Educating Surfers or Craftsmen: 
Introducing an ICT Curriculum for the 21st century

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Abstract
We claim that additionally to the use of ICT we have to integrate deeper knowledge about the tools (computers, networks) and the raw material (information) of ICT into our courses at secondary schools. This means knowledge about application, structure, limitations, construction and production principles, costs, alternatives and impact of tools and material. In our opinion this has to be done within a specific, mandatory subject. For this subject we have designed a new ICT curriculum that is being evaluated in Bavaria currently. We introduce this curriculum and consider some aspects of its logical structure.

Keywords
ICT curriculum, ICT tools and raw material, ICT education, informatics as a subject.

1 INTRODUCTION: LEARNING BY DOING

Imagine a curious chimpanzee sitting in front of a computer that is connected to the internet, closely watching the screen where a Web browser is launched. The primate has already enjoyed some specific training in using a mouse and has learned to click the left button exactly at the moment when the cursor turns into a pointing hand. Thus this ape is able to surf in the internet. Would anybody deny that this occupation (“learning by doing”) might be a major contribution to the mental development of this ape?

But what is wrong about the apes learning strategy? The answer is the following: the ape is using a very complex tool without any aim, goal or purpose. Transferred to the usage of a hammer it is knocking on a piece of wood without knowing anything about nails. Even though some people might be impressed by the noise it is producing, this work makes no sense at all.

In our opinion there is no essential difference between the apes approach and the behavior of people who spend their time by clicking themselves through the internet without having a definite goal or purpose and without having any knowledge about the possible consequences of their actions. In the following article we will refer to those users as “surfers”.

PAPER SUBMISSION
Theme 1: Learning Processes and IT

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In our opinion there is no essential difference between the apes approach and the behavior of people who spend their time by clicking themselves through the internet without having a definite goal or purpose and without having any knowledge about the possible consequences of their actions. In the following article we will refer to those users as “surfers”.
Here are some typical problems the surfer is (helplessly) faced with:

- He (or she) publishes a nice home page, including his Email address and his birthday date. On his next birthday he receives 250 congratulations from commercial companies.
- He sends some confidential data by Email. The next week he has to acknowledge that his whole company is informed about his secret.
- He is looking for some specific information about a certain topic. Every time he uses a search engine, he gets more that 10 000 hits. The first 100 are not useful at all. So he gives up.
- After detecting a very useful Web site, he writes its URL in his notepad. Three weeks later he wants to show the site to a colleague, but he gets the comment: “server not found”. What has happened?
- He is working with three other people on a joint document which is stored at the central server. After simultaneously editing the text, they notice that only one of them has succeeded in storing his work.
- He scans a beautiful picture of his children and sends it via Email to his brother. The following month he receives a very astonishing telephone invoice.

2 THE KNOWLEDGE OF THE CRAFTSMAN

It is obvious that the usage of a complex tool has to be supported by complex knowledge about the characteristics of the tool itself and of specific features of the raw material that is treated by the tool (Brauer, Brauer 1989). This is exactly what tradesman or craftsman have to learn during their long education, in order to enable them to answer questions like the following:

- Application: In which situation, for which purpose should I make use of this tool or that material?
- Structure: how can I get the best results out of it, how do I treat it right, how long will the treatment last?
- Limitations: what is possible and what will never be, at which stress will it break in parts?
- Construction and Production: how could it be improved?
- Costs: how can I optimize the costs with respect to money, time, energy, social impacts?
- Alternatives: Are there better or cheaper other tools or materials available?
- Impact: What damage might be done by the application, what dangers will I have to face?

3 EDUCATION AND USAGE OF ICT IN OUR SCHOOLS

Now what are the implications on the teaching and the usage of ICT in our schools? Obviously our tools are computers and networks (shortly called ICT) and our raw material is information. Thus we have to teach user skills, application criteria and basic concepts of computers and networks as well as strategies and methods to represent, process, transform or transport information (Hubwieser, Friedrich 1998, Isaac 1998).
The teaching of pure user skills and application criteria is suitable to be taught within nearly all subjects of the secondary school education, provided that the teachers enjoyed adequate education and training. The rest of our catalogue has to be implemented within a mandatory specific subject (informatics) in order to guarantee that the teachers will be properly educated.

We are talking about secondary schools which (at least in my country) have a very clearly defined purpose: to provide a broad general education and to construct the foundations for the following specific course of study respective vocational education. Thus we have to make some restrictions on the variety of possible learning contents, which (according to Bruner 1960, 1966, Schwill 1997) are the following:

- generality: the concepts should be applicable as generally as possible;
- durability: the knowledge should not become obsolete within the next 10 years
- teachability: the age of the students age has to be taken into account

4 THE BAVARIAN STORY

It seems naturally that we had to start our efforts in our own country, namely Bavaria, which is a part of Germany. Additionally we concentrated our reflections on the Gymnasium, which is the most advanced type of secondary schools in Germany, aiming to prepare the students (aged 10-19) for the University. Having its own school system like all other German states, Bavaria implemented ICT Education in the eighties, using two different approaches: there was an “across curriculum” implementation of user skills, called “Basic Education in Information Technology” and additionally some optional courses for the basics of computer science, what meant pure programming lessons at that time. From the current point of view we have to admit that both approaches failed. The implementation within existing subjects was hindered by insufficient teacher education and outdated teacher oriented pedagogical approaches, while the contents of the programming courses turned out to be too specifically oriented, missing real values for general education.

Out of this situation the Technical University of Munich convinced the Bavarian Ministry of Education that there has to be some substantial change in the ICT education. In our opinion this had to be implemented in a mandatory subject called “informatics”. For that purpose we developed a new approach to teach the basic concepts of ICT, shifting the emphasis from the tools (computers) to the raw material (information) (Hubwieser, Broy, Brauer 1997, Hubwieser, Broy 1996, 1997). Additionally we designed and implemented a new course of study for teacher students. Unexpected help came from by the explosive spread of the internet, which caused an information overflow that convinced many people that there has to be some additional education in handling complex information.

Our first big success was the introduction of two new types of Gymnasium which contained a mandatory subject “informatics”. The first of these types, called “mathematical / natural scientific type II” involves this subject in the grades 10 and 11 (age of 15 to 17 years), the second type called “European Gymnasium type III” additionally in grade 6 (age of 11-12). Currently the first type is being tested at about 30 Gymnasiums, while the introduction of the second type will start at about 20 schools in fall 1999.In recognition of its efforts the
Technical University of Munich was asked to develop a curriculum for this new subject, which was finished for grades 10 and 11 in January 1999.

5 THE CURRICULUM

Theoretical Framework
In order to provide some stringency we tried to develop a theoretical framework for all topics of the proposed curriculum. This framework is formed by the basic paradigm of information processing: In order to make information accessible to any kind of processing it has to be transformed into a physical representation according to the rules of a more or less formal language. This representation might be transported or transformed by processes that are described by other representations of information (usually programs). Finally the transformed representation has to be interpreted in order to provide (new or transported) information.

The emphasis lies on the representation of information about complex systems, which we call modeling. For that purpose we examined modeling techniques that are used in software development and tried to adapt them to the need of schools (Booch 1994, Rumbaugh e.a. 1991). In our opinion these techniques support the students in many problem solving tasks, within informatics as well as within all other subjects.

The content
Our considerations led us to the following curriculum:

| Grade 10 | Representation of information | • basic scheme of information, representation, processing, transport and interpretation, |
| Data oriented modeling | • language concepts, |
| | • description techniques: data, processes and complex systems, example: data-flow diagrams. |
| Data oriented modeling | • entity-relationship model, |
| | • relational data base systems, |
| | • data management techniques. |
| State oriented modeling | • states and transitions: state charts, state machines, |
| | • communication with state machines: I/O-machines, |
| | • implementation of state machines: basics of imperative programming, |
| | • computer systems as state machines |
| Grade 11 | Functional modeling | • decomposition of complex systems: subsystems, components,  
| | | • program modules: functions and procedures, interfaces,  
| | | • problem solving by recursion  
| | Object oriented modeling | • objects as state machines: attributes and methods, classes and instances,  
| | | • object models: refinement of decomposition, relations between objects  
| | | • communication between objects: invoking methods, democratic structure of object oriented programs  
| | Distributed systems | • communication of interactive systems: message sequence charts,  
| | | • synchronization of parallel processes: exclusive resources, semaphores, messages, protocols  
| | | • simple protocol stacks  
| | Project: development of a complex system | • planning techniques for large projects: time charts, milestones, goals, group organization, communication interfaces,  
| | | • problem analysis: careful examination of the problem and its surroundings  
| | | • system design: application of several modeling techniques,  
| | | • implementation: design of data structures, choice of algorithms, division of programming work,  
| | | • test and assessment: test methods and protocols  

**Embedding**
This curriculum has to deal with some preconditions: Despite the poor practice of the across curriculum implementation of ICT most students will have some experiences in using ICT, partly from their private computers, partly from school lessons. Additionally some of them might have absolved optional ICT courses in using standard software, internet, programming or any other theme around ICT.

**Logical structure**

10th degree
Thus we try to collect, compare and organize the fragments of the students knowledge within the first chapter of the 10th degree: information and representation. After introducing the basic scheme of information processing, we start to work with data structures (see picture 1), including data files, directories, text files, spreadsheets, pictures.
Now the students learn to construct descriptions of data processing techniques, using the basic structures of algorithms: sequence, choice and repetition. This first chapter is completed by the introduction of data flow diagrams which are instantly used to describe and repeat the rough structure of a computer system (see picture 2).

The first closer reflected modeling technique is data oriented modeling. This relieves the students from worrying about time dependent aspects and allows them to concentrate on the static structure of the system. The models are implemented using relational data base systems.

Afterwards we investigate time dependency by constructing state charts. The implementation uses imperative programming concepts. At this point we are ready to consider a computer system as a state machine (see picture 3), which concludes the 10th grade.
11th degree

While the emphasis during the 10th degree lies on information representation and processing, it is shifted at the beginning of the 11th degree towards aspects of distributed systems. We start with functional modeling techniques in order to handle the decomposition of complex systems. The implementation leads to the concept of programming modules and their interfaces.

The rough decomposition into subsystems is followed by a refined composition into objects which are considered as simple state machines: the attributes describe the states whose transitions are controlled by methods (see picture 4). Reflections on classes and instances improve the students abstraction abilities. Then we investigate the structural differences between a “democratic” object oriented, event driven program and a classical program which is driven by one main procedure.

Now the students are ready to deal with distributed, interactive systems. They learn to describe the order of events using message sequence charts before applying these charts to reflect the problems of synchronizing parallel processes that use exclusive resources like common data files. To consolidate this knowledge we investigate methods that are used to organize parallel processes: semaphores, messages, protocols, protocol stacks. This enables deep insights into the structure and the working principles of global networks.
The course is concluded by a large software project: the construction of a complex system. The emphasis is set on techniques to organize large projects as well as on the simultaneous application of several formerly studied modeling techniques.

6 CONCLUSIONS

Our schools have the obligation to enable the students to make their living as independent and responsible members of the “information society”. This society is deeply influenced by the spread and usage of ICT. This means we have to teach methods and concepts to assess the inherent possibilities and consequences of ICT and to use and control them economically as well in private life as in professional environments. Pure “learning by doing” may help many people to get a new hobby or to spend their boring leisure time, but it will never produce the knowledge that is needed to avoid getting lost in the OCT jungle.

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