracks of the Swiss Gymnasia. At that time a PC was essentially bare of software, thus it was necessary to develop applications by own programs, often written in Pascal [5, 6]. Spirit of discovery and creativity inspired the students, though at the same time many teachers were frustrated by frequent breakdowns and system changes. Many of those enthusiastic former high-school students – the first generation educated in computer science – are now successful computer scientists.

In the following years many applications were developed. Computers became ubiquitous, easier to handle and there was no need to program own applications.

[5] `http://www.digitalbookindex.com/about.htm`

The Internet was born and connected the world. Therefore a strong movement emerged 1995 in Switzerland that teaching programming in schools was no longer necessary. Instead one should concentrate on teaching skills to make good use of the computers. As the applications became more sophisticated and more complex, teachers had to be trained first. The computer industry, in particular Microsoft and Intel, made agreements with whole countries to train the schools on their products[6].

This paradigm change, shifting away from constructing programs toward just consuming and applying programs had a disastrous effect. It lead to an complete wrong image what computer science is. Skills were overemphasized and fundamentals of the discipline completely neglected. Many freshman entered ETH for computer science studies only to drop out soon because of their completely wrong picture of informatics as a science. Unease grew in industry and academia.

*ICTSwitzerland*[7] the umbrella organization of the Swiss IT-industry urged in 2010 with a memorandum to introduce real computer science in schools not only to teach how to use computers. The Hasler-Foundation[8] supported with the project *FIT in IT* in the last ten years the introduction of computer science as basic science in schools. In Fall 2014 finally the ministers of educations of the 21 German speaking Cantons in Switzerland decided to introduce informatics as a basic subject in all schools.

# 4 European Initiative

Computer science education developed differently in Europe. Eastern Europe kept focusing on fundamentals and on programming while Western states concentrated on just using computers with similar consequences as in Switzerland.

*Informatics Europe*[9] and *ACM Europe*[10] created a common task force to study that problem. The task force completed a report in 2013 on Informatics Education in Schools with the title *Informatics education: Europe cannot afford to miss the boat*[1].

At first it was necessary to define terms since many persons equate computer science with using new media. Fruitless discussions and disagreements are un-

[6] See for instance `http://www.saarland.de/17657.htm`

[7] `http://www.ictswitzerland.ch`

[8] The purpose of the Hasler Foundation is to promote information and communications technology (ICT) for the well-being and benefit of Switzerland as an intellectual and industrial centre.`http://www.haslerstiftung.ch/en/home`

[9] The association of computer science departments and research laboratories in Europe and neighbouring areas. `http://www.informatics-europe.org/`

[10] European Chapter of ACM, the world's largest educational and scientific computing society. `http://europe.acm.org/`

avoidable when people use the same words for different meanings, contents and in different contexts. The task force defined therefore

Computer Science in Schools = *Digital Literacy* + *Informatics*

and specified:

- *Digital literacy* covers fluency with computer tools and the Internet.
- *Informatics* covers the science behind information technology. Informatics is a distinct science, characterized by its own concepts, methods, body of knowledge and open issues. It has emerged, in a role similar to that of mathematics, as a cross-discipline field underlying today's scientific, engineering and economic progress.

The report makes the following observations:

- Informatics is a major enabler of technology innovation, the principal resource for Europe's drive to become an information society, and the key to the future of Europe's economy.
- European countries are making good progress in including digital literacy in the curriculum. The teaching of this topic should emphasize the proper use of information technology resources and cover matters of ethics such as privacy and plagiarism.
- Informatics education, unlike digital literacy education, is sorely lacking in most European countries. The situation has paradoxically worsened since the 70s and 80s.
- Not offering appropriate informatics education means that Europe is harming its new generation of citizens, educationally and economically.
- Unless Europe takes resolute steps to change that situation, it will turn into a mere consumer of information technology and miss its goal of being a major player.

Therefore the report makes the following recommendations

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.

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.

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 academia and industry.

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.

The report triggered similar activities in France and Germany. The *Académie des Sciences* published in May 2013 a report with the title "*L'enseignement de l'informatique en France. Il est urgent de ne plus attendre*".[11] A resolution was taken in November 2013 at the *Fakultätentag Informatik* in Germany with the title "*Informatik in der Schulbildung: Wir dürfen den Anschluss nicht verlieren!*".[12]

A parallel development happened in the UK. Michael Gove, the Secretary of State for Education, lamented the state of computer science education in his famous speech of January 2012[13]

> The UK had been let down by an ICT curriculum that *neglects the rigorous computer science and programming skills* which high-tech industries need.
>
> ...
>
> In short, just at the time when technology is bursting with potential, teachers, professionals, employers, universities, parents and pupils are all telling us the same thing: *ICT in schools is a mess.*

Michael Gove urges to reform the computer science education in the UK and refers to the PC-area when the computer inspired discovery and creativity of the students who were fascinated by using and exploring this new tool:

> With minimal memory and no disk drives, the Raspberry Pi computer can operate basic programming languages, handle tasks like spread sheets, word-processing and games, and connect to wifi via a dongle – all for between £16 and £22. This is a great example of the cutting edge of education technology happening right here in the UK. It could bring the same excitement as the BBC Micro did in the 1980s.

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[11] http://www.academie-sciences.fr/activite/publi.htm

[12] https://www.ft-informatik.de/52.html

[13] https://www.gov.uk/government/speeches/michael-gove-speech-at-the-bett-show-2012

Since Fall 2014 big changes are going on in the UK in informatics education. Simon Peyton Johnes describes in his TED talk with the title "*Teaching creative computer science*"[14] on YouTube the changes and the motivation for teaching informatics. On his slides he make the distinction between *skills*=ICT and *discipline*=informatics. The new concept for teaching is illustrated in this table:

What we want instead

| | | |
|---|---|---|
| Ideas | as well as | technology |
| Create | as well as | consume |
| Write | as well as | read |
| Understand | as well as | use |
| Knowledge | rather than | magic |

# 5 Why Informatics as Basic Subject in Schools?

The goals of informatics as a basic subject is

1. To teach the students to understand the principles and functioning of today's digital world.

2. To train the students in constructive problem solving.

Jan Cuny, Larry Snyder, and Jeannette M. Wing coined the term "Computational Thinking"[15]. What they mean is:

> Computational Thinking is the thought processes 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.

Jeannette M. Wing wrote in [7]:

> It [Computational Thinking] represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use.

Computational thinking is a methodology for anyone to be used to solve problems. Especially it applies to problems solving with computers. It involves the following steps

- *Analyze a task or problem*, model and formalize it.

[14] https://www.youtube.com/watch?v=Ia55clAtdMs
[15] http://www.cs.cmu.edu/~CompThink/

- Search for a way to solve it, find or design an *algorithm*.
- *Program*.
- *Run the program*: let the computer work, maybe correct, modify the program, *interpret the results*.

Programming is an essential step in this process. It is an important activity for all the students in general education. It is *creative* since there are often many ways to solve a problem. It is *constructive*. The solution has to be constructed like an engineer constructs a machine. Running the program is like starting a virtual machine. Programming finally teaches *precise working* since any small error prevents the solution and trains *computational thinking*.

# 6 Conclusions

Computer Science is the leading science of the 21st century. It is used like mathematics in all sciences. It has to become part of general knowledge in education.

Informatics Europe and ACM Europe convincingly state that computer science in the school must consist of two parts:

1. Learn to make good use of IT and its devices. This is called *Digital Literacy*, often also ICT. These skills are short living knowledge, they change with technology.
2. Learn the fundamentals of computer science which are essential to understand our digital world. This is called *Informatics*. It is long living knowledge which lasts forever and does not change with technology.

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