Informaticians and informatical professionals: a conceptual framework

Tom J. van Weert
School of Informatics, Faculty of Mathematics and Informatics
University of Nijmegen, PO Box 9010, 6500 GL Nijmegen
The Netherlands, e-mail: school@cs.kun.nl

Abstract

What informatics knowledge do noninformatics majors need? To answer this question the relationship between informatics and other disciplines must be clear. This relationship is dependent on which view of the world is taken. Here we take the view that the world of informatics regards systems of interacting processes. From this view follows a relationship between informatics and other disciplines. This relationship allows derivation of competencies needed by noninformatics majors from competencies needed by informatics majors. First a terminology set is presented. Then a conceptual framework is developed which makes a distinction between informatics as a discipline and so-called informatical disciplines as well as between informaticians and so-called informatical professionals. Finally a common core of informatics is identified.

Keywords

Informatics, other disciplines, noninformatics majors, curriculum (core), educational profiles

Informatics in Higher Education F. Mulder & T. van Weerts (Eds.)

1 TERMINOLOGY

The following terminology is used in this paper.

- Science = Discipline:
  a branch of knowledge or study, especially concerned with establishing and systematizing facts, concepts, theories, methods and techniques as by experiments and hypotheses.
- Application oriented science:
  scientific facts, concepts, theories, methods and techniques oriented towards an application domain.
- Technology:
  artefacts as applications of science.
- Professional:
  a graduate of higher education working in a particular discipline.
- Informatics = Computer Science = Computing Science.
- Informatician:
  a professional in informatics (this term can be seen as a direct analogue of the 'mathematician' who is a professional in mathematics).
- Informatical:
  the adjective of 'informatics' (this term can be seen in analogy with 'mathematical' or - as you like - 'physical' or 'economical').

2 INFORMATICS, ITS TECHNOLOGY AND THE WORLD

Technology push

Since the first electronic computer was introduced for performing calculations, a lot has changed. The next step was to develop technology for automation of simple administrative processes. Miniaturization then made computers reach the personal work place supporting processes of work with information processing technology. And now we are moving into a future were Integrated Broadband Communication (IBC) facilities make the computer the gateway to information. And the computer is reaching the home: in the first decade of the next century 50% of the private homes in Europe will have these IBC facilities according to the Commission of the European Union.

But there is more. Computers can change their own programs and therefore can learn. They can for example adapt themselves to their users through software embedded in microwave ovens or television sets. They can also learn to act as personal intelligent agents in a communication network.

Technology pull

The organization of activities in our society is changing (Hammer and Champy, 1993). Because of a growing demand for flexibility and quality, market oriented business units have appeared with a flat organization in which teams of professionals operate supported by participative management. It is a type of organization in which professionals need powerful information processing tools and in which horizontal communication is a must. These organizations exercise a technology pull on integrated and powerful computerized work places which are connected in a network supported by intelligent agent-based groupware.

Interacting processes
Unprecedented applications of informatics emerge from the more familiar areas of calculating or data and information processing. We are moving from a world of information to a world of communication and interaction.

3 DEFINITIONS OF INFORMATICS: VIEWS OF THE WORLD

Definitions of informatics reflect the perceived role of informatics and its technology in the world. They are connected with different views of the world.

3.1 Processing of data and information

An early definition of informatics is found in the 1971 IFIP Guide to concepts and terms in data processing (Gould, 1971). Informatics is described as 'those aspects of science and technology applicable to data processing'.

In later definitions the role of information processing is stressed. The International Bureau for Informatics of UNESCO states that informatics 'concerns the design, the realization, the evaluation, the use and the maintenance of information processing systems; including hardware, software, organizational and human aspects, and the whole of the industrial, commercial, governmental and political implications'. And Denning *et al.* (1989) define the discipline of computing as 'the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation, and application. The fundamental question underlying all of computing is: What can be (efficiently) be automated?'.

3.2 Hardware, software and beyond

The Computing Reviews Classification System (Coulter, 1991) distinguishes 11 areas:

A. General literature;
B. Hardware;
C. Computer systems organization;
D. Software;
E. Data;
F. Theory of computation;
G. Mathematics of computing;

H. Information systems;
I. Computing methodologies;
J. Computer applications;
K. Computing millieux.

This system actually is a very detailed four level tree of (sub)domains of knowledge and is used mainly for the classification of literature. This knowledge domain tree can be seen as a specification of the discipline. The tree is rooted in hardware and then folds out via software to other aspects of what traditionally in the USA is called computer science.

In the Unified Classification Scheme for Informatics (UCSI) which has been developed by Mulder and Hacquebard (1998) a specification of informatics as a discipline is given in a four level knowledge domain tree of which the first level distinguishes four domains:

- computer systems;
- software systems;
- information systems;
- context of informatics.

Although in this system informatics is seen as a broad discipline, it remains a bare hierarchy in which the various knowledge domains are separated. Knowledge domain trees have in common that they represent a typical static view of the world.

3.3 Applications orientation

Reflecting the growing importance of applications of data and information processing the following set of definitions was introduced in 1986 by an advisory group of the Dutch Minister of Education (Commissie Hoger Onderwijs InformaticaPlan, 1986). It includes the concepts of application oriented informatics and so-called 'informatiekunde', a Dutch neologism of which the closest English translation probably is 'information engineering'. The report distinguishes:

- Informatics:
  discipline dealing with data processing systems.
- Application oriented informatics:
  domain of informatics dealing with the development of data processing systems for broad application areas.
- Information engineering:
  field where (application oriented) informatics is integrated into a specific other discipline (for example: business information engineering, medical information engineering, physical information engineering, etc.).

Besides there is the whole range of self-contained other disciplines, not necessarily related to informatics. In these disciplines various applications of informatics are manifest or conceivable.

The interesting point in these definitions is the explicit denotation of a relationship between informatics and the disciplines in which informatics is applied.

3.4 Interacting processes in application areas

In the context of the technological developments outlined in section 2 a set of definitions may be proposed, building on the set of definitions in the previous subsection but now based on the interacting processes paradigm.

- Informatics (as a self-contained discipline):
  discipline dealing with programmed computer systems which embody (generic) systems of interacting processes.
- Application oriented informatics:
  domain of informatics dealing with programmed computer systems which embody specific systems of interacting processes from particular broad application areas.
- Informatical discipline:
  field where (application oriented) informatics is integrated into a specific other discipline (for example: informatical business administration, informatical medicine, informatical physics, etc.).
- Other disciplines:
  disciplines, different from informatics, in which various applications of informatics and its technology can be manifest or conceivable.

In these definitions the adjective 'informatical' is introduced as an analogue to 'mathematical' and 'physical'. An informatical discipline can be considered as a domain of the adopting discipline or eventually as a new hybrid discipline, emerging from the adopting discipline and informatics. Such hybrid disciplines are not new, take for example mathematical physics and physical chemistry. Of course when integrating disciplines, informatics can also be the adopting discipline and then the roles are reversed. An example is mathematical informatics, which is not the same as informatical mathematics.

4 COMPETENCIES OF INFORMATICIANS

We adopt the fourth view in which informatics is seen as a system of interacting processes (Wegner, 1997). From this 'process' view the activities of an informatician can be detailed as in Figure 1, which is an earlier version of the one found in Wupper and Meijer (1998).

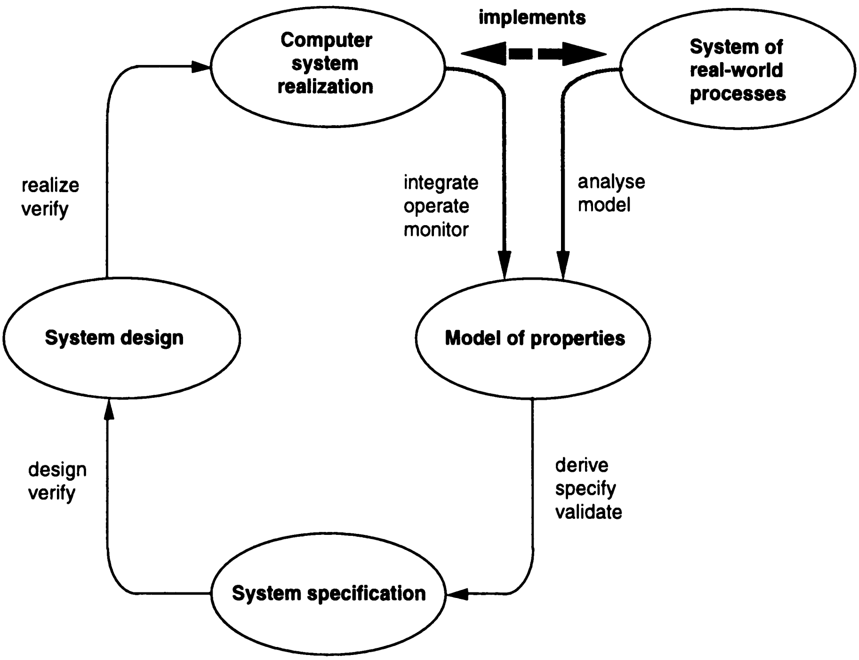

Figure 1 Definition of the activities of an informatician from a 'process' view.

Figure 1 shows the processes in which an (application oriented) informatician should be competent. Each of these competencies can be pursued in a practical sense (applying the competencies) and in a theoretical sense (developing the theory behind these competencies). We specify the required competencies below.

Problem analysis and modelling
- analyse properties of systems of real life processes;
- model properties.

Specification
- derive a specification from model;
- specify nonmodelled properties;
- validate specification.

Design
- derive concrete design from specification;
- verify design.

Realization
- realize design in computer system;
- verify realization.

Integration

- integrate computer system realization into the real world;
- operate computer system realization;
- monitor adequacy of computer system realization.

Not in Figure 1, but important as an overall set of competencies, is the following.

Activity control

- plan and schedule all activities;
- manage the sequence of processes;
- assure the overall quality.

5 INFORMATICS AND OTHER DISCIPLINES

Informatics and other disciplines are related to each other through application areas for which informatics produces computer system realizations of real world application processes.

5.1 Information processing support

Professionals from application areas in other disciplines can solve problems from these areas using information processing tools. Sometimes the technology used is generic (e.g. word processors, spread sheets, data base systems), sometimes application specific (e.g. juridical information systems). Sometimes the technology is 'off the shelf', sometimes it is tailor-made.

5.2 Dynamic modelling

Another type of application is to produce a computer system realization which is a dynamic model of a system of processes in a particular application area. When the relationship between the dynamic model and reality is systematically studied through experiments and hypotheses for establishing and systematizing facts, principles and methods, the modelled processes are part of the other discipline (Figure 2).

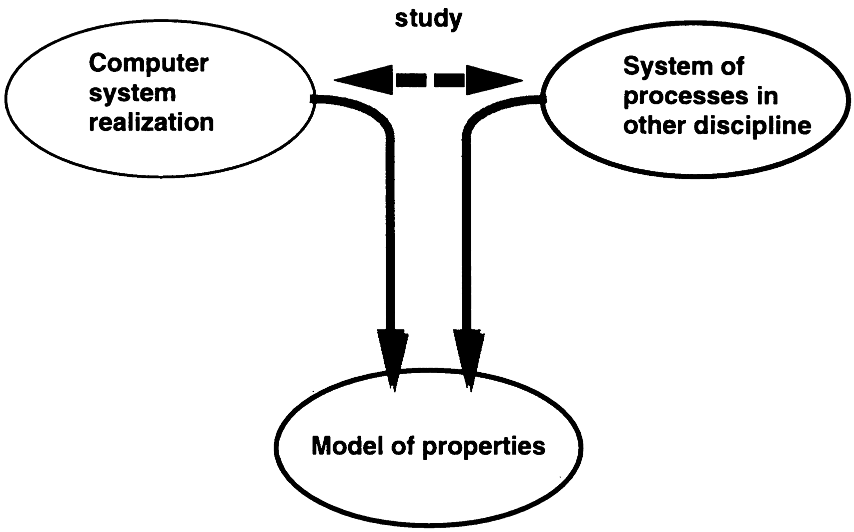

Figure 2 Dynamic models of reality.

We are used to modelling the world in static symbols. But informatics allows us to construct executable symbols (Van Weert, 1988) embodying complex dynamic conceptual models of reality; informatics allows us to build a virtual reality. Modelling then becomes 'programming' in conceptual application oriented or discipline specific executable modelling languages. Problems are analysed and solutions developed as dynamic models, brought to life on a computer, using methods and techniques of informatics.

5.3 Informatical disciplines

When specialized information processing tools or discipline specific executable modelling languages are required, the applicants must have both discipline specific and informatics know-how. The development of the computer algebra systems Maple and Mathematica can be taken as an example. In such cases particular scientific questions within the domain of a discipline can only be answered when informatics methods and techniques are applied. This integration gives rise to the informatical disciplines mentioned in subsection 3.4 (in this case informatical mathematics).

The relationship between informatics and an informatical discipline is pictured in Figure 3.

6 THE INFORMATICAL PROFESSIONAL

'Informatical professional' is a generic term used for those who practice an informatical discipline. Specific instances are for example: the informatical economist, business consultant, psychologist, linguist, chemist, mathematician, mechanical engineer and the informatical medical expert. The informatical professional has a solid background in a specific discipline, different from informatics, but also is familiar with methods and techniques from (application oriented) informatics. The tasks of the informatical professional complement those of the (application oriented) informatician. The informatical professional is able to communicate on a high level about these tasks with application oriented informaticians.

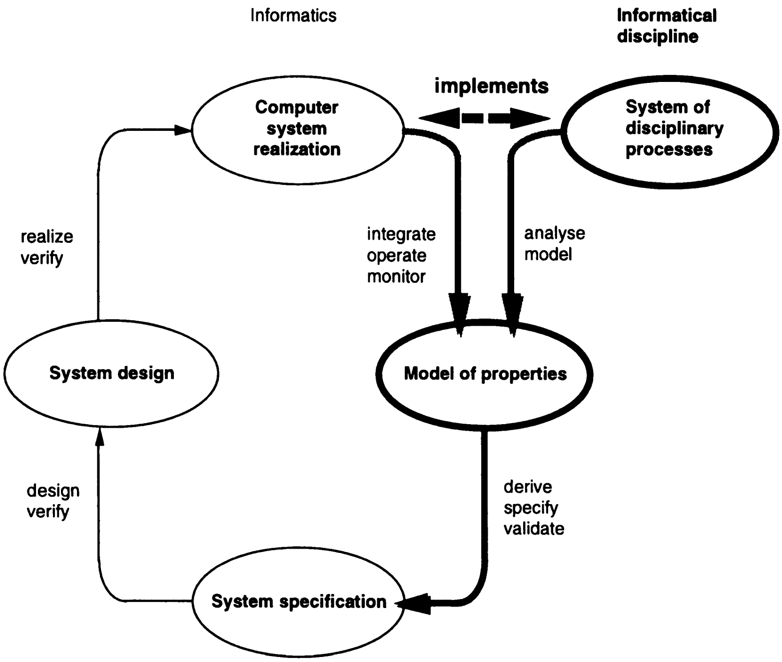

Figure 3 Relationship between informatics and informatical discipline.

The required competencies of informatical professionals can be derived from Figure 3. The informatical professionals must have their core competencies ('know how') in four of the six competency fields mentioned for the informaticians in section 4:

- problem analysis and modelling;
- specification;
- integration;

- activity control.

Two competency fields are of secondary nature ('know about', 'know how' in simple cases):
- design;
- realization.

7 EDUCATION OF INFORMATICAL PROFESSIONALS

Discipline specific and informatics know-how are integrated in an informatical discipline. Therefore educational programmes in informatical disciplines will contain three components: elements from the 'adopting' discipline, elements from (application oriented) informatics and integrative elements.

Typical core subjects from application oriented informatics are:
- process modelling and specification methods and techniques;
- human-computer interaction modelling and specification;
- software engineering.

Modelling and interfacing also appear as integrative elements. Familiar informatics subjects as the design of data bases and programming methods and techniques are of secondary nature for the curriculum.

7.1 Some examples

At Nijmegen University education in informatical disciplines is found in several departments (Van Weert, 1992). For example: informatical business administration, cognition science and language, speech & informatics, and also informatical medicine, physics and chemistry. Please note that in the referenced paper the adjective 'informational' is used instead of 'informatical'.

In Shaw (1991) computing specialists in disciplines outside information technology are mentioned as an example of people working in informatical disciplines. Shaw refers to programmes at Carnegie-Mellon University, George Washington University, the University of Illinois, the University of Colorado and the University of Toronto.

Informatical chemistry was presented as an example of an informatical discipline at the IFIP working conference 'Visualisation in scientific computing: Uses in university education' (Weber *et al.*, 1994).

7.2 A detailed example: cognitive science

The structure of the Master's programme of cognitive science at the Faculty of the Social Sciences of Nijmegen University is given in some detail as an example of an educational programme in an informatical discipline. Only elements from application oriented informatics and hybrid elements are presented.

Application oriented informatics (about 10% of the full programme)

- programming (top-down development of algorithms);
- programming (bottom-up development, data structures);
- information systems development;
- symbolic programming in Lisp.

An element missing in this programme is software engineering.

Hybrid topics (about 25% of the full programme)

- introduction to artificial intelligence (AI);
- programming paradigms for cognitive modelling and AI;
- computational psycholinguistics;
- introduction to expert systems;
- AI in education;
- knowledge elicitation for expert systems;
- human-computer interaction;
- information ergonomics;
- Master's thesis.

8 CONCLUSION

In this paper a conceptual framework has been presented which positions informatics in relation to other disciplines, especially in the context of education.

Informatics and informaticians

Informatics is the discipline dealing with programmed computer systems which embody (generic) systems of interacting processes. The modelled processes are from informatics itself. There is little interaction with application areas or other disciplines. The professionals are informaticians. The education is aimed at competencies, needed to realize generic systems (see section 4).

Application oriented informatics and informaticians

Application oriented informatics deals with programmed computer systems which embody specific systems of interacting processes from particular broad application areas, possibly in other disciplines. There is medium interaction with the application areas with visible results. The professionals are (application oriented) informaticians having additional expertise in a specific application area, possibly in another discipline. Education of these professionals is aimed at competencies needed to realize specific systems for broad application areas (see section 4).

Informatical discipline and informatical professionals
An informatical discipline is a field where (application oriented) informatics is integrated into a specific other discipline. The modelled processes are specific for the 'adopting' discipline and are described in discipline specific executable modelling languages. The scientific questions addressed belong to the domain of the adopting discipline, but can only be treated using informatics. Thus there is a strong interaction between informatics and the other discipline with visible results. The practitioners are called informatical professionals, underlining that they must have their roots in the adopting discipline, complemented and mixed with additional expertise in a core of (application oriented) informatics (see section 7).

Other disciplines and their professionals
What remains are all the other disciplines, in which various applications of informatics and its technology can be manifest or conceivable. Information processing tools, generic as well as application specific, support the problem solving. The scientific questions change under the influence of the use of this technology. The interaction with the technology of informatics is strong and its effects are highly visible. The professionals have their education in the specific discipline, which however includes the use of information processing tools within that discipline. There is no need for a generic informatics component in the curricula.

9 REFERENCES

Commissie Hoger Onderwijs InformaticaPlan (1986) *Eindrapport.* HBO-Raad, Den Haag, 13-16 [in Dutch].

Coulter, N.S. [ed.] (1991) Update to the Computing Reviews Classification System. *Computing Reviews,* **32** (1), 5-50.

Denning, P.J. *et al.* (1989) Computing as a discipline. *Communications of the ACM,* **32** (1), 9-23.

Gould, H. [ed.] (1971) *IFIP Guide to concepts and terms in data processing.* North-Holland Publishing Company, Amsterdam.

Hammer, M. and Champy, J. (1993) *Re-engineering the corporation.* Nicolas Brealy Publishing, London.

Mulder, F. and Hacquebard; A.E.N. (1998) Specifying and comparing informatics curricula through UCSI, in *Informatics in higher education: Views on informatics and noninformatics curricula* (eds. F. Mulder and T.J. van Weert), Chapman & Hall, London.

Shaw, M. (1991) Informatics for a new century: computing education for the 1990's. Special issue of *Education & Computing,* **7**, 9-17.

Van Weert, T.J. (1988) Literacy in the Information Age, in *Children in the Information* Age (eds. Bl. Sendov and I. Stanchev), Pergamon Press, Oxford, 109-122.

Van Weert, T.J. (1992) Application Oriented Informatics and Informational Disciplines: A symbiosis bridging the gap, in *Information Processing 92, Volume II* (ed. R. Aiken), Elsevier Science Publishers BV, Amsterdam, 144-150.

Weber, J. *et al.* (1994) Visualising microscopic molecular worlds in chemical education, in *Visualisation in scientific computing: Uses in university education* (eds. S. Franklin and A. Stubberud), Elsevier Science Publishers BV, Amsterdam, 9-24.

Wegner, P. (1997) Why interaction is more powerful than algorithms. *Communications of the ACM,* **40** (5), 80-91.

Wupper, H. and Meijer, H. (1998) Towards a taxonomy for computer science, in *Informatics in higher education: Views on informatics and noninformatics curricula* (eds. F. Mulder and T.J. van Weert), Chapman & Hall, London.

10 BIOGRAPHY

Tom J. van Weert is director of the undergraduate School of Informatics (Computing Science) of the Faculty of Mathematics and Informatics of the University of Nijmegen, The Netherlands. He also teaches management of large software projects to informatics students developing real software applications in multi-disciplinary teams. Previously he has worked in teacher education, teaching mathematics and informatics, and prior to that as a computer system engineer in an academic environment. His background is in applied mathematics. He has been active within several IFIP Working Groups and is currently chair of IFIP Working Group 3.2 on university education.