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Information technology in education: Risks and side effects

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ABSTRACT

The use of information technology (IT) in education carries risks and side effects, which are often overlooked or played down. In this paper, examples from the published literature are provided to demonstrate the down-side of IT in education: typing impairs reading and writing. Impaired reading and writing impairs learning and memory. IT leads to shallow processing, exemplified by the smaller amount of learning through the use of Google as compared to books, journals or newspapers. WLAN in lecture halls causes decreased student learning because of increased distraction. Finally, IT causes IT-addiction in a considerable number of students (up to almost 20%). In sum, the known risks and side effects of IT stand in marked contrast to the often claimed but largely unproven possible benefits. Educators and policy makers should take note.

Wherever there are effects, there are risks and side effects. This truism does not just apply to medicine but to any field of human activity. The automobile was a great invention for mobility, but causes obesity by inactivity, injury and death, as well as environmental hazards. X-rays are great for diagnostics but harmful to the body in larger doses. Asbestos works terrific for insulation and fire protection but causes lung disease and death. Burning fossil fuels keeps our economy going but wrecks our climate in the long run. Along the same lines, using information technology (IT) in educational settings – from childcare to the classroom to the lecture hall and beyond – may have benefits but also carries serious risks and side effects.

Let me give an example: early in 2013, Chinese authors published a paper on the reading capabilities of nearly 6000 pupils in grades three, four, and five, using the same tests that were already used 10 and 20 years ago [49]. Back then, the proportion of children with severe reading difficulty, defined as those children who performed two grades below their grade level (i.e., were 2 years behind their peers in their character reading development) while having a normal non-verbal IQ, ranged from about 2% to 8%. In a previous paper, the authors had already shown that the ability to read Chinese is strongly related to a child's writing skills [48]. Unlike in the Western world's alphabetic languages, where the characters represent how an utterance *sounds*, the characters of the Chinese logographic system represent what the utterance *means*. It therefore comes as no surprise that the relationship between phonological awareness and Chinese reading is much weaker than that in western alphabetic languages. What counts in terms of reading development in China is rather the practice of hand-writing a couple of thousand characters and thereby learning their meaning by heart.

Have you ever wondered how people in China use computers for writing? Do they use keyboards the size of a dinner table to represent all their characters? – To make it short: they don't. Instead they type, on regular alphabetic keyboards, how the word sounds (e.g., “li”), let the computer display a list all the possible words that sound “li”, and then select the appropriate Chinese character by clicking on it with the computer's pointing device (“mouse”). This method of typing Chinese characters is called *pinyin*. It is highly effective and therefore it is taught in Chinese elementary schools during the second half of third grade.

This increase in “media literacy”, as some may call it, however, is accompanied by a marked decrease in reading ability: using similar tests as one and two decades ago, the frequency of severe reading difficulty in the fourth and the fifth grades was found to be above 40% and above 50%, respectively. Quite tellingly, in the third grade reading ability was found not (yet) to have decreased. Additional correlational data obtained on a subsample of children on daily total time spent (still) handwriting, total time using IT in general, and average time using the *pinyin* method established a link between these variables and reading: traditional handwriting significantly increased reading capability, whereas IT use in general and use of the *pinyin* method in particular decreased it.

This study clearly demonstrates that teaching the use of IT in classroom settings can have severe side effects. The authors ([49], p. 1119) correctly state at the outset of their paper: “Written Chinese as a logographic system was developed over 3000 years ago.” You may add: it survived entire dynasties and even the “cultural revolution” of the 1950s and 60s – and now 3 months of using educational IT is enough spell doom for this extraordinary cultural achievement. Needless to say, the Chinese government was not

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SMILEY	BEDEUTUNG
:-)	Einfaches Lächeln, fröhliches Gesicht
:-))))	Sehr fröhlich oder überglücklich
:-D	Herzhaftes Lachen
:´-)	Zum Weinen glücklich
;-)	Lächeln mit Augenzwinkern
;->	Verschmitztes Lächeln
:-P	Zunge rausstrecken
:-C	Unglücklich
:-(	Traurig
:-((	Ganz traurig
(:-(	Sehr unglücklich
;-(	Weinen
>:-<	Verärgert
:-|	Nachdenklich oder auch gleichgültig
:-/	Skeptisch oder auch unentschlossen
:-o	Erstaunt oder auch schockiert
:-X	Schweigen (verschlossener Mund)
:-*	Kuss

Fig. 1. Cover (left) and sample page (right) of the guidelines for computer and internet use in preschools, funded by the *Austrian Ministry of Education* and the *European Union* ([34], p. 1, 37).

amused learning that more than half of the forthcoming generation is unable to read. It implemented countermeasures such as spelling contests during prime time, reinventing an old US-format, and challenging the Chinese youth to use their scripture.

Those who think this is just a minor problem in China should take note that handwriting has long been known to benefit learning and memory: you write something down and thereby keep it in mind. Recent studies from experimental psychology and neuroscience clearly found this bit of general wisdom to be true: compared to typing, handwriting – with longhand being superior to printing uppercase characters – is superior for memorizing anything from the shapes of characters to the content of a lecture [28–30,32,33]. And just as *handling* things, i.e., coming to *grips* with them, is important for thinking about them later [23], experiencing handwriting is beneficial to brain development [22,46], and the development of fine motor skills in particular [47].

Student writing in general is deteriorating, with ever more internet slang, abbreviations ("lol" for "laugh out loud"), and so called "emoticons" (☺ etc.) found in formal writing such as school work [26], making professors lament about declining writing skills in College Freshmen [12]. In the light of these studies and facts, it is hard to believe that in 2013, handwriting has been eliminated from the elementary school curriculum in 46 US States. It is even harder to believe that children at preschool age in Austria are *taugh* that ":-P" means "sticking out the tongue" (see Fig. 1), i.e., they *have to learn* at a very young age what responsible educators think kids *should not learn* even at an older age!

On top of this, educators must take note of the fact that the internet, computers, tablets, and smartphones have a strong potential to cause *addiction*. In South Korea for example, a nation with one of the most IT use by young people [2], smartphone addiction in the age range of 10–19 years has risen to almost 18.4% by 2012, up from 11.4% in 2011 (data from the South Korean *Ministry of Science, ICT and Future Planning*, quoted in [2]). According to Government data from Germany, the number of IT-addicts is about half a million.

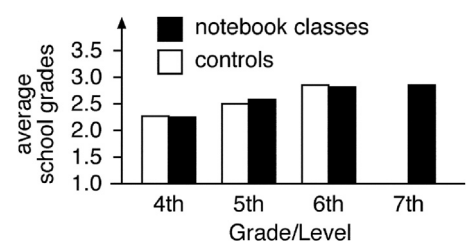

Fig. 2. Main result of the Austrian study on the effects of Classroom computers on school grades (data from [45], p. 48). There is no difference in the average grades (lower is better) of children with and without computers from 4th to 6th grade.

Media representatives, the IT-industry, as well as educational policy makers over and over repeat the statement that computers are good for learning in schools, and therefore, public money should be spent, even though this claim is not supported by any data. For example, data from the international PISA-Study (on no less than 250,000 15 year olds!) show that a computer in the teen's bedroom lowers school performance [16].

In line with as several US studies on the effects of computers on learning in schools [36,39,43,52–54] similar studies in Austria and Germany have demonstrated that computers have – at best – no positive impact on learning (Figs. 2–4), and clearly have distracting effects that hinder learning. Likewise, a study from Israel found computers to hurt performance in elementary and middle schools [1], just as Romanian children of low socioeconomic status, whose families received money to buy a computer, performed more poorly in school than children who did not have computers [31].[1]

Almost 20 years ago, Todd Oppenheimer debunked the belief that computers increase learning as *computer delusion*. For about the same time, the lack of any beneficial effects of the internet on

[1] This study as well as similar experiences from other counties show that the *One Laptop Per Child (OLPC)* initiative may not implement philantropy on a large scale, as claimed by its founders, but instead exemplify a poorly conducted experiment on the risks and side effects of IT in education [14].

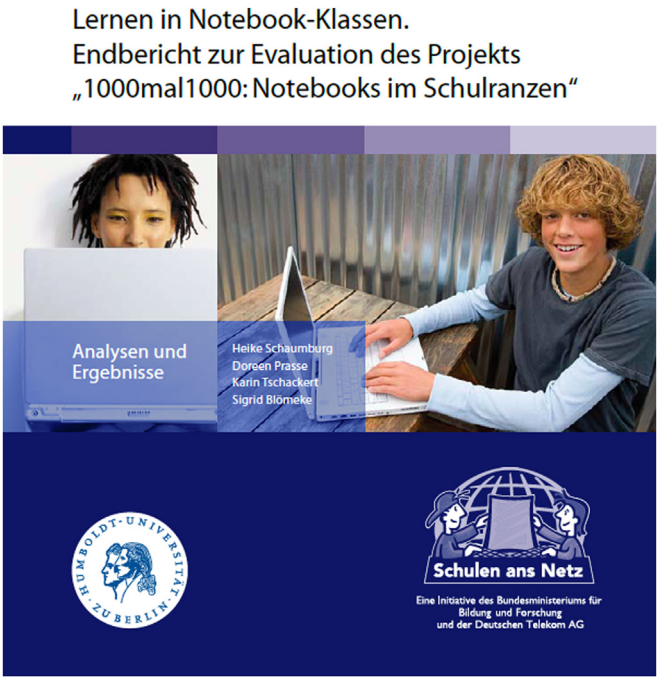

Fig. 3. The *1000 × 1000: Notebooks im Schulranzen* project [42], funded by the *German ministry of Education*, the *European Union* and the German telecommunications giant *Telecom*. Its findings were zero: "In sum, this study was unable to demonstrate that working with notebooks leads to better achievements and competencies or improved learning behavior. […] there was a tendency for pupils with notebooks to be more distracted" ([42], p. 120).

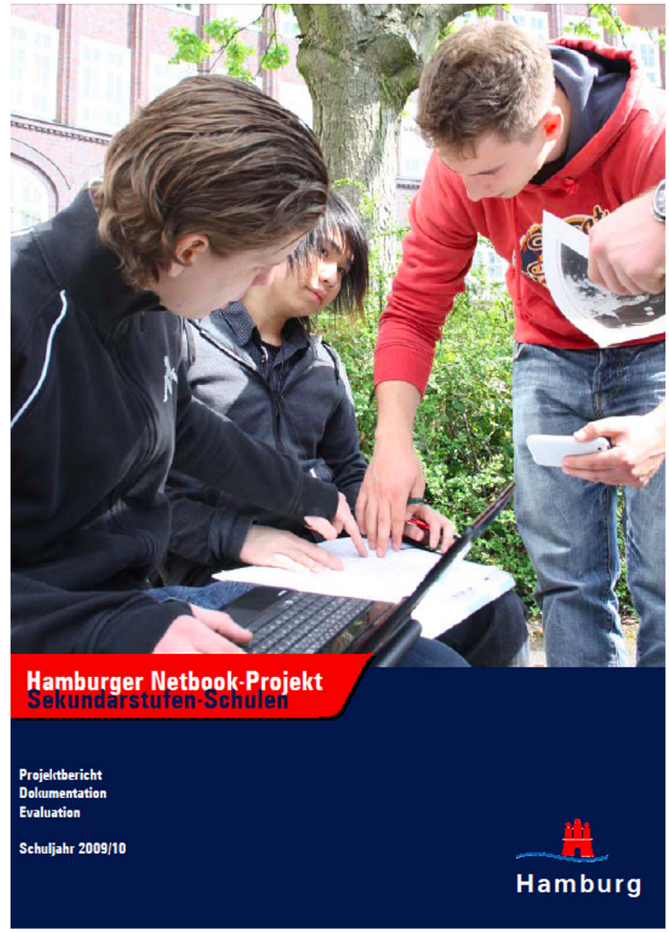

Fig. 4. Likewise, the *Hamburg notebook project* ([18], p. 118) found "no differences in achieved competencies".

education goes by the name of *Internet paradox* [25]. By the middle of the last decade, a large number of studies had demonstrated, over and over again, that computers either hinder learning in the classroom or – at best – have no effect on grades: this was widely publicized by the public presses, such as the *Wall Street Journal* [50], the Washington Post [7] and the *New York Times* [21]. But nothing happened, and when I published a book on the subject – entitled *Digital Dementia* – I was viciously attacked by the media and by media education people for "being old-fashioned" and for "causing fear of progress".

By the way: in a great many of the ensuing discussions about this issue, I noticed that the proponents of classroom IT almost always respond to the truth about IT's detrimental effects in education as follows: first there is denial, then aggression, and finally there is the fall back position: "We just have not learned how to do it right and need more research." For example, the leading scientist in the Hamburg notebook project does not conclude by his data that notebooks are of no use in the classroom. Instead, he now overseas an ongoing study that is even larger than the previous one [17]. In medicine, if therapy A performs worse than Therapy B in small studies, ethical boards (internal review boards, IRBs) make sure that no large studies on therapy A are performed. In education, it seems, there are no such IRBs to protect children from harmful research.

Given what we know from experimental psychology (for more than 40 years) and neuroscience (for more than 25 years), the negative effects of IT on learning are hardly surprising: the deeper any mental content is processed, the more learning takes place, is the main finding of the *levels of processing approach* to memory[2] [8,9]. Studies show that IT use while learning causes information processing in the brain to be shallow rather than deep, thereby preventing from information to be understood and encoded. Hence, students who use their laptops in classes are less likely to do well on tests and assignments (see below). A comparison of electronic textbooks with old-fashioned ones made out of paper that appeared in *Science* magazine showed that embedded videos and hyperlinks in the former are a distraction and hence impede learning [10]. And a study in the same journal that compared learning from books, magazines, journals or Google in four experiments found that information from Google is least likely to be encoded in memory [44]. So the answer to Nicholas Carr's question posed in the Atlantic Magazine "*Is Google making us stupid*?" [6] is plainly "Yes!".

Neuroscience research clearly supports the general ideas from of experimental psychology. When I studied medicine during the late 1970s and early 1980s, the question "why are there synapses" had no answer[3]. But literally thousands of papers published in the past 25 years demonstrated that neural connections change with their use, a phenomenon now widely referred to as *neuroplasticity*. So the less you experience and think for yourself (by having IT do it for you), the less you learn. If you use a pocket calculator, you get

[2] This view surpassed the earlier "boxes-approach", which held that mental content is encoded by passing from ultra-short term memory to short term memory to long term memory.

[3] I remember this quite well, because I once asked this question in the physiology course. The professor looked at me and made some remark that the action potential had to get from here to there. But for this, a nerve fiber is all it takes. So why all the chemistry? It takes time, consumes energy, i.e., is inefficient. If the reason for the existence of synapses were about getting an action potential from here to there, they would not exist!.

worse at mental arithmetic[4]. If you google, your brain knows "I can google this" and does not take much effort to encode. By the same token, taking pictures at a museum impairs your memories of the things you have seen [20], as you replace *close looking* by picture taking. Given what we know about neuroplasticity, i.e., learning and the brain, it is hard to believe that some education practitioners and policy makers still believe that reducing cognitive load is beneficial for the learner.

Quite the opposite is the case: The more effort you have to take, the better the learning outcome. A paper in the journal *Cognition* by a team of Princeton psychologists makes this point quite convincingly. In their study, one group of students was given the classroom materials with the disfluent fonts (such as such Haettenshweiler, Monotype Corsiva, and Comic Sans Italicized), while the other group was taught with the usual mixture of Helvetica and Arial. After several weeks of instruction, students' retention of the material was tested, and in every class (except chemistry), the students in the disfluent font condition performed significantly better than the students with the easy-to-read fonts. They concluded: "This study demonstrated that student retention of material across a wide range of subjects (science and humanities classes) and difficulty levels (regular, honors and advanced placement) can be significantly improved in naturalistic settings by presenting reading material in a format that is slightly harder to read. […] disfluency appears to operate […] presumably engendering deeper processing strategies ([11], p. 114).

Even when it comes to higher education, the risks and side effects of information technology do not come to an end. According to one survey of a representative sample of students [4], the majority is engaged in various distracting activities (cf. Table 1). Most of such *classroom multitasking*, as it has come to be known, is made possible by laptop computers and access to wireless local area networks (WLAN).

Some German educators have said that we have to teach multitasking in schools to students, as this behavior is required in today's professional world – many job descriptions nowadays contain "capable of multitasking" just as they contain "must be familiar with office applications" or "must speak a foreign language". The problem with this opinion is that we have evidence that humans can learn how to multitask just about as much as they can learn how to fly.

In a comparative study of "heavy multitaskers" and non-multitaskers, using six tests that tap into cognitive functions engaged when multitasking (e.g. switch tasks, suppress distractors), multitaskers performed worse compared to non-multitaskers in all of them [35]. This finding implies that when you multitask a lot, you do not get better at it, but instead, you train yourself to engage in a dysfunctional working style[5] and become inattentive. In addition, Multitasking while studying has been linked to negative affect [5] – a conclusion that should interest educators, given the fact that the American youth is engaged in a lot of multitasking for at least an entire decade by now [40].

In the light of what has been discussed so far, it is almost needless to say that several studies have found that the engagement in such distracting behavior as classroom multitasking is detrimental to learning [3,13,15,19,24,37,38,41,51,55]. Between these studies, the time spent on non-class related activity varied widely between about one and two thirds of the entire class time. In one of the studies, the detrimental effect on learning was quantified as an 11% loss of retention in a subsequent test, and one thing was found to be even more distracting than multitasking: watching two other people multitask in front of you (Fig. 5) makes you lose 17% of the material presented in the lecture.

To sum up: digital media pose serious risks and side effects when used in educational settings. They are distracting, in particular when used for non-course-related activities. They take valuable time away from learning children (i.e., replace more important activities for learning), and they do not appear to be beneficial to competencies, grades, and learning behavior in general. Given the higher rate of learning in younger children (preschool), they appear to me most vulnerable. The detrimental effects do not vanish after school but are pronounced even at

Table 1
Frequency of distracting behaviors by students in the classroom ($n=774$).

Distracting behavior	*n*	*%*
Facebook	191	24.7
Text message	392	50.6
Instant message	102	13.2
e-mail	116	15.0
Listen to music	51	6,5
Work on other classes	136	17.6
Talk on the phone	25	3.2
Eat	202	26.1
Drink	440	56.8
No multitasking	9	1.2
No multitasking except eating and drinking	44	5.6

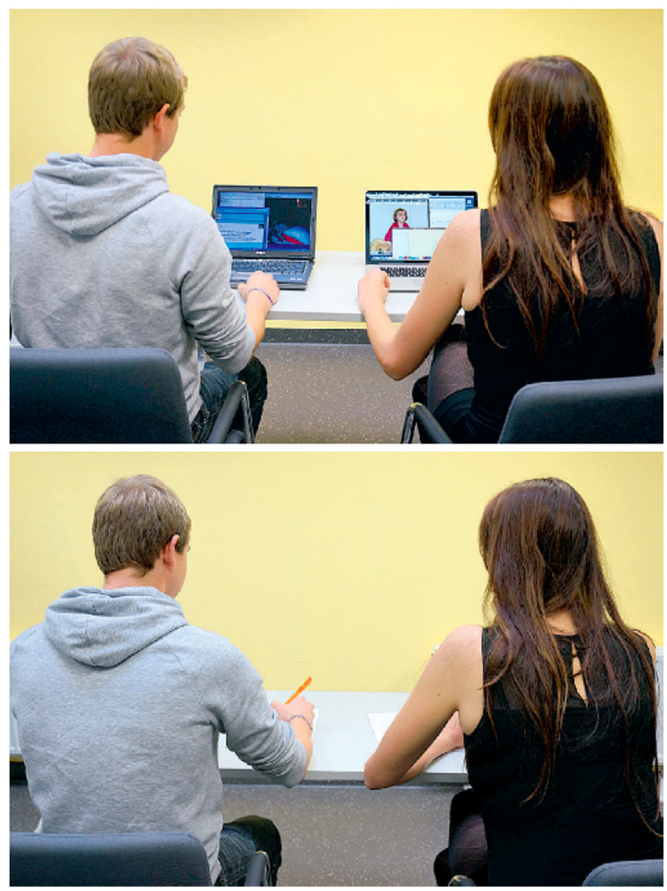

Fig. 5. Watching others multitask in front of you (foto from [46]) was found to be worse than multitasking yourself.

[4] I remember well that during my first extended stay at Harvard University in 1989/90, I often saw clerks in shops typing simple math such as "2+2" into a calculator to figure out the result. – I could hardly believe what I saw.

[5] "Basex, a business research firm, […] specializes in studying how professionals and office workers – 'knowledge workers' – do their work and use technology. It says the $650 billion figure is an estimate of the 'cost of unnecessary interruptions' in terms of lost productivity and innovation. The number, notes […] chief analyst for Basex, is mainly an effort to put a size on what is a big and growing problem" [27].

college age, when young adults should know better what to do during the time of study and learning. So it is the task of the professor to tell students about their misconceptions that lead them to dysfunctional learning behavior, the task of the teacher to know about these findings and be highly careful using IT in class at all, and the task of the preschool teacher to prevent little kids from using IT as well as to tell parents about risks and side effects. In the light of these general findings, the spending of public money for ever more IT in classrooms should stop.

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