The contribution of computer science to technical literacy

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Abstract: The idea of general education is, among other things, to bring pupils in contact with different ideas, topics, methods, activities, and areas of work independent of their social or family context. In this sense school serves as a "test living", where pupils can try out themselves in different fields. These attempts may fail here without any serious consequences. It is hoped that some of these tests will be successful, so that young people at the end of their school career can choose from a positive variety of life perspectives. If an important aspect is missing at school, this aspect cannot be tested there. But the pupils know very well that then the personal risk of a failure in that case is being shifted to the time after school. A positive decision for this aspect becomes difficult.

In High School technical thinking and acting hardly have any room. Since an ever growing number of students of an age group pass through High School, they hardly come in touch with technology-related topics. Consequently later they often ignore the enormous field of technical professions. If the spectrum of school subjects is to be extended by a new subject, which can establish a close link to technology, this subject should have its place in grades 7-9, because there the important pre-decisions for the later professions are made. The subject "computer science" is able to take over this task very well, because, due to the universality of its tools, it can use these tools without any additional equipment in many different areas.

The following contribution examines how the term "technical general education" can be concretized. On the basis of some examples the consequences for instruction are explained.

1 Introduction

In all subjects the selection of contents predominantly takes place due to subject-immanent considerations. Usually it is too little considered that these contents only are stones in a larger puzzle, which as a whole should result in a general education that, among other things, has the job to bring pupils in contact with different ideas, topics, methods, activities, and areas of work independent of their social or family context. In this sense school serves as a "test living", where pupils can try out themselves in different fields. These attempts may fail here without any serious consequences. It is hoped that some of these tests will be successful, so that young people at the end of their school career can choose from a positive variety of life perspectives. If an important aspect is missing at school, this aspect cannot be tested there. But the pupils know very well that the personal risk of a failure in that case is being shifted to the time after school. A positive decision for this aspect becomes difficult.

2 Technical literacy

At first we have to clarify how we have to understand "technical literacy" or "technical general education". If we consult Klafkis[1] well-known definition for general education, we learn, "general" means

- that all members of the society have access to contents of the education system,
- that the whole of the human possibilities is addressed, thus the person as a whole,
- and that education takes place by means of key problems, typical for the epoch.

The second aspect means that the pupils should find out the full width of their possibilities, and so surely an overview about the different sciences is needed. In High School technical thinking and acting hardly have any room. The huge field of technical professions and engineering sciences has no related subject. Physics could actually take over the task, but both at university and school it is handled as a pure basic subject, nearly without connection to current technology (see below). Since an ever growing number of students of an age group pass through High School, they hardly come in touch with technology-related topics. Consequently later they often ignore the field of technical professions. So the first aspect of Klafkis definition also is affected: High school students in Germany usually do not belong to the disadvantaged social groups. But they obtain an education which omits substantial ranges of a technical world.

It is trivial that the third aspect of Klafkis general education is fulfilled with IT-problems today. Similarly as in former times the technical application of electrodynamics substantially accelerated the introduction of the school subject "physics", the extreme social meaning of IT-systems will force a compulsory school subject "computer science". Actually it should have had.

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[1] [Kla85] S. 17

The other definitions of general education usual in the field of didactics of computer science also fit well to a technical variant. Among the criteria of Bussmann and Heymann[2] particularly the "*preparation for future life situations*" and the "*construction of a conception of the world*" are relevant. The "*stabilization of the ego of a pupil*" can be interpreted similar as Klafki definition. In the "*recommendations for a concept regarding the IT-education at schools*" of the GI[3] the points "*principles of effect of IT-systems*" and "*problem solving with IT-systems*" particularly fit.

How should the specific technical aspect be understood? A technical literacy in my view must cover three ranges:

- It has to produce **knowledge** about basic technologies, their applications and effects. In this sense it considers Klafkis "key problems".
- It has to obtain **technical thinking**, a goal- and product-oriented way of working. Here the gaining of knowledge is considered not so much as a way to understanding, but more instrumentally for reaching a purpose. The necessary knowledge has to be found independently. Not the contents are primary, but the kind of their acquisition and their utilization.
- It has to produce and strengthen **team ability**, in order to use individual knowledge and talents in cooperation with others to reach the common goal.

So, technical literacy has goals which traditionally are not straight in the centre of High Schools: "*Different from the natural sciences, where the laws of nature form the centre of interest, technology is arranged and created directly by humans. Thus the scientifically oriented canon of subjects cannot produce eo ipso technical literacy.*"[4] Particularly the individual marking opposes contrarily to team work, and independent learning can be found only in beginnings. The output orientation of the new education standards also will not change anything, because knowledge namely is more applied, but the kind of knowledge is given. More interesting are the planned core-curricula, which fix only a part of instruction and so leave place for extensions – at least they should. Since the idea is not completely new, I doubt that it will be carried out in the desired sense. Experience unfortunately teaches that on the one hand the "cores" are much too extensively defined and on the other hand the cores are taken for the whole by the teachers because in times of central school-leaving exams the tasks of the exams will refer necessarily to these cores. We have to look for another place for technical literacy.

Thus, if technical disciplines in their application orientated way of handling knowledge and their heuristic working method should be noticed by the pupils as a possible field of their later job, then a subject with a close link to technology should worry about it. Computer science as the only technology-oriented subject in High School would be outstanding suitable for this because in its lessons exactly this working method can be tested. To be effective, this subject should have its place in grades 7-9, because there the important pre-decisions for the later professions are made - less as positive decisions

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[2] [Bus87] roughly translated
[3] [GI01] as well
[4] [VDI02] as well

than as negative: Subjects are voted out. A "recruiting campaign" later does not reach the majority of pupils.

3 Time distribution to the subjects

Let us have a look on the distribution of time for subjects to find out, where the key topics in High School are. For example we choose the new timetables in Lower Saxony for the shortened system with twelve years:

	timetable 1 (197 hours)			timetable 2 (208 hours)		
field	subject	hours		subject	hours	
A	DE	24		DE	23	
	1. FS	23		1. FS	22	
	2. FS	20		2. FS	20	
				3. FS	19	
	MU	10		MU	9	
	KU	10		KU	9	
	sum:	**87**	**44,2 %**	sum:	**102**	**49,0 %**
B	GE	11		GE	10	
	EK	9		EK	9	
	PO	8		PO	9	
	RE/WN	12		RE/WN	12	
	sum:	**40**	**20,3 %**	sum:	**40**	**19,2 %**
C	MA	24		MA	23	
	BI	11		BI	10	
	CH	8		CH	7	
	PH	9		PH	8	
	sum:	**52**	**26,4 %**	sum:	**48**	**23,1 %**
others	SP	12		SP	12	
	Verfg.	1		Verfg.	1	
	Ags	5		Ags	5	
	sum:	**18**	**9,1 %**	sum:	**18**	**8,7 %**

Expanding field A …

… chargeable to field C.

We can see that about half of the time is reserved for the languages, music and arts, less than a quarter for math and natural sciences.

What do pupils learn there? In a very rough manner we can say:

They learn

- in field A to produce, understand and (literarily) interpret texts,
- in field B to understand and recognize relations in texts and data,
- and in field C to find data and recognize relations.

Pupils thus work predominantly interpretively with texts and they analyze and evaluate data. Constructive work we find actually only in field A. That changed a bit with the new media, because e.g. within the B-field presentations etc. often are produced about special topics and current developments. But these products also have to be regarded as "text production" in a wider sense. Instrumental knowledge is hardly acquired.

So in this traditional canon of subjects only the natural sciences physics and chemistry are candidates as a place for technical questions.

PH/CH	17	**8,6 %**	PH/CH	**7,2 %**

The entitled amount of time for them is small, compared e.g. with the foreign languages.

4 The motivation of teachers and pupils

Even in the natural sciences the conditions for technical learning normally are not given. The basic studies e.g. of a physicist, which corresponds to the studies of a physics teacher in a large degree, is concerned exclusively with physical fundamentals, thus with finding of and handling with physical regularities. These are in their original form applicable to idealized situations, but not to material technical problems. A normally trained physics teacher does not understand anything about technology at all. As a result material technology hardly emerges in his lessons - if the secrets of the iron does not regard. Above all technical thinking as mentioned above does not arise. A physicist acquires knowledge in order to understand connections. Whether something and which of this knowledge can be applied anywhere is subordinate. He has completely different priorities as someone, who wants to solve a technical problem and evaluates knowledge in regard to a possible solution of the problem. The experience of technical problem solving is not obtainable in physics lessons, and even with a reorientation of the teachers no time for technical literacy would be present within their small portion of the timetable, because the natural sciences have to achieve their own goals.

Completely different is the situation for computer science teachers. The nearly always insufficient, usually completely missing training prevents a theoretical orientation of the subject, and also the motivation both of teachers and pupils comes from another direction. Peter Berger[5] writes: "*In the innovative school subject `computer science´ innovation takes place at present less from inside, by the innovative teacher, who finds a new paradigm of instruction and learning - but rather from outside, by a new paradigm, that `finds its teacher´ and forces him, also the quite traditional one, to use increasingly innovative patterns.*" Pupils are different motivated than in other subjects as well. At an interrogation of pupils in higher level courses[6] rather clear tendencies showed up:

- Pupils in computer science courses classified themselves as little careful, industrious, ambitious and planning. They resemble therein with pupils in math or physics courses and are, compared with those, still under the average. In the subject however they approved themselves a substantially better work attitude.
- Within the fields of creativity and social learning the self-assessment is similar to the language courses.
- Extremely pronounced is the self estimated ability and the expectation in instruction concerning independent, problem oriented learning.

As examples the following partial results may serve. I asked among other things for the self-assessment about creativity and the desire for independent work, both generally and in the selected subject:

	IN	MA	PH	DE	EN
creativity generally	65 %	69 %	57 %	74 %	71 %
creativity in the subject	82 %	46 %	62 %	79 %	57 %
difference:	**18 %**	**–23 %**	5 %	5 %	–14 %
independent work gen.	29 %	38 %	57 %	68 %	71 %
independent work i. t. subject	65 %	46 %	67 %	58 %	62 %
difference:	**35 %**	8 %	10 %	–11 %	–10 %

The wish for problem oriented lessons, which permits independent learning with effects beyond school was obvious:

"I would like to select tasks for myself, which becomes part of the lessons."					
	IN	MA	PH	DE	EN
generally	63 %	46 %	55 %	68 %	62 %
concerned to the subject	**88 %**	38 %	57 %	74 %	62 %
difference:	**25 %**	–8 %	2 %	5 %	0 %

[5] [Ber98] roughly translated

[6] [Mod03]

	IN	MA	PH	DE	EN
"Contents should follow from problems"					
generally	69 %	77 %	90 %	79 %	90 %
concerned to the subject	**81 %**	**100 %**	**90 %**	**79 %**	**90 %**
difference:	**13 %**	**23 %**	0 %	0 %	0 %
"I would like to find out contents for myself e.g. from books or from the Internet."					
generally	31 %	31 %	29 %	47 %	71 %
concerned to the subject	**75 %**	23 %	48 %	53 %	62 %
difference:	**44 %**	–8 %	19 %	5 %	–10 %
"In lessons I would like to win suggestions for work in addition to the lessons."					
generally	**38 %**	54 %	67 %	79 %	71 %
concerned to the subject	**81 %**	69 %	76 %	74 %	71 %
difference:	**44 %**	15 %	10 %	–5 %	0 %

It is obvious that in computer science – followed from the difficulties in teacher training - aspects of application should be more important as e.g. theoretical aspects. Computer science teachers and pupils "want to do something", and the appropriate tools are available for them. Due to the universality of these tools, they are applicable without any additional equipment to very different fields, in times of financial bottlenecks a real advantage.

5 The contribution of computer science to technical literacy

In computer science pupils

- may be acquainted with valid hard- and software-models of computer science systems and/or learn to develop and test them. The understanding for developments in a world, shaped by technology, is supported, e.g. by work in and with networks, as well as their social effects. It has to be noted, that this is one of the few fields in which schools have experiences since many years.
- gain experience in instrumental acquisition and employment of knowledge. The fields of appliance can be selected freely from a wide range due to the universality of the tools and methods of computer science. Here experiences in independent work are much more easily possible than in other subjects. Due to the enormous efficiency of the tools, first and inefficient beginnings of problem solutions are realizable and testable, so that independent problem solving becomes possible as standard requirement without excessive demand to the pupils.
- partial are active in work-sharing phases within a team - if lessons are organized accordingly.

6 Result

- In the face of the development of information technologies, technical literacy has to be an obligate goal for all school forms, especially for High Schools. Because the integration of information-technical basic formation into schools has failed, a special subject is required.
- The position of information technology as crucial fundamental technology makes it possible to select computer science as technical reference subject. The proximity of the subject to the engineering sciences, its result- and product-oriented methods and the power of its tools make instruction possible on different, self-selected problems and with experiences in teamwork, independent learning and problem solving. And that without additional expenses.
- The proximity of computer science to technology offers the chance to extend the spectrum of High School subjects decisive by obligate computer science instruction. So the renouncement in contents of technical computer science in the new EPAs is a crucial error, in my view. Computer science, which relies alone on algorithmically, theoretical and socio-political aspects of the subject, gives up thoughtlessly the possibility of adapting the High School education to current conditions.

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