Informatics in Education, 2002, Vol. 1, 31–42

An Information-Oriented Approach to Informatical Education

Norbert BREIER
University of Greifswald, Department of Mathematics and Informatics
F.-L. Jahn-Str. 15a, 17487 Greifswald, Germany
e-mail: breier@mail.uni-greifswald.de

Peter HUBWIESER
Technical University of Munich, Faculty of Informatics
80290 Munich, Germany
e-mail: peter.hubwieser@in.tum.de

Received: May 2002

Abstract. After a discussion of the experiences with the integrated concept of Basic Information-Technical Education in the different variations implemented by the 16 German states and some considerations of the basic subjects and structure of Informatical Education we present a comprehensive, information-oriented overall concept for Informatical Education. This concept is based on the four guidelines: interaction with informatics systems, operating principles of informatics systems, informatics modelling, interaction between informatics systems, individuals and society and provides detailed proposals for the learning objectives every age group of school education.

Key words: informatical education, information, competences, guidelines.

1. Introduction

In order to safeguard education in the coming millennium, it must be seen as the duty of schools today to prepare students for life in an information society. To this end, regardless of gender, origins and social situation, access to the modes of thought and work of Informatics and to modern techniques of information and communication is to guarantee. Just as the cultural techniques of reading, writing and arithmetic are not taught in passing within other subjects, the basis for dealing competently with information and modern techniques of information and communication has to be acquired early and as a subject in its own right having Informatics as its science of reference at all stages.

But since the mid-90s attention has centred on developing and changing school through the ”new media” so that sometimes the impression is given that ordinary schools are interested in using computers only as a medium: Informatics as a school subject has been more or less ousted from public interest. This is absurd, for it means excluding the basic discipline that is of ever greater importance not only for the development and presentation of the new media but also for the most varying fields of work and life in general.

2. Informatical Education in the Federal Republic of Germany

In 1984 the Federal Commission for Educational Planning and Research Promotion (FLC) resolved on an overall concept for ”Information-Technical Education”. This term was coined to distinguish it from the subject of Informatics in higher education to make clear its orientation towards the ”conscious user”. The foundation was called **Basic Information-Technical Education** (BLK, 1984). In the recommendation continued in the overall concept for Information-Technical Education 1987 it says:

”Information-Technical Education is to be differentiated between school, vocational training, higher education and further education. It is divided into

– Basic Information-Technical Education,
– more detailed Information-Technical Education in the form of Informatics,
– vocationally oriented Information-Technical Education,
– courses offered on Informatics and its applications.” (BLK, 1987).

In this overall concept of the FLC it is expressly stressed that Basic Information-Technical Education is not to be taught as a subject in its own right, but is to be integrated into the existing subjects.

Some states modified the term Information-Technical Education in their own specific applications: Schleswig–Holstein, Hesse and Thuringia speak of Information- and Communication-Technical Education, Saxony–Anhalt, North Rhine–Westphalia, Lower Saxony and Brandenburg call it Information- and Communication-Technological Education, and Mecklenburg–West Pomerania 1991 introduced the term Informatical Education which has become accepted throughout the country. The Informatics Society’s committee No. 7.3 is called ”Informatical Education in Schools”. The reason for choosing the term *Informatical Education* is quite simple: technical aspects are not concerned, particularly in the basic education, and in contrast to the FLC one wanted to express the fact that, in all phases of Informatical Education, Informatics is the science of reference. It has become clear that a strict division – also in terminology – between Informatics teaching in the senior classes of grammar schools and the basic education in secondary level I is no longer in keeping with the times.

The individual states have very varying approaches to integrating Basic Informatical Education into already existing subjects; put simply, these can be classified as interdisciplinary (project model) or subject-oriented (pilot subject model, distribution model). Exceptions are Saxony and Mecklenburg–West Pomerania.

Straight after unification, Saxony established the subject Applied Informatics in secondary level I of Mittelschulen (senior school with junior high school), which covered the basics.

In the school year 1998/99 Mecklenburg–West Pomerania introduced Basic Informatical Education as an autonomous subject in grades 5 and 6 in schools of all types, and this is increasingly being taught by trained Informatics teachers. In grades 7 and 8 of senior schools (Hauptschulen) and junior high schools (Realschulen) it is offered as one of the required optional subjects. Only in grammar schools is it still integrated into related subjects in grades 7 and 8.

In the majority of cases a basic course is given in grades 7 to 9 or 10. Newer concepts, besides Mecklenburg–West Pomerania also in the grammar schools of Rhineland–Palatinate, or in Saarland, begin at grade 5. Bavaria is planning to have Informatics as an mandatory subject from grade 6.

Criticism of existing basic courses on the basis of the FLC concept is becoming more frequent and louder.

Brauer (1990) was one of the first to declare, ”I consider the term and the concept of Basic Information-Technical Education to be wrong for two reasons: It excludes the concept of Informatics and prevents this important subject from developing a uniform profile in school and thus among large sections of the population. And it leads people to believe that this new subject can be reduced to using appliances and discussing possibilities for their use and risks”.

Liessel (Augsburg) is not alone in his opinion when he writes in LOG IN ”that the FLC concept created a framework for introducing Basic Information-Technical Education as a compulsory elementary qualification, but in terms of content rather less has been achieved than before” (Liessel, 1994).

Breier (1994) noticed: ”Today, ten years after the FLC concept was published, we see that basic courses have not become universally accepted in the western states of Germany, and that they are regarded ironically or not taken seriously at all by information scientists or Informatics teachers”.

In that article he forecast ”that Basic Information-Technical Education in the sense of the FLC would already within a few years be resolved into the use of computers as a medium in other subjects on the one hand and the autonomous subject of Informatics at secondary level I on the other hand.”

Today the situation of Informatics is comparable with that of the Sciences when they were admitted to schools 100 years ago. Just as Informatics today, they had to assert themselves against the resistance of established subjects (today not least Mathematics). In order for Informatics to hold its own in such a conflict, its specific contribution to general education must be made clear, in other words it must be shown what Informatics can do that other subjects cannot.

At the first Colloquy on Informatics Didactics of Dresden’s Technical University Breier 1994 (see also Breier, 1994) developed the following thesis:

Thesis

”Informatical Education is that part of general education that regards the world from the point of view of information, whereas the natural sciences are centred around matter and energy.
In Informatics teaching appropriate to our age, not the algorithm but information processed by machines is the central point. Not algorithms, but the concept of information give us the chance to build a bridge between the natural sciences, the humanities and technical subjects, so as to encourage students not to pigeonhole knowledge into apparently unconnected subjects.”

Due to the rapid growth of knowledge, the aim of an information society in which the basics of life can be gained from considering and evaluating information can only be achieved by organizing and networking information so that it can be processed by machines. Informatics, as the science that systematically studies possibilities for organizing and manipulating information and uses them in informatics systems, plays an important part, so that it is imperative for all who go through general schools to have a basic understanding of techniques of information and communication and how they work, as well of appropriate methods of solving problems.

2.1. *But what is Information?*

Colloquially, *information* means notification, instruction or communication which triggers certain reactions in the receiver and increases his knowledge. Since the middle of this century the concept of *information* has been established as the third basic parameter in the natural sciences (Wiener, 1948): ”Information is Information, neither matter nor energy”. As for other fundamental categories, there is no exact definition of this term. We can only compile important features which characterize the concept sufficiently:

- Information cannot exist ”per se”, but is always bound to a medium.
- Matter and energy can both function as information media.
- Information is inscribed on the medium in the form of a **structure** agreed between the sender and the receiver, i.e., a **code**.

Being able to deal with information, especially when digitally represented, and cope with informatics systems are therefore indispensable supplements to the traditional cultural skills of reading, writing and arithmetic. They include

– collecting information,
– representing information in signs which can be processed automatically (data),
– having data processed and disseminated automatically and
– generating new information by interpreting the data one has got.

Information has to be represented in the form of data using suitable techniques before it can be processed automatically. Such representations, often spatially disseminated, are subject to transformation or transportation processes in order to generate new representations from which new information can be obtained by interpretation. The diagram in Fig. 1 (Hubwieser, 2001) illustrates this paradigm.

In 1997 Sprengel classified Informatics within the canon of subjects as follows (Sprengel, 1997): ”If we go by the three basic parameters (matter, energy and information) and the classic disciplines, this almost inevitably gives us a system in which the traditional natural sciences are classified: Chemistry as the discipline of matter and its transformation, Physics as the discipline of energy and its transformation, Informatics as the discipline of information and its processing, Biology as the discipline of interplay of matter, energy and information in animate systems, Technology as the discipline of the interplay of matter, energy and information in inanimate systems.”

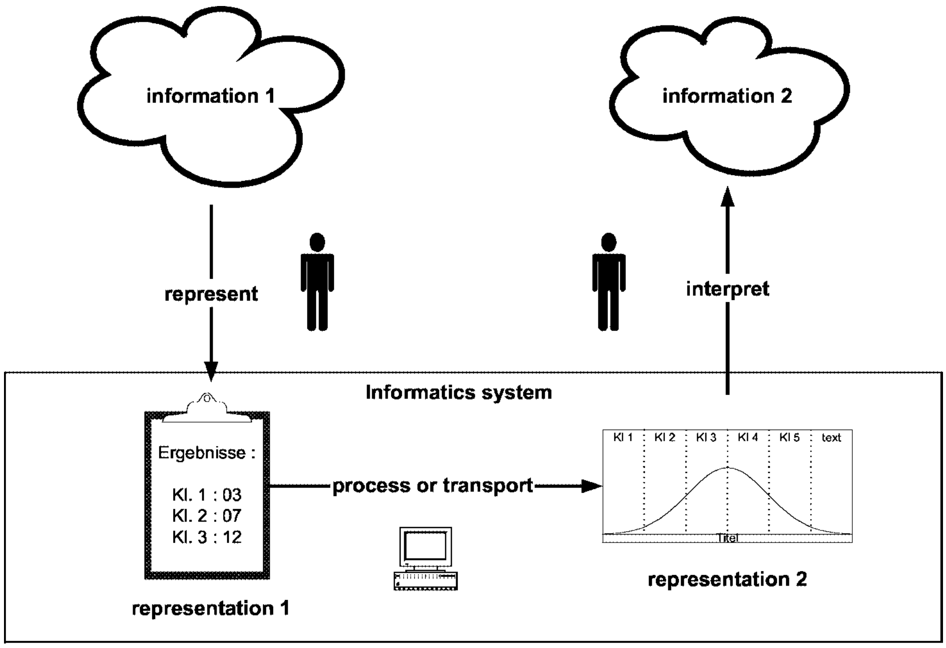

Fig. 1. Representation and transportation of information.

3. A Comprehensive, Information-Oriented Overall Concept for Informatical Education

In the following we should like to sketch a comprehensive, information-oriented overall concept for Informatical Education which is being developed in committee 7.3 "Informatical Education in Schools" (GI, 2000). Comprehensive is meant in the sense that it includes all stages of Informatical Education from primary school to "Abitur".

We understand Informatical Education as the result of learning processes in which the basics, methods, applications and social significance of information and communication technology are to be made accessible. Informatics teaching in secondary levels I and II are particularly intended to contribute to this. Courses in which computers are used as a medium in other subjects are classified as Informatical Education only if informatics aspects are consciously thematized. In all phases of Informatical Education we regard Informatics as the science of reference.

In contrast to the failed concepts of integrated Basic Information-Technical Education and counterproductive concepts such as the "computer pass", the "Internet pass" or "citizens' Informatics", which can be reduced to superficial operating skills through training in how to use a particular version of some software product, this overall concept aims to develop background knowledge in all phases of Informatical Education and make the operating principles of informatics systems transparent from the simple use of a computer to the creation of applications.

The overall concept is structured according to following guidelines:

– interaction with informatics systems,
– operating principles of informatics systems,
– informatics modelling,
– interaction between informatics systems, individuals and society.

These are guidelines for the subject which are connected to the world the students know. The aims of Informatical Education organized according to these points of view are intended to be realized in varying degrees at primary level, secondary level I and secondary level II.

3.1. *Interaction with Informatics Systems*

Students are to acquire a stock of basic strategies and methods and transfer them to analogous situations in the world around them in order to collect, organize, process, store and retrieve, represent, interpret, present and evaluate information. They are to be able to find their way around and research in global information spaces Students are to be able independently to familiarize themselves with the use of informatics systems and choose and use suitable tools for solving problems. In doing so they are also to pay attention to aspects of software ergonomics, how to create informatics systems appropriate to people's needs and the authenticity of information.

3.2. *Operating Principles of Informatics Systems*

Students understand how informatics systems are constructed, according to what principles their components interact and how these can be situated in the context of larger systems. To this end they get to know basic ideas and concepts (e.g., digitalisation and coding, the universal machine), the functioning of important components of modern informatics systems (e.g., processors, memories, bus systems), principles, processes and algorithms and the general structure of more complex ones. In doing so they can experience how the complexity of information can be reduced and how human potential can be extended by automating intellectual activities. Both exaggerated expectations of what is possible and fatalistically attitudes of being helpless in the face of informatics systems should be counteracted.

3.3. *Informatics Modelling*

Students understand that every informatics system is a result of informatics modelling of a section of the world, which after completion functions as a part of the real world with all characteristics of an incomplete, artificial system. They evaluate software as an informatics model developed following analysis of a problem as a reduced image of reality made by humans and implemented on the informatics system. They can classify models and make modifications, know and can apply modelling techniques. The modelling techniques learned by analysing informatics systems also enable students to organize and control large and complex quantities of information in general.

4. Competences

With these guidelines based on the requirements of the discipline, students develop competences which are indispensable in our present information society and also in the foreseeable future and thus are an essential basis of present-day general education. These are above all subject competence, methodological competence, social competence and self competence.

4.1. *Subject Competence*

Students achieve subject competence by acquiring knowledge of the subject and interdisciplinary knowledge and the ability to combine, deepen and critically check their knowledge, and use it in active contexts. This requires thorough knowledge of principles and methods of Informatics.

4.2. *Methodological Competence*

Methodological competence is intended to enable students to collect, organize, process, store and retrieve and represent information, correctly interpret and evaluate the results generated by machine and present them in suitable form, recognize and analyse problems and flexibly develop and test various solutions and use them appropriately according to the situation.

4.3. *Social Competence*

Social competence means being able to learn, work and live together, in other words to take notice of other people and talk to them, and to take responsibility as a member of a teaching and learning group, to tolerate other opinions and values, and being prepared to solve conflicts with others peaceably. In the information society it is more and more becoming a prerequisite for successful learning and work, for complex problems increasingly require interdisciplinary cooperation as well as within a discipline. This means planning and helping to organize group processes, taking criticism and being able to express it constructively, experiencing a change of work roles and being able to accept this, being flexible in order to get out of dead-ends, being able to improvise, take decisions, assess oneself, work in a team, communicate and resolve conflicts. Flexibility and mobility in thinking and acting, solidarity and responsibility for others are becoming key competences. Increasing globalization through networked information systems leads to learning and working in international and multicultural groups and requires cultural understanding and tolerance.

4.4. *Self Competence*

Self competence is the ability to develop, test and preserve one's own identity. It comes from the constant effort to deal with one's own wishes, needs, strengths and weaknesses, failures and inner conflicts, to reflect on one's own feelings, thoughts and actions and thus to stimulate willingness to achieve and make an effort. Students experience their own competence in dealing with information and modern informatics systems, they themselves discover significant values in facts and processes of teaching and learning, and in doing so constitute long-term individual inclinations, specific talents and interests.

5. School Levels

5.1. *Grades 1–4*

Computers are already part of children's environment at kindergarten age. At school they are used as a medium and tool ever earlier and in ever more subjects. For this reason first basic skills in dealing with informatics systems should already be acquired – at least intuitively, but correctly – at primary level within pre-subject teaching, and also first basic knowledge, suited to the children's age, should be taught. Only through such early establishment of aspects of Informatics can social and gender-specific disadvantages be compensated for and thus equal chances for all students be guaranteed.

The first encounter with informatics systems at primary level must be arranged very carefully and responsibly from the point of view of both pedagogics and the subject. Using suitable problems from the world of their experience, students become acquainted with the components and functioning of an informatics system in relation to specific tasks appropriate to their age. Handling and using individual system components are never in themselves an aim of teaching, but arise from functional application to concrete tasks. In the production of documents children particularly learn how to generate, process and interpret representations of information (data).

5.2. *Grades 5–6*

In these grades Informatics is to be given as a compulsory subject in its own right in order to allow all students to develop subject competence, methodological competence, social competence and self competence in dealing with information, especially as represented digitally. Thus they also acquire the practical competence necessary for using a computer as a tool and medium in other subjects. In planning the teaching, what has already been learned in pre-subject teaching should be taken into consideration. What is taught and how it is taught should be chosen so as to awaken, develop and encourage the students' interest in Informatics.

5.3. *Grades 7–10*

These grades include the decisive stage in the general Informatical Education of all students in schools of all kinds, whereby informatics modelling is of particular importance. As in the previous grades, at the beginning of this age group informatics systems are above all modelled, i.e., starting from their application to concrete tasks they are systematically studied and described with regard to the organization of their components and processes and to their internal and external communication behaviour.

Typical starting points could be the digitalisation and coding of information as data, the automation of manipulating such data, the organization of information spaces with the help of directory and hypertext structures or data banks, or the use and analysis of search engines, whereby the students get insights into the fields of computer architecture, computer networks, operating systems and the structures of data and algorithms. The choice, application and analysis of suitable informatics systems for a particular problem enables them to acquire and improve their knowledge of the structure, functioning and classification of typical informatics systems and, building on this, a firm practical and critical competence

Towards the end of this age group, besides informatics systems other complex systems from the world as the students' experience it comes increasingly to the fore, and these are analysed, organized, described and simulated with the help of informatics methods. The students get to know informatics aids for controlling complex systems, whereby the classification of objects and the construction of object-based solutions is learned as the essential strategy for solving problems in Informatics. Another prime aim of Informatics teaching at this level is to make the students aware of the problems of data protection and data security.

5.4. *Grades 11–12 (13)*

Building on the foundations laid in grades 5–6 and 7–10, a propaedeutic introduction to the systematics of informatics is held for the students who choose to go into it more deeply. There are different curricula for the basic and special courses. In the basic course students can use examples to develop ways and thinking typical of informatics. They learn to argue, explain basic concepts of the subject and describe creative tasks using appropriate terminology. In the special course students can additionally acquire formal concepts of informatics with which to analyse complex applications and discuss complicated tasks. The use of terminology aims at a more abstract level in interpreting principles, laws and theses of informatics.

5.5. *Curriculum for the Basic Course*

Examples are used to deepen knowledge of the cognitive, social and ethical aims of Informatics in the within the priority topics ”Informatics Systems” and ”Informatics Modelling”, linking these with the relevant legal framework.

Students acquire the basic concepts of selected ”informatics systems” through analysis, modification and evaluation. The tasks of an operating system in managing processes and devices are sketched in model. Computer networks and dispersed systems are characterized using layer models, protocols, addressing and applications typical of schools. The structure and functioning of computers are generalized on the basis of the organization plan of a von Neumann computer.

The solving of problems is an important contribution of Informatics to general education. Varying modelling procedures mean varying strategies for solving problems which students are to learn. For this reason an introduction to various modelling procedures is indispensable. Students acquire selected principles, methods and tools for ”Informatics modelling” in order to:

– model data,
– make models based on state,
– make functional models,
– make models based on the object.

Criteria such as correctness, reliability and suitability allow models to be compared. Algorithms and data structures are discussed using the example of application systems and program languages. A lot of room is given to the formalizing and describing of models. Programs are understood as operational descriptions. Program constructs such as recursion and loops and the concept of variables as used in Informatics can be used for productive tasks. Selected theoretical concepts such as encapsulation of data and complexity observations and concepts of software ergonomics develop students’ ability to evaluate solutions to tasks.

6. Consequences

6.1. *Establishment in the Canon of Subjects*

Informatical Education needs an autonomous subject Informatics in the canon of obligatory subjects, beginning early and taught by qualified teachers with the first and second State Examination in Informatics.

In future Informatics must be established with the same importance as other subjects and included in the ”Abitur” with the same value as the natural sciences and must be able to be chosen as an examination subject.

6.2. *Teacher Training*

In all German states it must be possible to choose Informatics for secondary levels I and II as one of two subjects for teacher education. For the second phase of training the institutions need to offer seminars in Informatics Didactics. In-service training as Informatics teachers should take the regular training as its orientation as regards both standards and qualifications awarded and should include analogous quantities of Didactics of the subject. The enormous pressure to innovate which results from informatics and the new cultural technique of knowledge management requires further training to be continually available for teachers of Informatics.

In all teacher-training courses Basic Informatical Education should be compulsory in the first phase, including practical training; this would then be continued in the Didactics of the respective subject and in the second phase of teacher training.

Analogous in-service training must be available to allow those already working as teachers to acquire this Basic Informatical Education.

References

Bund-Länder-Kommission für Bildungsplanung und ForschungsfŠrderung (BLK): Rahmenkonzept für die informationstechnische Bildung (in German, Bund-Länder Commission for Educational Planning and Research Promotion: Framework of Information Technical Education)(1984). Reihe "Materialien zur Bildungsplanung", Bonn.

Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung (BLK): Gesamtkonzept für die informationstechnische Bildung (in German, Bund-Länder Commission for Educational Planning and Research Promotion: Framework of Information Technical Education) (1987). Reihe "Materialien zur Bildungsplanung", Heft 16, Bonn.

Brauer, W. (1990). Trends der Informatik-Ausbildung (in Germany, Trends in Informatical Education). In A. Reuter (Ed.), *20th Annual Conference of the GI (I), Reports of Informatics*, **257**, Springer–Verlag, pp. 456–464.

Breier, N. (1994). Informatische Bildung als Teil der Allgemeinbildung. Stand und Perspektiven (in German, Informatical Education as a Part of General Education. State of the Art and Perspectives). *LOG IN*, **14** (5/6), 90–93.

Gesellschaft für Informatik (GI). Empfehlungen für ein Gesamtkonzept zur informatischen Bildung an allgemein bildenden Schulen (in German, Recommendations on a Framework of Informatical Education in General Education) (2000). *LOG IN*, **20**(2), I–VII.

Hubwieser, P. (2001). *Didaktik der Informatik* (in German, Didactics of Informatics). Springer-Verlag, 1, corrected reprint, Berlin.

Liessel, W. (1994). Die Informationstechnische Grundbildung (in German, The Basic Information Technical Education). *LOG IN*, **14** (3), 55–56.

Sprengel, H.-J. (1997). PC oder Telekommunikation? (in German, PC or Telecommunication?) *Schulverwaltung*, **97**(11), 303–305.

Wiener, N. (1992). Kybernetik – Regelung und Nachrichtenübertragung in Lebewesen und in der Maschine (in German, Cybernetics û Control and Information Transmission in Living Organisms and in Machines). Econ–Verlag, Düsseldorf, Originalarbeit (Cybernetics), 1948.

N. Breier studied mathematics and graduated from Greifswald University in 1972. He took his doctor's degree (Dr. rer. nat) in mathematics (theoretical informatics) at Greifswald University in 1977. Since 1985 he has worked in didactics of informatics. In 1991 he habilitated and obtained venia legendi for didactics of informatics at the University of Halle. Since 1992 he has been privatdozent for didactics of informatics at the Department of Mathematics and Informatics of Greifswald University. His research interests are didactics of informatics and computer applications in schools. Since 1999 he has been a speaker of the working committee 7.3 ”Informatical education in schools” in German Informatics Society (GI).

P. Hubwieser passed his first (scientific) state examination (Mathematics and Physics) and his second (pedagogical) state examination (teacher at Gymnasium, Mathematics and Physics), both at the Ludwig-Maximilians-Universität Munich. From 1985 to 1992 and 1994 to 2002 he was teaching Mathematics, Physics and Informatics at Bavarian Gymnasiums, interrupted by programming commercial data base systems. In 1995 he received his doctorate (Dr. rer. nat., Theoretical Physics) at the Ludwig-Maximilians-Universität Múnchen. From 1994 to 2002 he has been part-time delegated to the Faculty of Informatics of the Technical University of Munich on behalf of the Bavarian Ministry of Education: Implementation of new courses of studies for teacher education in Informatics, implementation of Informatics as a mandatory subject at secondary schools. Since 1995 he is giving lectures in “Didactics of Informatics” at the Faculty of Informatics of the Technical University of Munich. In 2000 he received the state doctorate (“Habilitation”) at the Faculty of Informatics of the Technical University of Munich. In 2002 he was visitant professor at the Faculty of Informatics of the University of Klagenfurt, Austria. Since June 2002 he is working as an associate professor at the Faculty of Informatics of the Technical University of Munich.

Informacinio išprusimo informacinis lavinimo metodas

Norbert BREIER, Peter HUBWIESER

Straipsnyje aptariama integruoto pagrindinio informatikos techninio lavinimo patirtis įvairiais variantais, kuruos įgyvendino 16 Vokietijos žemių. Taip pat svarstomi pagrindiniai informacinio lavinimo klausimai bei jų struktūra, pateikiama visapusė, orientuota į informatiką, bendra informacinio lavinimo idėja. Ši idėja remiasi keturiomis gairėmis: sąveika su informatikos sistemomis, informatikos sistemų valdymo principai, informatikos modeliavimas, informatikos sistemų sąveika, individų ir visuomenės sąveika. Straipsnyje pateikiami pasiūlymai mokymo tikslams kiekvienai mokyklinio amžiaus grupei.