MODELS OF EDUCATIONAL CHANGE

The Introduction of Computers in Dutch Secondary Education

A.C.A. ten Brummelhuis

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In 1987 I started to work in the Comped study as a National Research Coordinator. During this research project I became fascinated by finding a balance between on the one hand conducting a study optimally to the Dutch situation and on the other following international guidelines assuring comparability of findings across countries. The discussion with National Research Coordinators of the other participating countries as well as with the members of the Dutch Steering Committee were very stimulating and helpful in finding solutions for these conflicts of interest.

It would have been impossible to complete this study without the contribution of many principals, computer coordinators and teachers who completed one or more questionnaires for this study. I wish to express my thanks and appreciation to all the respondents who gave their time and energy so that we might understand what is happening in schools with com1`puters and why. As with any large-scale research, many people other than the respondents and the researchers made this study possible. I already mentioned the Dutch Steering Committee and I would like to thank all members for their critical comments and their constructive support for making this study fitting as much as possible to the Dutch situation within the international design. I also want to thank the colleagues of the International Coordinating Center who were my neighbours at the institute and were always willing to clarify the international guidelines.

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Alfons ten Brummelhuis
June, 1995

It isn't that people resist change as much as they don't know how to cope with it
(Fullan, 1991)

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Purpose and Plan of the Study

Computers are being used increasingly in the worlds of work and learning, and are accepted more and more as an integral part of life. It is also generally agreed upon that computers, especially in configuration with audio and video, have great potential to help improve education. The potential for benefits include providing tools for more individualization in learning, implementing curricular reforms and increasing the instructional productivity of schools. In order to realize these benefits of computers and computer mediated tools into classroom practice, many governments and organizations have supported the introduction of computers in education over the past two decades. One of the important educational issues facing almost all nations around the world concerns the development, use and impact of new technologies. Perhaps the most important development in this context is the personal or microcomputer, a device that is altering many lives at home, as well as at work and in schools.

However, the history of previous promising developments in the field of educational technology (e.g., school radio, school television, language lab, video) provides many examples of limited theories, products of poor quality, and naive approaches to implementation (Eraut, 1994). In order to find out whether the worldwide efforts of introducing computers in education meet the promising benefits, it is necessary to record the realities of implementation. In this context, the International Association for the Evaluation of Educational Achievement (IEA) in 1985 decided to embark on an international comparative study of Computers in Education (Comped). The study was aimed at obtaining information about the status of the availability and use of computers in education and analyzing relationships among various factors concerning the use and application of computers in education (Wolf, Plomp, & Pelgrum, 1986). The results should serve as a valuable source of information for policy makers, teachers, administrators and other educational personnel engaged in planning, implementation and evaluation in the field of computers in education.

The problem in context

The implementation of computers in education begs a diversity of questions that can be summarized in terms of ‘what’, ‘how’ and ‘under which conditions’. Each of these questions will be briefly discussed in this section. At first, the content of the innovation which is in this study the introduction of computers in schools. Second, the process of educational change and third the conditions for implementation which will be discussed by means of the problems related to the introduction of computers in schools.

The introduction of computers in schools

During the 1980s many governments in industrialized countries, amongst them the Netherlands, developed policies to stimulate the introduction of computers in education. Although in the early 1960s computers first began to be used in education as a research tool on a very limited scale, it was only by the early 1980s that computers as both a teaching and learning tool attracted the attention of educators throughout the world. Basically, there are three important reasons for introducing computers in education:

- to prepare students to live in an information oriented society;
- to develop a more productive work force;
- and to improve teaching and learning (Advisory Committee for Education and Information Technology [AOI], 1982; Organization for Economic Cooperation and Development [OECD], 1989; UNESCO, 1992).

These reasons for introducing computers in education are summarized by Hawkridge (1990) in the subsequent rationales: social rationale, vocational rationale and pedagogical rationale. Each of these reasons or rationales represents a perspective of legitimacy for the introduction of computers in education. However, from each of these perspectives questions have also been raised about the appropriateness of the educational response to the advent of new technologies. The first perspective refers to computer literacy as an essential element of preparation for life in society (AOI, 1982; Ministry of Education, 1982) and raises questions like:

- What kind of knowledge and skills are relevant for citizens in order to deal with applications of information technology in daily practice?
- At what age do students have to learn about computers?
  Is there a need for a specific course in computer literacy and computer science?

The second perspective refers to economic concerns (Burke & Rumberger, 1987) and raises questions such as:

- How much education does the human workforce need to operate and succeed in a technological world?
- What kind of education and training will prepare future human workforce best for this world?
- How can the educational system respond best to the new demands of the economy?

Both perspectives refer to the computer as subject of education and have the topics that should be taught about computers as general theme. The third perspective refers to the use of computers to improve the teaching and learning environment and raises questions such as:

- What is the cognitive impact of computers on students' learning?
- How will computers change the teaching style of teachers?
- How can the computer be implemented effectively in existing subjects?

It is generally assumed that schools have a responsibility to prepare students to become users of computers. Especially in the past decade educational policy makers, curriculum and courseware developers, administrators and teachers started to implement computers in education and soon it became clear that schools had to deal with a complex and demanding challenge. No tool ever before seemed to hold out the educational promise of the computer. In the past, technologies such as radio and television were expected to transform education, but neither have reached potential power as learning tools. What is different and special about computers is that they are interactive. It is this interactive nature of computers, and of related communication technologies based on computers, that marks a cultural turning point from the passivity of viewing television or listening to radio (Giacquinta, Bauer, & Levin, 1993).

However, many of the questions related to computer introduction are still unanswered and attempts to answer them have generated widespread debate among policy makers, business leaders, educators and scholars. Although research findings are accumulating, at present there is still little information available about the factors that are crucial for a successful introduction of computers in educational settings.

The process of educational innovation

Since the 1960s there is an interest in the question of how educational change works in practice. During that first period, educators and researchers were preoccupied with the acceptance or adoption of innovations (Havelock, 1969; Rogers & Shoemaker, 1971). At the beginning of the 1970s the interest shifted towards the implementation process (Berman & McLaughlin, 1976; Hall & Loucks, 1977; Fullan & Pomfret, 1977). During this period focus was put on the nature and extent of actual change in educational practice. This perspective is wide and captures both the contents and process of dealing with ideas, programs, activities, structures and policies that are new to the people involved. Policies or innovations should not be considered to simply enter schools and then to produce the intended results. Focusing on implementation implies registering what is going on in educational practice. If an innovation does not result in the intended outcome, the information on the implementation process can help in judging whether poor ideas were implemented or teachers were unable to implement good ideas (Fullan, 1994a).

The process of educational change is a dynamic one involving interacting factors over time. When more factors work against implementation, the process will be less effective. Consequently, when more factors support implementation, more change in practice will be accomplished. The results from a large number of studies on educational change make clear that influencing factors often have a different impact in different settings of educational change (Fullan, 1991). Besides, the impact is often related to different stages of the innovation process. Determinants, which will be discussed in Chapter 2, should not be considered in isolation from each other.

Problems related to the introduction of computers in schools

Based on the results of previous research which will be reviewed in more detail in Chapter 2, it can be concluded that there are four categories of important obstacles for a successful integration of computers in education: national context, school organization, external support and innovation characteristics (Fullan, Miles, & Anderson, 1988; Akker, Keursten, & Plomp, 1992).

At the level of national context difficulties may arise if there is a lack of explicit policy on the aims and a lack of external pressure, financial support or encouragement 'from above' for computer initiatives and activities in schools.

The school organization may have problems when encouragement and support from school principals fall short. This applies especially to the provision of facilities for training, acquisition of hardware and software, rearrangements of time tables and other organizational measures. Other school organizational factors that may hinder the implementation of computers are: a negative school climate, teachers who are not mutually supportive by exchanging ideas and experiences and by providing feedback; the lack of a computer coordinator and no long-term arrangements of supply and maintenance of hardware and software.

External support such as in-service training programs often emphasize the technical aspects of computers while paying too little attention to the integration of computers into daily classroom practice.

Finally, the vagueness about the innovation characteristics such as the relevance, goals, complexity, quality and practicality of the innovation are often obstacles for the implementation process of computers in schools. Questions about these kinds of characteristics are often asked by teachers and other practitioners, who ultimately are the central actors in the implementation of computers in educational practice.

Weaknesses in one or more of the categories mentioned above may cause major obstructions in the implementation of computers on school and classroom level.

Aims and relevance of the study

There is an increasing awareness that many obstacles, as mentioned above, have to be overcome before computer use in education is actually implemented. This study attempts to present the results of the Dutch stimulation policies on the introduction of computers in secondary education from 1982 to 1992. The aim of the study is to describe the degree of computer use in Dutch secondary schools from an international comparative perspective and to identify factors that explain why certain schools are using computers in their educational practice to a greater extent than others. International comparisons provide context information that is relevant for a good understanding of the relative position of computer use in Dutch lower secondary schools. Results of this study may be of importance for policy development with respect to computer use in the Netherlands, the understanding of educational change, and the measurement of factors related to the implementation process.

Contribution to policy development

An educational system consists of a large number of actors who determine how the system is functioning. Each actor has certain responsibilities within the total educational system. Concerning the introduction of information technologies in education, the Dutch government defined her responsibilities or goals as (Ministry of Education, 1981; AOI, 1982; Ministry of Education, 1986):

- familiarising the civilian population with information technology;
- creating 'human capital' to strengthen the market sector and to ensure better and more efficient functioning of social provisions;
- improving the learning process by facilitating and introducing information technology in schools.

In order to determine whether these goals are met, and whether adjustments in the government policy are needed, feedback is necessary to tune the goals and actual situation with respect to information technology in the schools. These adjustments are essential for an educational system to perform appropriately (Banathy, 1973; Pelgrum, 1989). The function of providing this feedback is called monitoring without which systems malfunction (Romiszowski, 1981).

In the international comparative survey of ‘Computers in Education’ (Comped) of IEA data were collected about the computer use in schools in 1989 and 1992 and provided the Netherlands and other participating countries with the opportunity to evaluate the effectiveness of their stimulation policies on an empirical basis. Although the Dutch governmental stimulation policy of introducing computers in education has almost come to an end, the relevance of these analyses is that lessons can be learned for future innovations and particularly promising technologies. Because new developments in information technologies, such as multi-media and telecommunication networks, show great promise for helping teachers to make education more effective, it is important to find the factors that have been relevant for the introduction and implementation of computers in education. This information may be useful for the implementation of new technologies within the Dutch educational system and may also be relevant for other countries to get an evaluative view on the stimulation activities of the Dutch government.

Contribution to the understanding of educational change

Advocates of technological innovation often seem to focus their attention on the technology itself and the goals they believe the technology can accomplish. They do not pay much attention to the beliefs and behaviors that need to accompany a technology for it to have the desired effects. These are assumed to simply follow the introduction of technology and are treated as of secondary importance or are overlooked completely (Giacquinta et al., 1993). From an implementation perspective, the heart of an innovation does not reside in the technology itself or even in its goals. Instead, it is to be found in the attitudes and activities that people need to adopt before they can use the technology to achieve specific goals. In the case of computers in schools, Mehan (1989) stresses that people’s experience with computers is the crucial ingredient and not its ‘inherent’ features. It is what people do with the machine, not the machine itself. The central theme of this study is to identify determinants of successful introduction and actual use of computers in education. Theory and previous research can tell a great deal about the factors influencing decisions to initiate and implement major change in education (Huberman & Miles, 1984; Fullan et al., 1988, Fullan, 1991; Velzen, Miles, Ekholm, Hameyer, & Robin, 1985; Creemers & Scheerens, 1989). However, much of this body of knowledge is derived from ‘grounded theory’ (Glaser & Strauss, 1968). Grounded theory refers in this context to a logically consistent framework of inductive theories based on data generated mainly by case studies of educational change and innovation. A consequence of this approach, mainly based on qualitative data, is that no quantitative measures are available on the degree of interaction among different factors influencing the process of educational change.

This study may contribute to the development of innovation strategies that take the interrelatedness of the factors that influence actual implementation sufficiently into account.

Contribution to the measurement of innovation processes

Educational measurement is basically concerned with the construction of variables that may be useful in educational research. The theory about educational change often involves highly theoretical abstractions such as ‘teacher readiness’ and ‘innovation relevance’. These theoretical variables cannot be measured from a single observation: some kind of composition of multiple observations is needed. In case several measures of a given theoretical variable are available, structural equation modeling can be used to estimate the reliability of the variables. The statistical package LISREL (Jöreskog & Sörbom, 1989a; 1993a) provides the procedure that is applied for most theoretical variables involved in this study. The structural equation modeling approach enables the researcher to represent a complex set of interrelationships between variables by means of mathematical equations, which are commonly represented in diagrammatic form. A structural equation model (or LISREL model) provides a statistical summary of the relationships among the variables.

Although there are criticisms of the use of LISREL models (which will be discussed in the final chapter in relation to the meaning and implications of the results of this study), it is generally accepted that the use of LISREL is effective in the testing of hypotheses and in the generation of theory about mediating and causal processes (Russel, 1994). Using LISREL modeling for the measurement of innovation processes invites the researcher to advance hypotheses about causal processes, enables to assess the accuracy of these hypotheses, and to estimate the magnitude of the effects involved.

The research questions

As argued in the previous sections, educational change, and more specifically the introduction of computers in education, is a process involving a large number of influencing factors. From previous studies much information is available about the nature of these determinants on educational change in general. It is assumed that the same set of factors also influences the implementation of computer use in instructional practice (Grunberg & Summers, 1992; Akker et al., 1992). Based on the theory of educational change, this study explores a statistical model for the interrelatedness of a set of factors on the introduction of computers in Dutch lower secondary schools. More specifically, this study covers the following two research questions:

- To which degree are computers used in Dutch lower secondary schools compared to the use in other countries?
- What factors influence the implementation of computers in Dutch lower secondary schools, and how important are these in predicting computer use?

The first research question will be answered by mainly using descriptive statistics on computer use in Dutch lower secondary schools. For a good understanding of computer use in Dutch lower secondary schools comparisons will be made over time and also several aspects of computer use will be compared to the situation in other countries. In most developed countries the equipping of schools with microcomputers occurred during the 1980s. Also in the first years of the 1990s a considerable growth with regard to hardware and software availability took place in many countries. Although this growth in the infrastructure for information technology is substantial, it is unclear why the growth of actual computer use by teachers in the same period is relatively limited (Pelgrum, Janssen Reinen, & Plomp, 1993). This makes it relevant to examine the influence of other factors on the use of computers in education in combination with the availability of resources.

Based on a review of the literature on educational change a set of influencing factors is identified and an exploratory structural equation model is developed in order to find a structure of interrelatedness between these factors. The results of these exploratory analyses can be indicated as a hypothesized model. Subsequently, the hypothesized model is tested empirically in a confirmatory analysis using data obtained by means of a repeated data collection. Finally, the model is improved by removing factors that, according to other studies on educational change, influence successful implementation but could not be identified as relevant factors in this study.

Plan of the book

This book is intended for everyone whose interests are related to the implementation of computers in education, such as policy makers, creators and distributors of educational software and accompanying curriculum materials, educational researchers and scholars of educational and technological change in schools. However, not all chapters will be of equal interest for the different groups of professionals.

The next chapter presents a conceptual framework including factors that have been identified in other studies as being relevant to successful implementation of an educational innovation. The design of the data collection and characteristics of the sample are described in Chapter 3.

Chapter 4 focuses primarily on the Dutch situation in the field of the introduction and use of computers in education. This chapter contains a description of the Dutch stimulation programs for the introduction of computers in secondary schools. It also includes an overview of the major results of the Dutch stimulation policy in terms of the infrastructure for computer use and the degree of computer use at schools and in classrooms. Furthermore these results are compared to the situation in some other European (Germany and Austria) and non-European countries (Japan and the United States).

The next two chapters, Chapters 5 and 6 successively, focus on the data analyses of the study. Chapter 5 covers the process of developing the exploratory structural model. Based on a data collection from 1989 this chapter provides detailed information about the constructs and their indicators. Using data from another data collection in 1992 involving the same variables as were used in 1989, the results of a confirmatory test of the model are presented in Chapter 6 as well as a first step to further improvement of the structural model. The final chapter gives a summary of the key findings and implications for educational policy, school practice and further research. Although the book is not specifically written for principals and teachers, they might find the conclusions of the study valuable for their school practice.

2

Educational Change: The Research Question in a Theoretical Context

The central research problem of this study is to identify the factors explaining successful implementation of computers in lower secondary schools. This problem is related to the research conducted in the field of educational change. During the last decades educational change has been a continuing field of interest for researchers, policy makers, educators and others who are, by virtue of their profession, involved in the area of education. In this chapter several theories on educational change will be discussed briefly and factors that have proved to be relevant in previous research in this area will be reviewed. These findings form the basis for the conceptual model for the implementation of computers in education which is developed subsequently in this chapter. The factors included in the model can be relevant to answering both research questions. First, they are used for the selection of aspects on which the introduction and implementation of computers in Dutch lower secondary school is described in Chapter 4. Second, the set of factors is the starting point for answering the research question on the interrelatedness of influencing factors on computer use in the Chapters 5 and 6.

Theories on educational change

In general, educational change can be initiated from two distinct sides. One form refers to educational change initiated by policy makers, with researchers at their side, attempting to find ways of assisting schools to implement a particular innovation. This strategy is labelled as 'top-down', 'from above' or 'imposed change'. The other form of educational change is initiated by teachers and often undertaken with outside support. This form is indicated by 'bottom-up', 'grass-roots' or 'voluntary change' (Wideen, 1994; Fullan 1994b). Regardless of the direction of change, all real changes involve loss, anxiety and struggle (Fullan, 1991).

Wideen (1994) examined the areas of educational change and distinguished the following five domains: curriculum development, school improvement, school effectiveness, teacher research and teacher development. Each area or perspective has its own approach to change. The curriculum development domain proposes to improve education by the implementation of better curriculum materials. The school improvement approach focuses on the school as the unit for change and primarily gives attention to the problems and internal conditions in one or more schools. The school effectiveness approach has an outcome focus in terms of student achievement and those characteristics which are correlated to achievement. According to Wideen (1994), in the teacher research approach the teacher is involved as a researcher in the change process. This is a kind of teacher emancipation to solve classroom problems. Finally, teacher development is a recent line of research that grew out of the previous mentioned developments. Teacher development focuses upon the teacher as a learner and an active person. This approach places the teacher more centrally within school reform and educational change rather than simply seeing the teacher as a means to implement innovations.

Although these areas did not develop independently from each other and do not have clearly defined boundaries, from a specific point of view, each area provides a rich source of knowledge about education in general and educational change in particular. In a very general sense, curriculum reform, school improvement and school effectiveness represent a paradigm within which the stimulus for change comes from those who either direct or support change. The fields of teacher research and teacher development represent a paradigm in which the teacher initiates or is central in educational change. This study incorporates these concepts from the different areas that are identified as affecting the ongoings of the implementation process of school innovations.

According to Fullan (1982, 1991), the essence of educational change is putting something new into practice. In most situations educational change occurs along several dimensions. These dimensions are for example: new materials (curriculum materials or technologies), new teaching approaches (teaching strategies or learning activities) and alteration of beliefs (pedagogical assumptions or perceived relevance). Educational change restricted to one of these dimensions, for instance the use of a new textbook or materials without any alteration of teaching strategies, refers to a minor change. If an innovation covers all three dimensions of potential change, it refers to a more complex innovation.

It is important to notice that it is difficult to define an innovation objectively as more or less complex. The degree of complexity is not primarily a characteristic of the innovation itself but also depends on the current teachers’ materials, strategies and beliefs. Therefore, complexity of an innovation is a characteristic of the individual teacher and refers to the discrepancy between the state of existing practice and beliefs of the individual teacher, and the future state when a change has taken place. From this perspective the complexity of an innovation is associated with the subjective meaning of educational change.

Somewhat parallel to the definition of the complexity of an innovation is the dilemma of two different ways in which an innovation can be implemented. The first way is called the ‘fidelity approach’ and is based on the assumption that an already developed innovation exists and the task for the teacher is to implement it in practice in a way the developer intended. The second way of implementing a change is called the ‘mutual adaptation approach’ which stresses that change is often a result of adaptations and decisions made by teachers as they work with new materials. The teacher’s situation and the new materials are mutually determining the outcome.

The theory on educational change is described by Fullan (1991) as a ‘*theory of probing and understanding the meaning of multiple dilemma’s*’. He characterizes the current knowledge base as a situation in which ‘*no one knows for sure what is the best*’ (p.110). The problem is the number and dynamics of factors that interact and affect the process of educational change. The following section contains an overview of the phases in the process of educational change and the key factors affecting this process.

Concepts of educational change

Educational change represents a developmental process of change consisting of the following three phases: initiation (adoption), implementation and institutionalization (continuation, incorporation) (Gross, Giacquinta, & Bernstein, 1971; Fullan, 1982). Each of these stages does not represent an autonomous process in the sense that a phase has to be completed before a next phase can start. The relationships between subsequent phases are loosely coupled and interactive (Fullan, 1991).

The factors underlying decisions to initiate a major change in education and the factors that influence the successful implementation of an educational innovation have been at the heart of much research. Huberman and Miles (1984), Fullan et al., (1988) and Fullan (1982, 1991) discuss a large number of indicators which, according to theory and previous research, influence both the decision to initiate educational change and the actual use of the innovation. Fullan (1991) identifies three clusters of indicators that seem to be associated with the decision to initiate or to adopt an innovation in education: relevance, readiness, and resources.

Relevance refers to perceptions of educational practitioners concerning the usefulness of an innovation, for example the introduction of computers in schools. Research on the impact of relevance on the implementation process makes clear that substantial change is more likely to be adopted and successfully implemented than simple change. The explanation for this phenomenon is that the size of the change has to be large enough for one to perceive it worth the effort, but not so massive that according to the teachers' perception, they will not be able to cope with the innovation (Crandall, Eiseman, & Louis, 1986).

Readiness involves the school's capacity to initiate and develop the innovation and being prepared to use new equipment, activities, behaviors or practices. Readiness also involves the availability of the prerequisite knowledge and skills at the individual teacher level, needed for a successful implementation of the educational change.

Resource availability involves financial means, time, equipment and appropriate materials related to the intended change. In the case of the introduction of computers the hardware and software belong to the resources that have to be available at schools in order for teachers to be able to use this new technology.

Louis & Miles (1990) and Fullan (1991) also list a set of indicators considered to be particularly important for successful implementation of innovations: the clarity of school policy with respect to the goals, means and ends of the innovation; the organization of staff development activities; the setting up of procedures for monitoring and evaluation; the supply of (technical) support to teachers in need of practical help; and the support (from above) of the principal, government and other agencies.

One of the central concepts derived from previous research is that these influencing factors do not affect the process of implementation in isolation from each other but form a system of variables that interact to determine the success or failure of the educational change. It is concluded that the more factors support implementation, the more change is accomplished in practice. The success or failure of educational change is not determined by the availability or absence of an individual factor but is primarily the result of '*a dynamic process involving interacting variables over time'* (Fullan, 1991, p. 67).

The introduction of computers as a case of educational change

The introduction of computer use in schools can be seen as a specific case of the wider field of educational change. Research that was aimed at identifying the barriers to the introduction of computers in schools showed that these factors were specific examples of the barriers to educational change in general (Cox & Rhodes, 1989).

After comparing results of research on educational change in general and the results of research on computer use, Grunberg & Summers (1992, p. 272) conclude: '*Factors affecting computer innovation are often the same or similar to those affecting other innovations. Much can be learnt from other attempts to* *implement change even though the subject and context may have been rather different*'.

Also Akker et al. (1992, p. 65) conclude that *'disappointing experiences with the introduction of computers in education are a consequence of insufficiently taking into account factors that are crucial when introducing change in educational settings'*.

A limitation of these review studies is that they provide overviews of factors affecting implementation without much insight in the interaction between the listed factors. Based on the influencing factors listed in the studies mentioned above, this study explores the interrelatedness of these factors.

Conceptual model

Relationships can be hypothesized among the indicators mentioned above. Figure 2.1 shows a conceptual model in which several of these implementation indicators (adapted from Fullan, 1991) are ordered on the basis of a sequence involving four frame factors (Dahllöf, 1971; Torper, 1994): exogenous preconditions, endogenous adoption conditions, endogenous implementation conditions, and implementation outcomes.

Exogenous preconditions refer to indicators external to the school, for example the amount of logistical, financial and training support offered by central and local authorities, businesses, and/or resource centers. Certain school indicators, for example school size and the previous experience of the school with respect to educational innovation, which cannot easily be manipulated, are also considered as exogenous variables. Three indicators are grouped under the heading *endogenous adoption conditions*: the availability of resources, the school's readiness to initiate and develop the innovation and perceptions of the school leaders concerning the relevance of the innovation. A third group of indicators is subsumed under the label *endogenous implementation conditions*. These are interpreted mainly in terms of the formulation of an explicit policy committing the school to introduce computers, the presence of staff development activities, the provision of technical and organizational assistance to teachers who use computers for instructional purposes, and the active use of a strategy for monitoring the implementation of the innovation. The fourth category refers to *implementation outcomes*. The focus in this study is on one outcome in particular, namely the use of computers for educational purposes in school subjects in lower secondary schools.

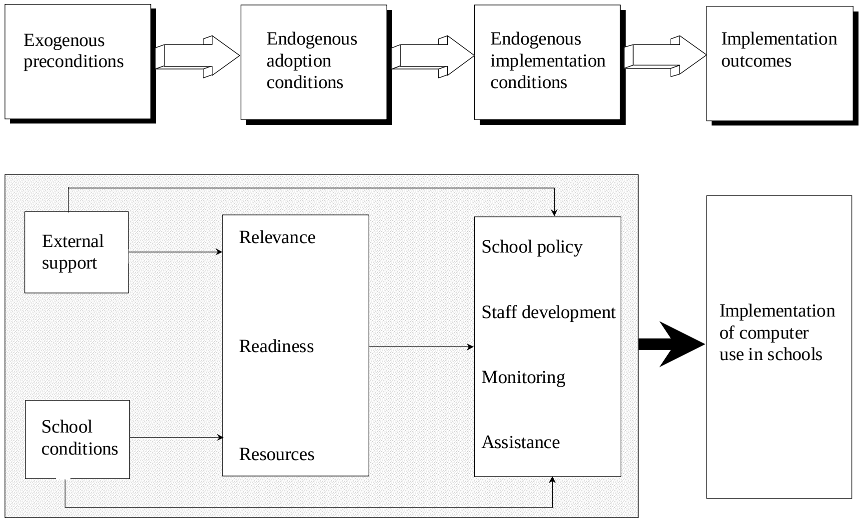


Figure 2.1 Indicators influencing the process of educational change at school level

It should be noted that the design of the model shown in Figure 2.1 is to a certain extent also influenced by the design of the IEA study on computers in education. The design of this study is described in more detail in the following chapter. As a matter of feasibility, it was not possible to include all potential factors that have shown influence on the implementation process in previous research in the instruments of the IEA study on computers. Nevertheless, this study is relevant because the aim is to subject the conceptual model to a rigorous test. These analyses have to be seen as a starting point in an iterative process of model building on factors influencing educational change. In future analyses variables may be removed that have shown to be less relevant and other variables may be added. The development of the model and the examination of the effects of additional indicators present challenges for future research. Within the range of the included factors, this study is primarily focusing on the interrelatedness of the factors included in Figure 2.1.

Hypothesis and development of a path model

As concluded above, the influencing factors on educational change operate as a system of variables and the importance of a factor can vary in different phases of the overall process. Therefore, for each of the factors in the shaded part of Figure 2.1 indirect influences (relations between influencing factors) as well as direct influences are hypothesized on the outcome: implementation of computer use in schools. This hypothesized conceptual model is taken as a starting point for building a recursive path model. The results of the data analyses are presented in the Chapters 5 and 6 but preceding to these chapters the design of the data collection is discussed in Chapter 3 and an overview of the Dutch policy with regard to the introduction of computers as well as the results of this policy are presented in Chapter 4.

Summary

Theories on educational change provide a set of factors affecting the initiation and implementation of innovations. The success or failure of educational change is not determined by the availability or absence of an individual factor but is the result of a dynamic process involving interacting factors. This study focuses on the introduction of computer use in schools as a specific case of educational change. The aim of the study is to explore, test and respecificy a model for the implementation of computers while taking the interrelatedness of influencing factors into account. The hypothesized relationships among influencing factors on computer use are represented in a conceptual model.

3

Design of the Data Collection

In 1985, the Comped study was initiated by the International Association for the Evaluation of Educational Achievement (IEA). The Comped study was designed as a longitudinal study with data collections in 1989 and 1992 (Wolf et al., 1986). In 1987, the Dutch government decided to participate in this study and the Institute for Educational Research in the Netherlands (SVO) funded the Dutch research activities for the period 1987-1993.

One of the reasons for the Dutch government to participate in this study was the opportunity to get an overview of the actual place and role of computers in the schools. Moreover, the Comped study would make it possible to compare the Dutch situation to the developments in other countries and to study this major educational innovation systematically almost from its earliest state of development onwards. As described in Chapter 1, during the 1980s policy makers were facing many questions about the role of computers in education. In general they had little information that could guide them in answering questions such as: Is there a need for a separate course in computer literacy and computer science? How can computers be used effectively in existing subjects? What is the effect of computer use on student learning, on teachers' behavior, on the school and classroom organization? In order to provide policy makers and other professionals interested in the introduction of computers in schools with up-to-date information, the preliminary results of the Dutch part of the Comped study were published as primarily descriptive results immediately after each of the two data collections (Brummelhuis, Plomp, & Pelgrum, 1990; Brummelhuis & Plomp, 1993a). Several references to these sources in policy documents illustrate the relevance and impact of these mainly descriptive Comped data for the decision making process in the field of information technology and education (Ministry of Education, 1991, 1992a, 1993b) Although descriptive data, as presented in the following chapter, can provide an overview of many characteristics of the introduction of computers, they do not provide insight in the interrelatedness of these characteristics. As central theme the research in this study reports about the interrelatedness of a set of factors influencing the introduction of computers in education. This chapter describes the background, conceptual framework, design and instrumentation of the data that have been used for these analyses.

Conceptual framework of the Comped-study

The Comped study consisted of two stages. The first stage (1987-1990) was meant to acquire a clear picture of the status of computer use by collecting data on school and teacher level in 1989. The second stage of the study (1990-1993) was intended to replicate the first stage in order to study developments over time. Besides school and teacher level data, the student level was included in the second stage of the study with data collection in 1992.

In order to determine which information was to be collected in the Comped study, a framework was developed, identifying key factors which the study should take into account. The framework as shown in Figure 3.1 is the result of discussions between the participants of 23 countries that were involved in the Comped study. The framework is described by Pelgrum and Plomp (1988) and represents an educational system as a complex of subsystems at different levels: at the macro level the educational system of a country or state, at the meso level the school, and at the micro level the classroom and the student. On each level, educational decisions are influenced by different actors; for example at the school level: the school board, the principal, the subject department, and the teacher. External influences may be exerted by, for example, business and industry, or parents. The output of a subsystem at a certain level can be conceived as the input for the subsystem on the next level.

From a curriculum perspective the framework represents a distinction between the intended, implemented and attained curriculum (Garden, 1987; Travers & Westbury, 1989). The intended curriculum refers to the curriculum plans (at the macro level), which may be laid down in official documents or which may exist as shared conceptions of what the important curriculum content is. The implemented curriculum (at the meso level) consists of the contents, time allocations, instructional strategies, etc. which the teacher is actually realizing in his/her lessons. The attained curriculum (at the micro level) is defined as the cognitive skills and attitudes of students as a result of teaching and learning.

Furthermore, the framework identifies actors who operate at the different levels in an educational system and influencing factors that are relevant for each of the actors. This book focuses on data at meso level and especially covers the influencing factors in the process between intended (macro level) and implemented (meso level) output.

Design of the study

The nature of the Comped study was that of a survey. In this section characteristics of the Comped survey approach are described as well as other aspects of the data collection: the target population, the sampling design, the instruments and the achieved dataset.

Survey approaches

Although there are many different types of survey, they have the common characteristic of obtaining measurements from a sample of individuals (which might be people, but for example also schools or classrooms) selected from a predefined finite population in their natural setting (Walker & Burnhill, 1992). In a survey approach results are generalized from a sample to a population. The Comped study is a cross-sectional type of survey as well as a longitudinal survey. In a longitudinal survey measurements are made at intervals over a period of time. Longitudinal research is concerned with the process of constancy and change and therefore requires that observations are made for at least two points in time. In the case of the Comped study data were collected in 1989 and 1992. In the Netherlands, the second data collection (1992) was not restricted to the individuals selected in 1989. An updated sample representative for the population of 1992 was added. Therefore, each of the data collections separately can be characterized as a cross-sectional type of survey research. In a cross-sectional survey the measurements are obtained at a particular point in time and for the most part the purpose is to describe situations in terms of frequencies (Walker & Burnhill, 1992). In the case of the Comped study the survey was also designed to test hypotheses arising from studies of smaller, selected groups and to seek explanations for relationships that are found between variables. For this purpose, the Dutch survey of the Comped study additionally included a specific stratum of schools (all 100 lower secondary schools that participated in the first stimulation project on information technology). This was done in order to be able to answer the question whether there would be differences in computer implementation and problems with computer use at these 100 schools (which can be seen as the early adopters) as compared to other schools which could profit only in the later promotional programs (Brummelhuis & Plomp, 1993b). Furthermore, specific questions related to the Dutch stimulation activities have been added to the international set of variables.

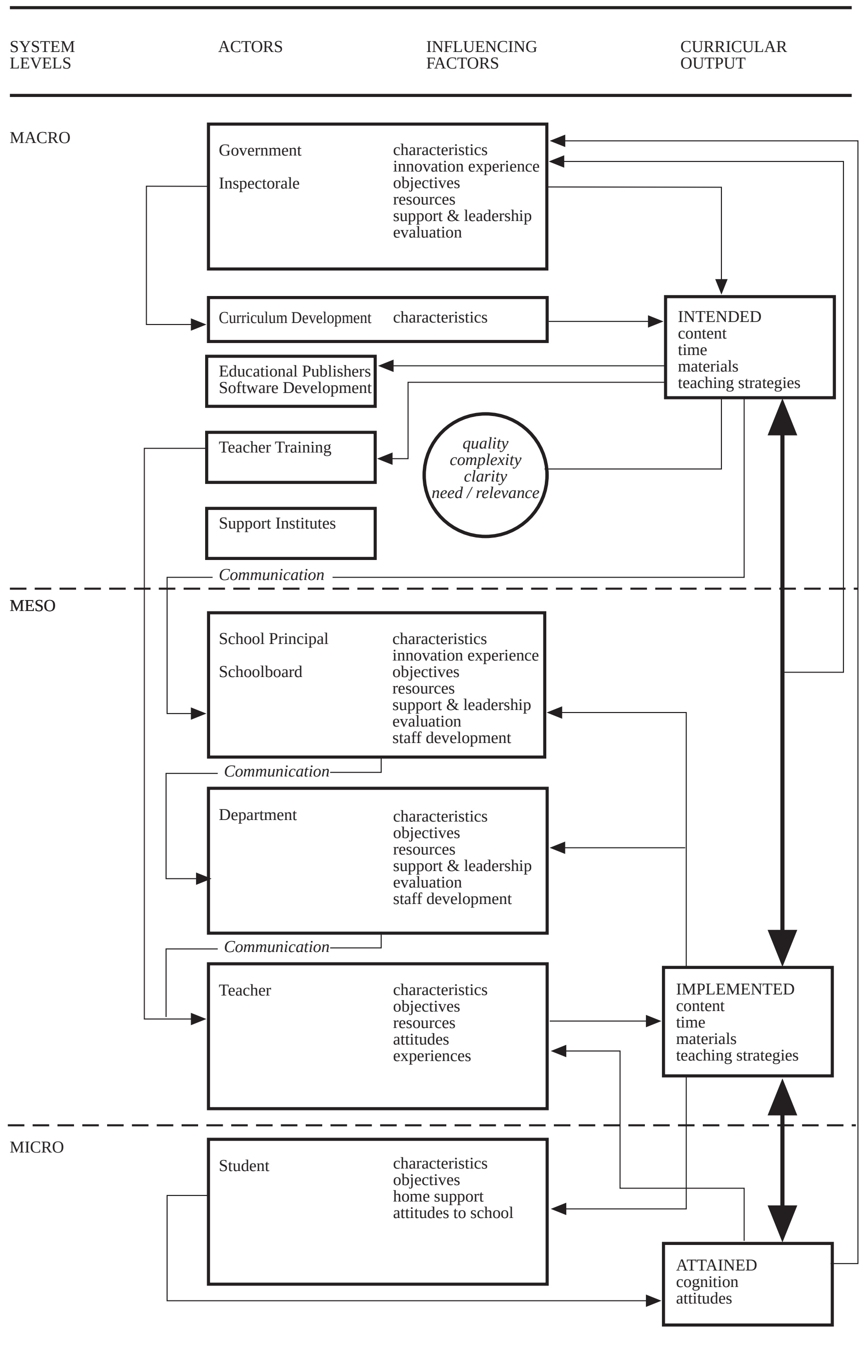


Figure 3.1 Global conceptual framework of the Comped study (Pelgrum & Plomp, 1988)

Target population

The populations of interest for the Comped study were located in primary, lower secondary and upper secondary education. Although the data collection in stage I of the study (1989) was confined to the level of schools and teachers, the longitudinal character of the study required that the populations were defined in terms of student characteristics. The definitions were such that they matched the definitions which were used in earlier IEA studies as closely as possible. In stage I, data were collected at schools for primary, lower secondary and upper secondary education in the Netherlands. In stage II schools for primary and lower secondary education were again involved. The results presented in this book are restricted to lower secondary schools. The target population of lower secondary schools was defined as consisting of all schools enrolling students in the grade in which the modal age is 13 years (grade 8).

Sampling design

The Dutch sampling design closely followed the guidelines recommended by IEA in both stage I and stage II. According to the IEA procedures, the Dutch sampling plan was approved by the Comped sampling expert.

The sampling frame used in the Netherlands was a complete listing of all (lower) secondary schools including the number of students. Separate schools for agriculture and international schools were excluded from the frame before selection. This group is less than 5 percent of the total number of lower secondary schools and contains less than 5 percent of all students.

The population of lower secondary schools was stratified according to school type (four strata representing the Dutch school types for lower secondary education: avo/lbo, avo/vwo, lbo, ibo) and school size (small = < 400 pupils; medium = 400-800 pupils; large = > 800 pupils). The total sample size in 1989 comprised 536 schools and the number of selected schools within each category (school type x school size) was calculated proportional to the school size of the categories. Within each stratum schools were selected with equal probability. In order to be able to do small subgroup analyses, oversampling has been applied if, within strata, the precision would become lower than +/- 10 percent with a 95 percent confidence interval.

Table 3.1 shows the sizes of the samples of the lower secondary schools that were drawn in 1989 and 1992. The substantial decrease of the number of schools during the period 1989-1992 is due to the large number of schools that have merged.

Table 3.1

Sample sizes of the Dutch Comped survey in lower secondary schools in 1989 and 1992

Year	Sampled	Population
1989	536	2337
1992	885	2084

Within the sampled schools the data collection at teacher level was aimed at the grade levels corresponding with the modal age of 13 years defined (grade 8) plus and minus 1 year. Thus, the grade range 7-9 was taken into account when sampling teachers. In order to reach a representative sample of teachers, a list of all teachers of interest (i.e., computer education teachers, mathematics teachers, science teachers and mother tongue teachers who teach classes in the grade range 7-9) was collected from each sampled school.

Instruments

The framework as shown in Figure 3.1 has been used as the basis for the instrument development of the Comped study. Figure 3.2 contains an overview of all core instruments developed in the Comped study. As mentioned before, the scope of this book is restricted to school level data. Therefore, the presented results are based mainly on the questionnaires completed by the principal and the computer coordinator. As far as teacher level data are included (used for two variables: ‘internal innovation assistance’ and ‘teacher competence and readiness’), these are presented at school level by aggregating the available teacher data to school level. It should be noted that the teacher questionnaire for each of the studied subjects is the same except for the specification of the subject area

The achieved data set

The sampled schools were invited to participate in the study and to provide lists of names of the target groups of teachers. This so-called screening survey provides a sample frame at teacher level and information on key variables for all sampled schools. The response rate on the screening survey in 1989 was 94 percent. From the 433 identified computer using schools 72 percent was willing to participate in the survey. In each of these schools a questionnaire was sent to the following persons: principal, computer coordinator, computer education teacher, mathematics teacher, science teacher and mother tongue teacher.

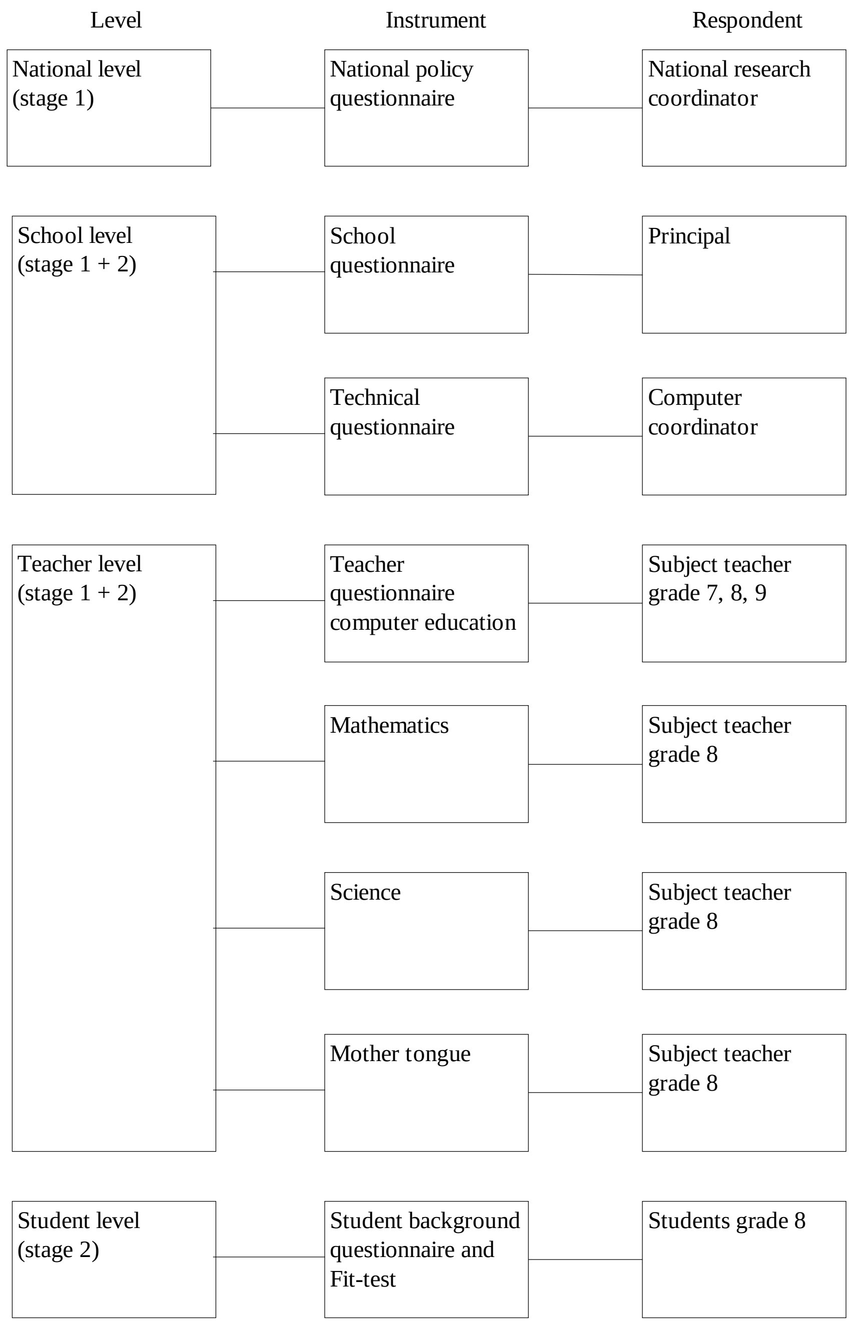


Figure 3.2 Overview of instruments and their respondents

In 1992 the same schools as in 1989 were approached and an additional sample was drawn to correct for mutations that occurred in the period 1989-1992 in the pools of schools due to mergers, and increasing or decreasing numbers of pupils. For stage II 885 lower secondary schools were in total invited to participate. The response rate on the screening survey in stage II was 94 percent. From the identified computer using schools 52 percent (432 schools) was willing to participate. In these schools questionnaires were sent to the principal, the computer coordinator, teachers (computer education, mathematics, science and mother tongue) and grade 8 students. An overview of the sampled schools, response rate in the screening survey, participation rate to the study and response rates on the questionnaires, is presented in Table 3.2. It should be noted that the percentages included in Table 3.2 refer to the ratio between the numbers connected by an arrow.

Table 3.2

Response rates

Year	Screening survey			Schools willing to participate		Response on questionnaires	
1989	sampled: 536 → response: 505 (94%)						
	computer using schools	433	→	310 (72%)	→	principal	275 (89%)
	non-using schools	59				computer coordinator	266 (86%)
	not identified schools	13				teacher	253 (82%)
1992	sampled: 885 → response: 835 (94%)						
	computer using schools	833	→	432 (52%)	→	principal	344 (89%)
	non-using schools	0				computer coordinator	371 (86%)
	not identified schools	2				teacher	351 (82%)

Because the applied sampling design was a mixture of probability sampling (total number of selected schools within a stratum was proportional to the stratum size) and equal probability sampling (within strata the selection probability was equal), survey weights were calculated to ensure that the sampled data could be used to make accurate inferences about all the Dutch lower secondary schools. A large number of analyses with weighted and unweighted data showed comparable results. Based on these results, it was decided to use unweighted data in the analyses that will be presented in the following chapters.

The data on key variables from the screening survey were used for a chi-square test on schooltype, schoolsize and state to check for non-response bias or non-participation bias. The results of these analyses showed no difference between the participating and non-participating schools in both 1989 and 1992. The most important reasons for schools not to participate in this study were lack of time (1989: 9%; 1992: 24%) and tiredness of research participation (1989: 13%; 1992:

14%). It can be concluded that no indications were found for systematic non-response bias and the results can be seen as representative for the target population of lower secondary schools in the Netherlands.

Although the Comped study provides a framework including a large number of variables related to the introduction of computers in education, this study is limited to a selection of variables. As the selection base of variables the set of indicators presented in the conceptual framework of Chapter 2 is used. The data used for developing the indicators employed in the analyses came from the questionnaires to which the school principal, the computer coordinator and different groups of teachers responded. The teacher level data are aggregated to school level. This means that at school level a summary statistic is calculated across teachers from the same school. An overview of the variables used for calculating the indicators as well as the procedure applied for the aggregation of teacher level data to school level, is covered in detail in Chapter 5, in the section called 'The measurement model: constructs and their variables'.

Summary

This chapter contains a description of the background and conceptual framework of the Comped-study, an international comparative study on the use of computers in education. Data collected for the Comped-study in 1989 and 1992 have been used to answer the research questions about the degree of computer use and the factors explaining the use of computers in Dutch lower secondary schools. Furthermore, information is provided about the design, instrumentation and sample sizes.

4

Introduction of Computers in the Netherlands: Policy and Results in an International Comparative Perspective

This chapter covers two aspects of the introduction of computers in education in the Netherlands. The first part of the chapter gives an overview of the Dutch policy aimed at the introduction of computers in secondary education. This overview is mainly based on the following three documents: a report to the European Community (Krins, Plomp & Scholtes, 1992), a supplement to this report (Brummelhuis & Plomp, 1994b) and a chapter written by Plomp, Scholtes and Brummelhuis for a volume (in preparation) about policies in different countries around the world on computers in education.

The second part of the chapter describes intermediate results of this policy in terms of the availability of hardware and software, support structures, and frequency of computer use in lower secondary schools. Several reports about the introduction of computers show that the state of the art of computer use within a country (Anderson, 1993; Becker, 1986; Brummelhuis, 1993; Haider, 1994; Watson, 1993) or between countries (Pelgrum & Plomp, 1991; Pelgrum et al., 1993) can be described by means of a great number of different aspects. The selection of topics covered in this chapter is mainly directed by the Dutch policy aims. This means that those aspects are described that were directly influenced by the policy of the Dutch government (such as hardware and software provision) or were expected to change as a result of the policy (such as attitudes of educators and their knowledge about computers). Furthermore, the selection is based on the results of the review of literature on educational change that was discussed in Chapter 2.

In order to be able to evaluate the results in the Dutch situation, a comparison on relevant aspects is made with other European (Germany and Austria) and non-European countries (Japan and the United States). These comparisons are mainly based on the international data set of the IEA study Computers in Education (Comped). The international design of this study is described in detail by Pelgrum & Plomp (1991). An overview of this design is presented in the previous chapter as far as applicable for the Dutch contribution to the Comped study and relevant for the results presented in this book.

Policy developments 1980 - 1992

Beginning in 1982, the Dutch government decided upon a series of stimulation policies to promote the introduction of computers in education (Ministry of Education, 1981; 1982). The stimulation took place via a set of programs that can most easily be described in terms of three separate time periods. In each of the periods the programs were different in emphasis. The first period (1982-1983) had an exploratory character. The program for the second period (1984-1988) can be characterized as basic provision and introduction of computers in secondary schools. The program during the third period (1989-1992) was aimed at the implementation of computer use in educational practice.

Each of the programs and policies concerning the introduction of computers in secondary education will be briefly reviewed below. As can be seen from Table 4.1, several of the stimulation activities that involved lower secondary schools, like the Information Technology Stimulation Plan (INSP) and the PRoject Implementation New Technology (PRINT), were not completely restricted to the schools for secondary education but were embedded in a general policy including several educational sectors. Table 4.1 summarizes the goals, budget and scope (from Krins et al., 1992) for the projects concerning lower secondary education.

Exploration: 1982 - 1983

The first steps in promoting the use of information technology in lower secondary schools were taken with the so-called ‘100-schools-project’. The aims of this project were wide and can best be characterized with the phrase ‘Let a thousand flowers bloom’. At that time, the possible use of information technology for education was too vague to be able to formulate clear objectives. The 100-schools-project focused on creating computer awareness and improving computer and information literacy. It included the provision of computer hardware, in-service training, and assistance with courseware development for a very small group of lower secondary schools.

Provision and introduction: 1984 - 1988

INSP

The INSP (Information Technology Stimulation Plan)-project embodied a national policy to promote the use of information technology in education (Ministry of Education, 1985a). Policies and their accompanying budgets were organized either according to educational sector or according to function (for example, to facilitate in-service training or software development).

Table 4.1

Stimulation programs concerning new technologies for secondary schools in the Netherlands (from Krins et al., 1992)

Program	Exploration 1982-1983	Provision and introduction 1984-1988					Implementation 1989-1992	
project	100-schools	INSP	NIVO	NABONT	POCO	New Media	PRINT	OPSTAP
budget in mln	6	270	100	95	26	14	100	50
SECTOR								
primary education		x			x	x	x	x
general secondary education	x	x	x		x	x	x	x
junior and senior sec. voc. ed.		x		x	x	x	x	x
higher vocational education		x		x				
university education								
adult education		x					x	x
infrastructure[1]		x				x	x	x
(in service) training		x		x		x	x	x
AIMS								
training for citizenship[2]	x	x	x				x	x
human capital[3]		x		x			x	x
CAI		x	x		x		x	x
computerization of administration								
EXPENDITURE								
hardware acquisition	x	x	x					x
courseware development	x	x	x		x		x	
courseware acquisition			x					x
applications software acquisition		x						
in-service training	x	x	x	x			x	
curriculum development		x	x				x	
support for implementation							x	
information			x				x	

Note: [1] measure to stimulate production of educational software, [2] preparation for the information society, [3] preparation for satisfactory performance at work

INSP had two main objectives:

a. to promote information and computer literacy as an essential element of preparation for life in society;
b. to improve the quality of vocational education by preparation of 'human capital' (Ministry of Education, 1985a).

During the project the use of information technology to enhance the learning process itself became more and more important and a significant proportion of the development activities focused on this aspect.

The INSP led to a number of parallel projects in educational practice. The four major projects (Nivo, Nabont, Poco and New Media) will be described below.

NIVO

The NIVO (New Information Technology for Secondary Education)-project (1985-1989) was a collaborative effort of government, business and the educational umbrella organizations to provide hardware, courseware and in-service training on a large scale (Ministry of Education, 1985b; NIVO, 1987). The project was financed by the government and the companies who initiated the project: IBM-Netherlands, Philips and Tulip Computers. The NIVO-project was divided into several subprojects. In the hardware subproject all lower secondary schools received a configuration consisting of one file server and eight pupil workstations (16-bit; MS-DOS 3.1 or higher) linked in a network, plus two stand-alone computers intended for specific use in the subject areas. This approach established a hardware standard for secondary schools in the Netherlands.

In the in-service training subproject a minimum of three teachers of each secondary school (of whom at least one had to be a woman) received 80 hours of initial training in educational computer use. To cover all schools and to build a broad training base within a short period of time, a cascade model was applied. Sixty lecturers from teacher training colleges were trained by specialists from computer manufacturers and software houses; these lecturers then trained three teachers per school, and the trainees themselves were asked to disseminate their knowledge to colleagues in their schools. In addition to the introductory course, teachers were offered in-service training in information and computer literacy and in the use of information technology as a tool in subject areas.

The courseware subproject (in combination with curriculum development) was directed at developing teaching materials for information and computer literacy as well as for use of the computer to teach other subjects. Each school received a 'starter package' of software including a word processor, spreadsheet, data base program and an author language.

Schools also received a software coupon of Dfl 2000 (US$ 1300) to spend on other software to be used in the school. Furthermore, exemplary lesson materials related to programs of the starter package were provided.

NABONT

During the period 1986-1992, the NABONT-project (in-service training for vocational education in the New Technology) organized large-scale in-service training activities. In the Dutch educational system, junior secondary vocational education is part of the general secondary schools. The idea behind the project was that it is important for teachers in vocational education to have enough knowledge about the business and industrial applications relevant to the vocational-oriented subjects they teach. For that reason, in-service training was offered by corporate training institutions and by hardware and software suppliers. The aim of the training was to stimulate the use of new technologies in vocational education by up-dating the knowledge and skills of the teachers (Nabont, 1988).

POCO

The POCO (Software Development for Computers in Education)-project was intended to supply the education market with a critical mass of usable computer programs (Ministry of Education, 1987). This project was initiated as a response to the failures in earlier projects to produce sufficient, meaningful and easy to use software. In the POCO-project, software development was based on information from a curriculum analysis and on wishes of the educational world. As a result, a standard user interface was developed, and the courseware development took place according to a fixed pattern. The products developed were then offered to educational publishers in order to make them available to the schools through the usual channels and at an acceptable price (schools could use their software coupons for buying software). Any profits POCO made were to be used for starting new projects.

A disadvantage of this approach was the separation of the responsibility for courseware development (handled by a specially established management team) from the responsibility for converting the courseware into salable products, which, according to the Dutch rules, had to remain in the hands of the publishers. This resulted in the situation that POCO developed courseware products while the publishers were not interested in distributing these products on the market (Ministry of Education, 1990; 1992a; 1993a).

New Media

During the 1980s it became clear that computer controlled systems incorporating audio and video would become available. These systems are called new media or multi media. The New Media project was responsible for the orientation on potential applications of new media in education such as: two-way communications, cd-rom, cd-interactive, telecommunication networks. To this end, the project monitored developments in the Netherlands and abroad, initiated or supported projects and promoted research. One of the major projects was a pilot study at a lower secondary school that was provided with new media materials for testing and generating experiences about the possibilities and limitations of new media in an 'ordinary' school setting. In the final report of the New Media project it was concluded that expectations of multi media have been too high and the potentials of multi media could not easily be implemented in the current educational practice (Ministry of Education, 1992b).

Implementation: 1989 - 1992

OPSTAP

A new period began when the government decided to provide a further impulse for information technology within education by making funds available for another period of four years. The Dutch word chosen to describe this policy was OPSTAP, which means 'going away' or 'moving on'. The government wanted to express its intention that, after the first period of 'stimulation and orientation', this new four-year-period of support was aimed at implementation. The OPSTAP-policy was aimed at finalizing the process of initiation and implementation of information technology in education. At the end schools in principle should have implemented and independently maintain the use of information technology in their educational practices. The aims of OPSTAP looked very much like the aims of the earlier described INSP-project (Ministry of Education, 1988). The OPSTAP policy document indicated that the stimulation and implementation of information technology in schools in the different educational sectors should be organized in a single development project: PRoject Implementation New Technology (PRINT).

PRINT

The PRINT-project was meant to offer support to schools with their own process of implementing information technology in educational practices. This was done through organizing courseware development (in conjunction with the POCO project), organizing professional development activities, and providing a 'help' function (advice and information about use of information technology and actual and new products) (Ministry of Education, 1989a, 1989b). These activities were organized sector by sector. In the sector of (general) secondary education the lines set out in the INSP and NIVO-project were continued. A new activity was curriculum development for 'Information and computer literacy', a 20 hours course in the new Basic Education (lower secondary) curriculum. Other projects concerned (a) the use of computers in subject areas such as mother tongue, mathematics and general technique, (b) curriculum development in the area of computer science in the middle years of secondary education and (c) the integration of information technology in examination syllabi of upper general secondary education subjects like physics, social studies, mathematics and business economics. In this period a norm-based reimbursement was introduced for hardware maintenance and replacement, software acquisition and costs of consumables. The guidelines implied that the government provided approximately Dfl 12,000 (US$ 8000) per schoolyear for information technology to a school with 1000 pupils.

Results from an international comparative perspective

This section presents results of the respective policies identified above. These results will be described by means of the following aspects: initiators for the introduction of computers, financial support to acquire an infrastructure for computer use in the school, availability of hardware and software, support structures for computer use, resource needs, relevance of and policy for computer use at school level and finally the actual use of computers by teachers. As already mentioned before, the selection of these aspects is based on the Dutch policy aims as well as on the review of literature on educational change that was discussed in Chapter 2. It has to be noted that the international comparisons are mainly based on the international dataset of the Comped study.

Initiators and first year of computer use

According to the principals of the secondary schools under study, the initiative for the introduction of computers is mainly taken by teachers and supported by the NIVO-policy. As indicated in Figure 4.1, in 90 percent of the secondary schools teachers were more or less responsible for the school first getting involved in using computers for teaching activities. In 8 percent of the schools the NIVO-project is mentioned as the only source for getting involved in using computers. In many schools (57%) the introduction of computers was initiated through a combination of teachers' interest and the stimulation activities in the context of the NIVO-project.

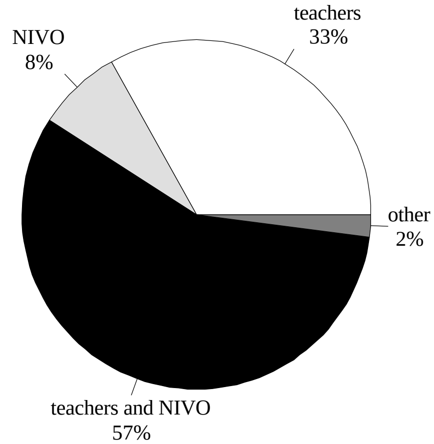


Figure 4.1 The major initiators for Dutch schools first getting involved in using computers

On average computers were introduced in secondary schools in 1984. The cumulative growth of schools with computer use is depicted in Figure 4.2. This figure clearly shows that a substantial increase of computer availability took place in the early 1980s. During the NIVO-project (1985-1989) all secondary schools were provided with computers.

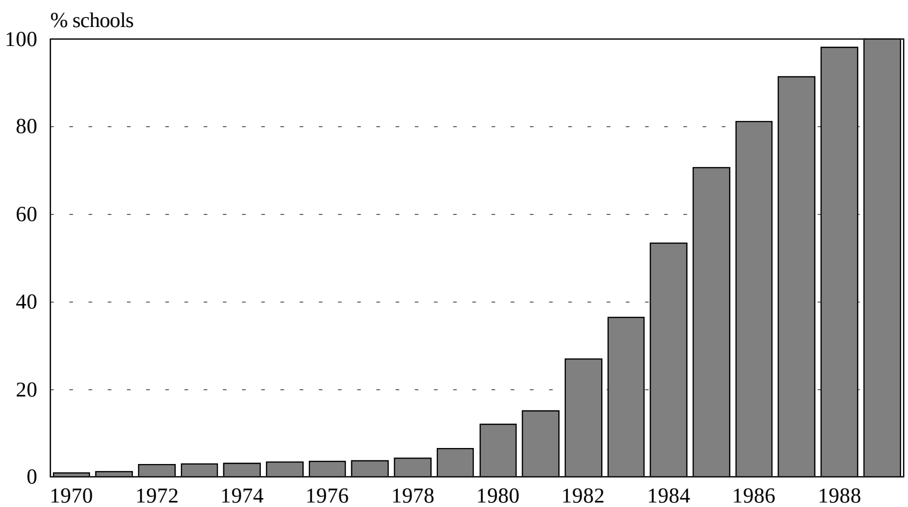


Figure 4.2 Cumulative growth of computer use at Dutch lower secondary schools

Although the figure above reflects the government policy of the 1980s that was aimed at providing all secondary schools with computers, the success of the introduction of computers was not only the result of a top-down policy. Looking at the year of computer introduction for the different groups mentioned in Figure 4.1 (teachers, NIVO and the combination of NIVO and teachers), the Comped-data show that the schools where computers have been introduced solely on teachers' initiative were the early computer users: they started on average in 1983 (Figure 4.3). These schools introduced computers before the NIVO-project started and used computers significantly earlier than other schools. For the majority of schools, both teachers' interest and the NIVO-project were the reason for introducing the computer. In general these schools obtained their first computer in the school year 1984-1985. For the very small group of schools that acquired their first computer solely as a result of the NIVO-project, the introduction of computers can be indicated as the result of a top-down strategy and in these schools the first computer entered the school on average in the school year 1985-1986. They were the last group of secondary schools that introduced computers.

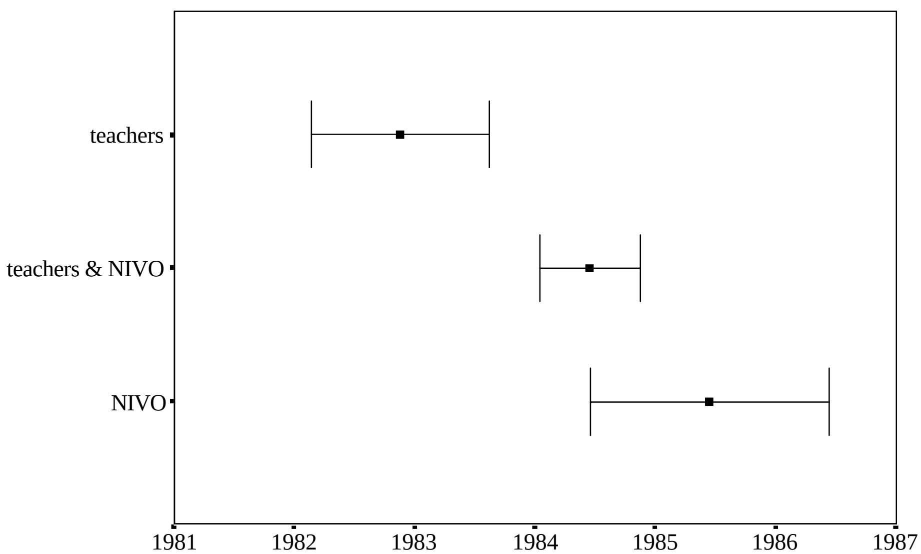


Figure 4.3 Average year of introduction of computers related to the initiators of computer use at Dutch schools and corresponding 95 percent confidence interval

Financial support

The introduction of computers in education requires the acquisition of hardware and software. The installation of an infrastructure for computer use at schools is expensive and often cannot be paid out of the regular school funds. The percentage of schools that received additional financial support from the government for acquisition and maintenance of hardware and software is depicted from an international perspective in Figure 4.4. In this figure a school has received financial support from the Ministry of Education if it has been supported in such a way that, according to the principal, the use of computers would clearly have been different without this financial sustenance. From the results across countries it becomes apparent that more than 80 percent of the schools in the Netherlands and the United States have received important financial support from their national or state government. In other countries such as Austria, Germany and Japan, less than 40 percent of the schools received financial back up from their government for the acquisition of hardware and software.

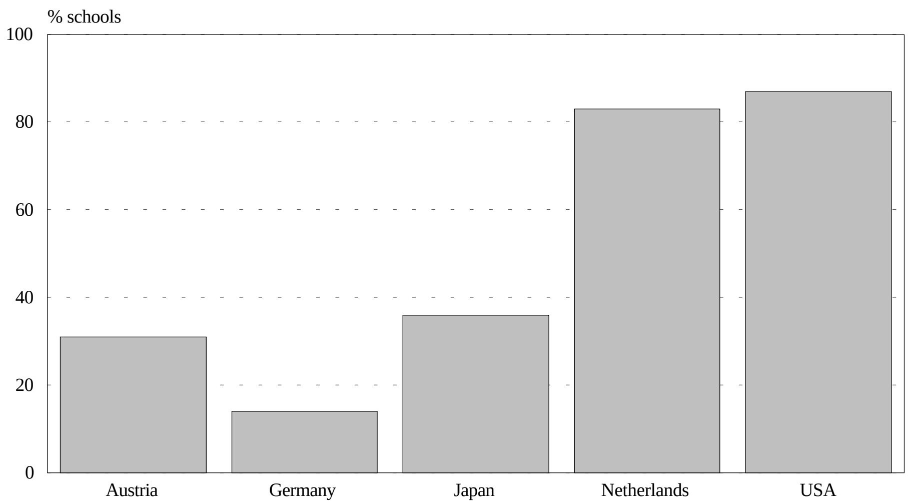


Figure 4.4 Percentage of lower secondary schools that received important financial support from their government for the acquisition of hardware and software

Availability of hardware

At the moment the NIVO-project started with the provision of hardware in 1986, the majority of lower secondary schools had already acquired some computers on their own initiative (Figure 4.2). For a limited number of schools the first computers were introduced by the NIVO provision of hardware. As can be seen from both Figure 4.2 and Table 4.2, the NIVO-project resulted especially in an increase of the number of computers at schools and as a consequence in a decrease of the student-computer ratio. Even though the Dutch policy was aimed at having provided all schools with computers in 1989, this goal could not be realized due to delays in the delivery of the equipment. It was 1990 when all secondary schools possessed on average 22 computers. Ten of these computers were provided during the NIVO-project and the others were purchased by the schools. Most of the computers were equipped with the MS-DOS operating system.

Table 4.2
The percentage of Dutch secondary schools with computers, the average number of available computers (based on schools with computers) and the corresponding student-computer ratio for the period 1984-1992

School year	percentage of schools with computers	average number of computers per school	average student-computer ratio per school
1984/1985	62	10	125
1985/1986	76	11	97
1986/1987	84	13	68
1987/1988	88	17	53
1988/1989	93	21	44
1989/1990	100	22	41
1990/1991	100	23	38
1991/1992	100	24	34

As part of the NIVO-project every school was provided with a fixed number of 11 computers. The consequence of this strategy was that the student-computer ratio in small schools became significantly smaller than the student-computer ratio in larger schools. This effect is clearly illustrated in Figure 4.5 presenting the average student-computer ratio for three different school size categories.

The ‘small’ schools have less than 400 students (44% of the secondary schools), the ‘medium’ schools have more than 400 but less than 800 students (31% of the secondary schools) and finally the ‘large’ schools have more than 800 students (25% of the secondary schools). The average student-computer ratio in small schools is 18, schools with a medium school size have an average student-computer ratio of 28 and large schools have a ratio of 49. These results indicate that students in small schools have many more opportunities to work with computers than students in larger schools.

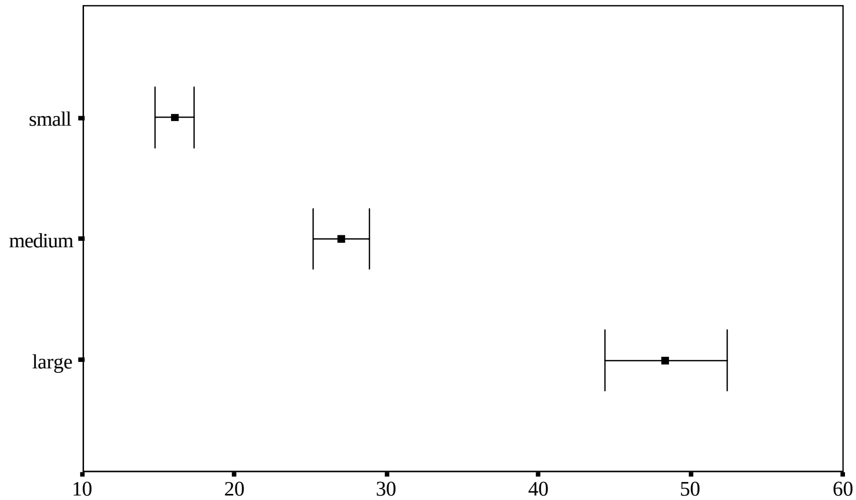


Figure 4.5 Average student-computer ratio related to school size and corresponding 95 percent confidence interval in the Netherlands

When comparing the availability of hardware in Dutch lower secondary schools with the situation in other countries (Figure 4.6) the conclusion is that, during the past decade the hardware situation in Dutch secondary schools was about one or two years behind the United States.

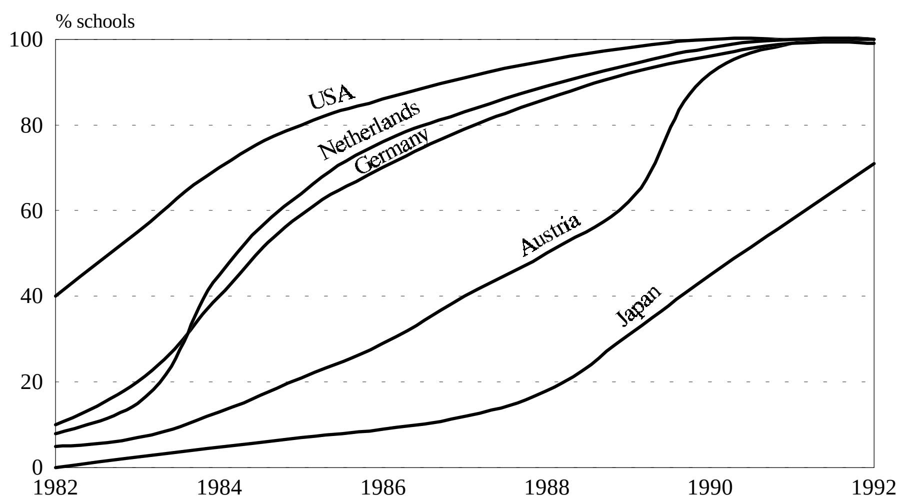


Figure 4.6 Percentage of secondary schools using computers for instruction over years per country

However, in the beginning of the 1990s there is no difference anymore between the situation in the United States, the Netherlands, Germany and Austria. The growth of secondary schools with computers in Germany is comparable to the Netherlands in this period. Austria caught up during the past years and recently Japan started to provide its secondary schools with computers.

Although the percentage of schools possessing computers for instruction is an important measure for student access to computers, the processor type is an important indicator for the quality of the hardware. The availability of a more powerful processor type indicates that more sophisticated educational software can be used. The percentage of computers with 16 bit or more powerful processors is an indication of the extent to which schools are equipped with up-to-date computers.

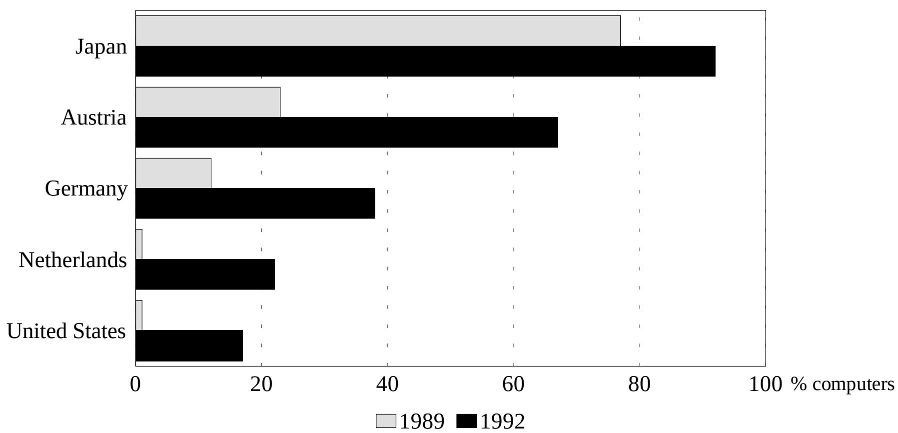


Figure 4.7 Mean percentage of computers in computer using schools equipped with processor types of 16 bit or more

Figure 4.7 includes the percentage of computers in secondary schools equipped with a processor type of 16 bit or more in 1989 and 1992. This figure shows two developments. First, in all countries the availability of powerful computers has increased substantially in the period 1989-1992. Second, the two countries that started with the large scale distribution of computers during the last 5 years (see Figure 4.6: Japan and Austria) tend to have more powerful and up-to-date computers than the early starters.

The ‘law of restraining lead’ seems to hold in this situation: those countries that started about ten years ago as the first in the world with the introduction of computers in education, nowadays have an old-fashioned infrastructure for information technology. The forerunners of the 1980s have become the laggards of the early 1990s. It is interesting to follow the developments in these countries in the coming years and see whether they will have the possibilities and financial resources to catch up during the remaining years of the 1990s.

Availability of software for subject areas

Most of the Dutch secondary schools have software for informatics, mathematics, science, Dutch language, foreign languages and social studies (geography, history, and civics). This means that almost all Dutch secondary schools are in the possession of software for most subject areas (Figure 4.8). This can be seen as one of the achievements of the NIVO-project which saw to it (as described in the policy section of this chapter) that all secondary schools were provided with a number of different programs via the NIVO-starters-package.

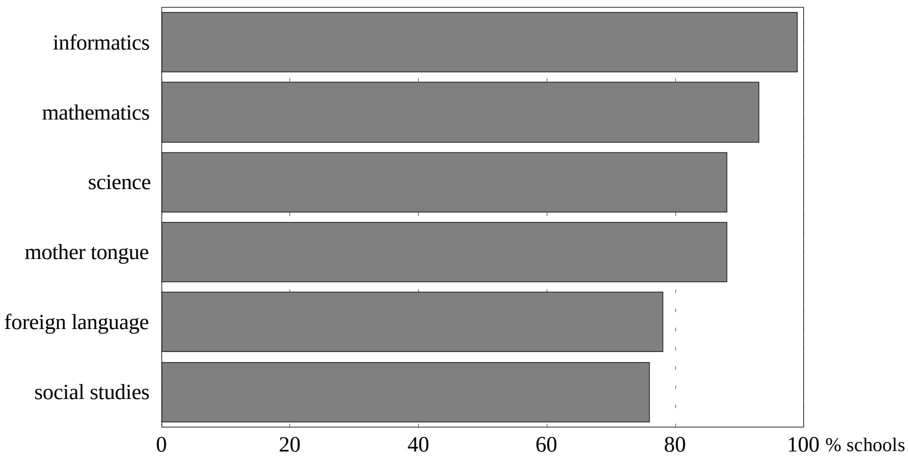


Figure 4.8 Percentage of Dutch schools with availability of software for subject areas

Besides general application programs such as a word processor, a database management program and a spreadsheet, this starter package also included computer training programs, an authoring system for development of CAI-programs, educational games, simulation programs and courseware (lesson ideas) for several subjects, e.g., physics, mathematics and foreign languages.

On average, Dutch secondary schools have software programs for at least five of the six subject areas mentioned above. When looking at the availability of software for the subjects in international perspective (Figure 4.9), it is found that the Dutch secondary schools have the widest range of software.

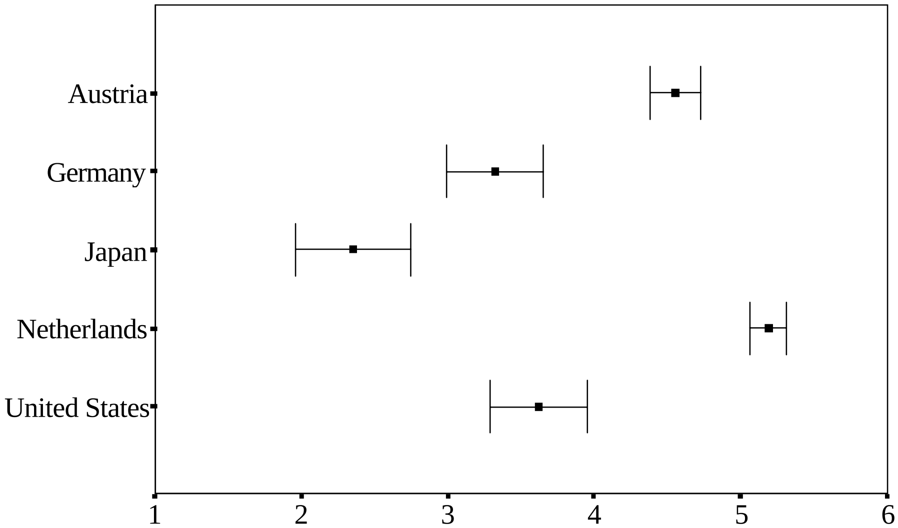


Figure 4.9 Average number of subjects for which software is available in each country and corresponding 95 percent confidence interval

It is noteworthy that, despite the high degree of dissemination of software in the Netherlands, in no other country the lack of usable software and problems related to the integration of software in instructional practice is experienced as being a hindrance in the implementation process as frequently as in the Netherlands (Brummelhuis & Plomp, 1993a; 1993d). The explanation for this apparent contradiction can be found in the practical usability of the courseware that is available to schools. Results from a study about the diffusion, use and practicality of the starter package of software show that only 2 percent of the teachers in science, mathematics and mother tongue used the subject specific courseware that was provided to the schools (Brummelhuis & Plomp, 1993b).

Support structures for computer use

As mentioned before, the use of computers in many schools was initiated by enthusiastic teachers. But the presence of one or more enthusiastic teachers in a school is no guarantee for a successful introduction of computers by all teachers in the school. In order to help schools with their activities in introducing computers, in the 1980s many courses were set up for teachers. Figure 4.10 gives an overview of the institutions and agencies that supported schools with teacher training on computer use. According to the principals, almost 80 percent of the secondary schools have been supported with teacher training by educational support institutions. This reflects the policy of both NIVO and OPSTAP in which these institutions were considered to be responsible for support and training activities with regard to the introduction of computers in education. Besides the support institutions (75%), the teacher training colleges supported the secondary schools (43%) by training teachers in computer use.

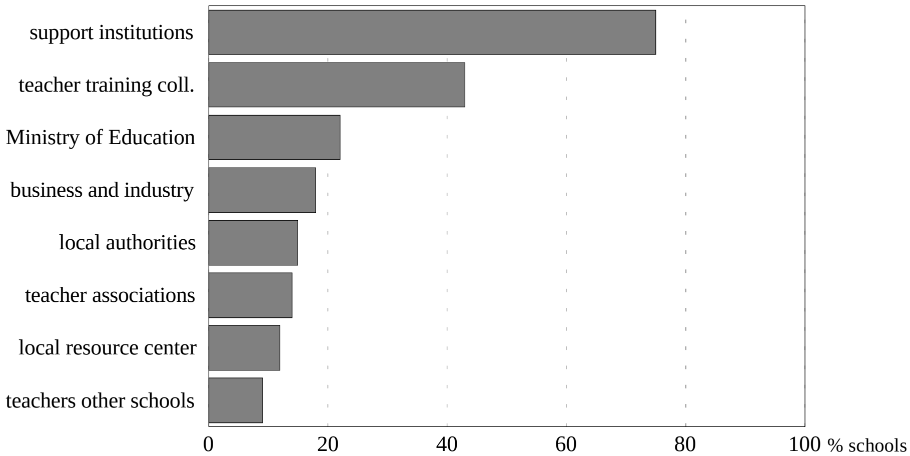


Figure 4.10 Percentage of Dutch schools supported with teacher training by external agencies

The contribution of other institutions or agencies with respect to teacher training is relatively small. On average two institutions or agencies have supported schools with teacher training for computer use. This is in line with the other countries where two institutions or agencies were also usually involved in supporting schools with teacher training for computer use.

In almost all countries, teacher training is available and being organized by agencies external to the school. These external courses are aiming at how to use computers (general introductory course), using general application programs (e.g., word processors, spreadsheets, databases), programming and using computers in specific subjects. A high level of external training support for all these topics is available in Austria and Germany; a moderate support level is available in Japan and a relative low level of external support is available for schools in the United States (Figure 4.11). The training support in the Netherlands is mainly concentrated on computer science and subject specific use. Support on introductory courses and general applications is available for somewhat less than half of the secondary schools and is therefore comparable to the situation in Japan.

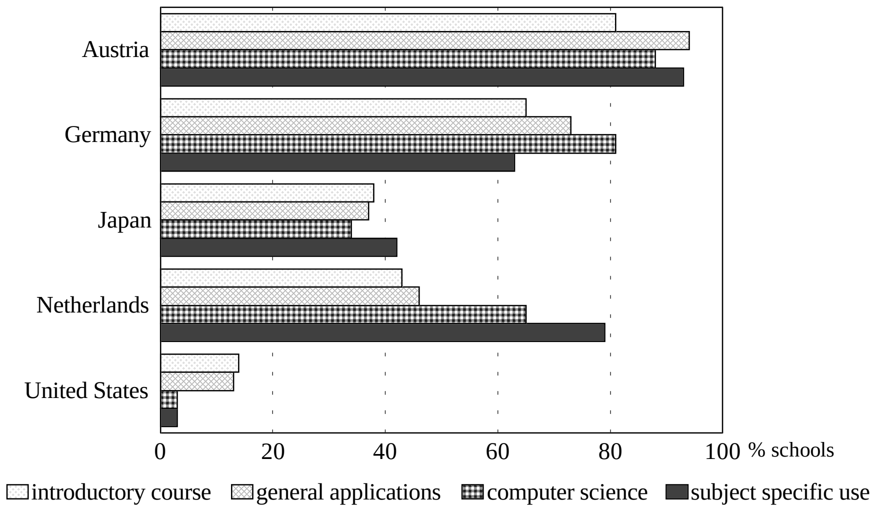


Figure 4.11 Percentage of schools with teacher training courses provided by external agencies

Not only an external support structure for computer use is important, a supportive environment in the school itself is important as well. From this perspective, it is significant to look at the training opportunities for the teachers organized by and within the school. Across countries, the courses schools most frequently organize are introductory courses and courses for general applications programs (see Figure 4.12). Besides, from the five countries of which results are presented the Netherlands is the only country where the majority of the schools organized courses for using computers in specific subjects and courses for computer science and programming. It is assumed that this situation is caused by the Dutch policy for lower secondary schools that concentrates on these two aspects of computer use: (a) the introduction of a (new) subject for computer education and (b) the use of computers in existing subjects. To inform teachers of the existing subjects about the contents of the new subject computer education, as well as the possibilities of the computer for educational purposes, courses were organized in many schools covering the topics computer science and subject specific use. In general, the opportunities for staff development concerning the introduction of computers are high in the European countries (Austria, Germany and the Netherlands). The US-teachers have the fewest opportunities for attending computer training organized by either external agencies (Figure 4.11) or the school (Figure 4.12).

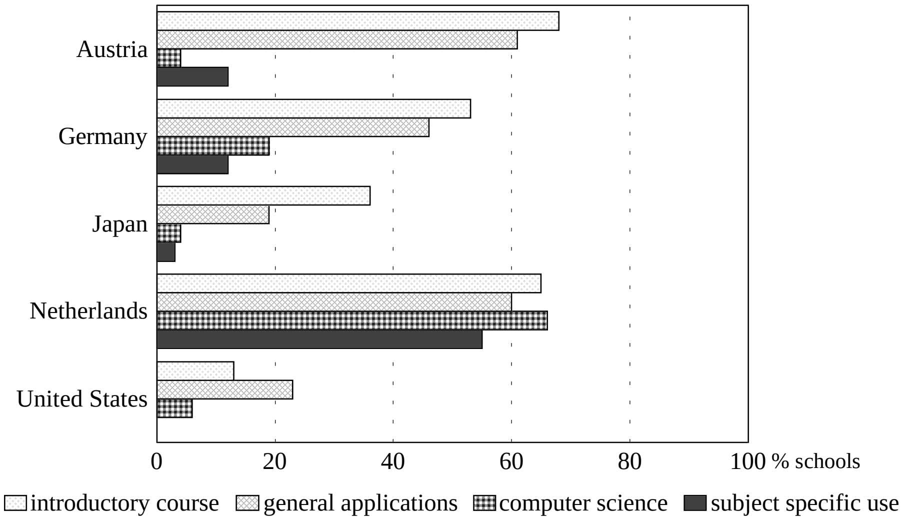


Figure 4.12 Percentage of schools with teacher training courses provided by the school

One of the outcomes of both teacher training and support for computer use can be measured by teachers' knowledge about and skills on how to use computers. In the Comped-study teachers' competence was measured by a self rating scale consisting of the following three dimensions (Pelgrum & Plomp, 1991; see also p.122):

- knowledge (9 items about knowledge of hardware and software);
- programming (5 items about programming skills);
- capability (8 items about the ability of using the computer as a tool).

The total amount of teachers' competence is presented in Figure 4.13. This shows that teachers in Austria rate themselves the highest on the self-rating items. Although in Germany the variation in teacher competence is larger than in The Netherlands, the average self-rating level is almost equal in both countries. The Japanese teachers feel the least prepared to work with computers. Based on the results presented in the previous two graphs about the availability of teacher training on the one hand and the findings about teacher competence on the other hand, it can be concluded that countries with the highest training opportunities are also the countries in which teachers feel themselves the most competent to use computers. Data from the United States are missing in this figure, because in 1992 in the US part of the Comped study no data were collected on teacher level.

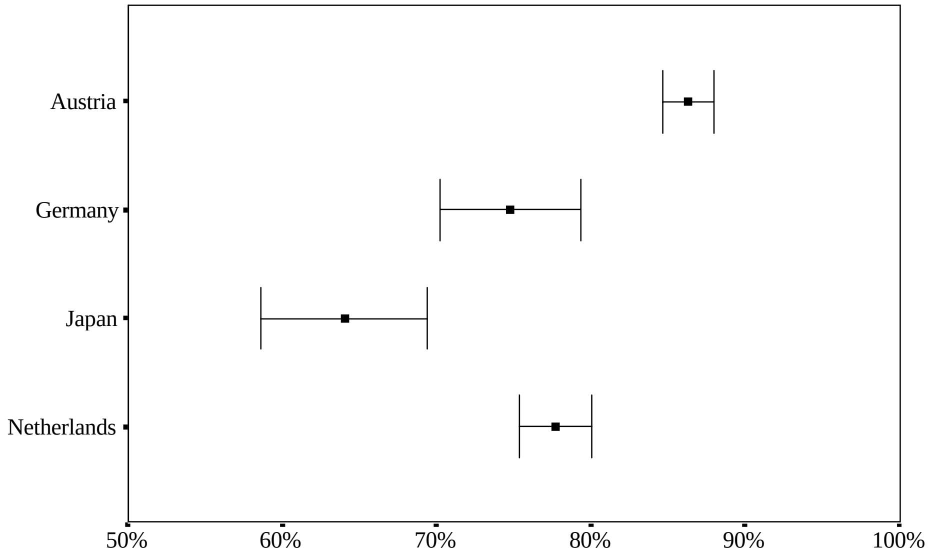


Figure 4.13 Average percentage of correct answers on teacher competence for computer use including the 95 percent confidence interval

Resource needs

To get an idea of the future developments of computer use in schools it is interesting to look at the priority of computer related expenditures in school plans. Figure 4.14 gives an overview of the most important expenditures that according to computer coordinators, are part of schools' policy plans.

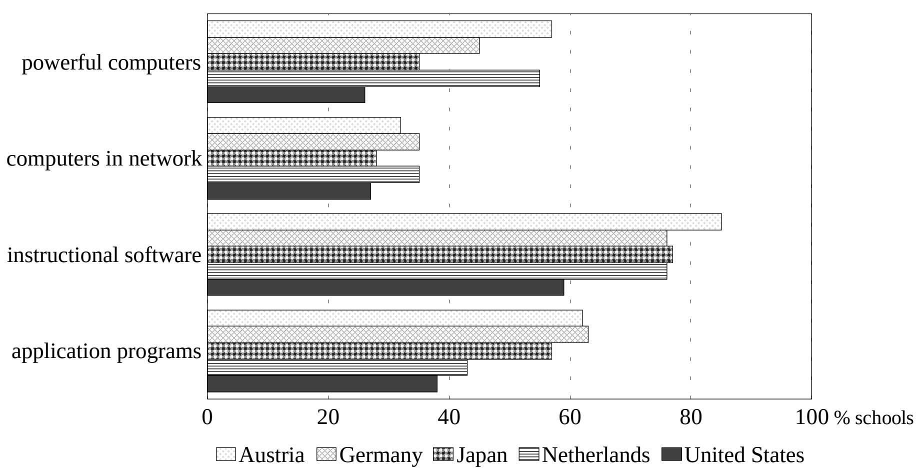


Figure 4.14 Percentage of schools with most important resource needs for computer use

In all countries the highest priority is given to expenditures related to instructional software. Furthermore, secondary schools in most countries want to purchase powerful computers and general application programs like graphing programs, modern word processors and database programs. Although the US-schools have a low percentage of powerful computers (see Figure 4.7), it seems that only a minority of the schools make financial reservations for purchasing more powerful computers.

Relevance of and policy for computer use at school level

From previous studies it is known that implementation of an innovation can be a multidimensional concept (Fullan, 1991; Hopkins, Ainscow, & West, 1994). This is certainly the case with the introduction of computers which is not simply a matter of providing schools with materials (i.e., hardware, software) and offering training opportunities for teachers how to work with information technology. Other aspects, such as the relevance of the innovation and the availability of a policy for implementation in the school that has to provide a framework for action (Fullan, 1991), also have to be taken into account. This section presents results from the Comped study on these aspects.

From the point of view that principals are assumed to be important change agents in schools and their attitudes towards computers are a potential influencing factor in the success of implementation in schools, their opinion on computers is important (Pelgrum & Plomp, 1991). The relevance of this innovation is studied from the perspective of this change agent.

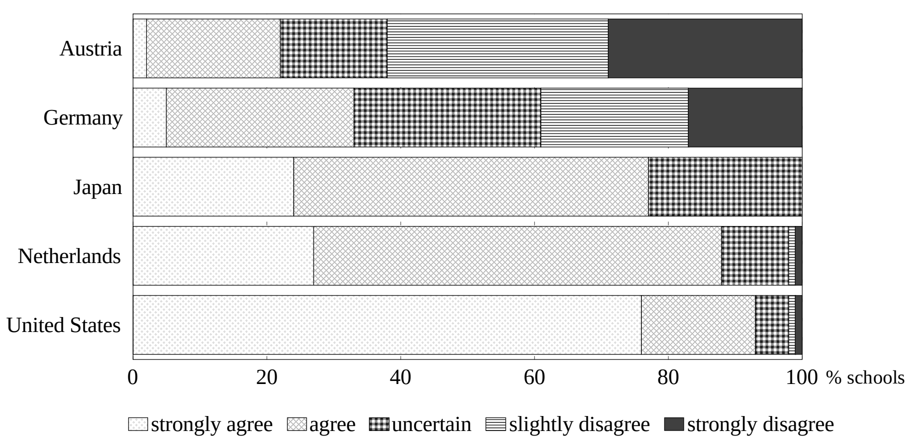


Figure 4.15 Principals' opinion about the computer being a valuable tool to improve the quality of a child's education

Principals were asked their opinion on the general statement that computers are being a valuable tool to improve the quality of a child's education. The results in Figure 4.15 show that especially the US-principals are (strongly) convinced of the value of computers for educational purposes. Although, compared with their US colleagues, the principals in Japan and the Netherlands agree less strongly with the statement, more than three out of every four principals agree with the statement. A completely different situation is found in Germany and Austria. In these countries no more than one out of every three principals is convinced that the computer is a valuable tool to improve the quality of education.

The principals' attitude towards the educational impact of computer use was measured by a scale consisting of five items. This scale included the following items:

- Using computers in classes leads to more productivity among students
- Students are more attentive when computers are used in class
- Computers help to teach more effectively
- The achievement of students can be increased when using computers for teaching

Principals were asked to rate their agreement with these statements on a five point scale (1 = strongly disagree; 2 = disagree; 3 = uncertain; 4 = agree; 5 = strongly agree). Reliability analyses on this scale showed that the reliability coefficient varies across countries between 0.74 and 0.84 (Austria 0.84; Germany 0.77; Japan 0.82; Netherlands 0.74; United States 0.78).

Figure 4.16 shows the results for this educational impact scale across countries. In accordance with Figure 4.15, compared with principals in other countries the US-principals perceive computer use as having the most educational impact. The attitude of the Dutch principals towards educational impact of computers is on average comparable to that of the German and Austrian principals.

The attitude of the Japanese principals is significantly higher compared with the European principals but significantly lower in comparison with the US-principals. In general, the principals in Japan and the US have a positive attitude towards the educational impact of computers. The European principals are more often in doubt about the impact of computers for educational purposes.

Although the Dutch principals of secondary schools generally have a positive attitude towards computer use (Figure 4.15), they are not convinced of the impact of computers for educational purposes.

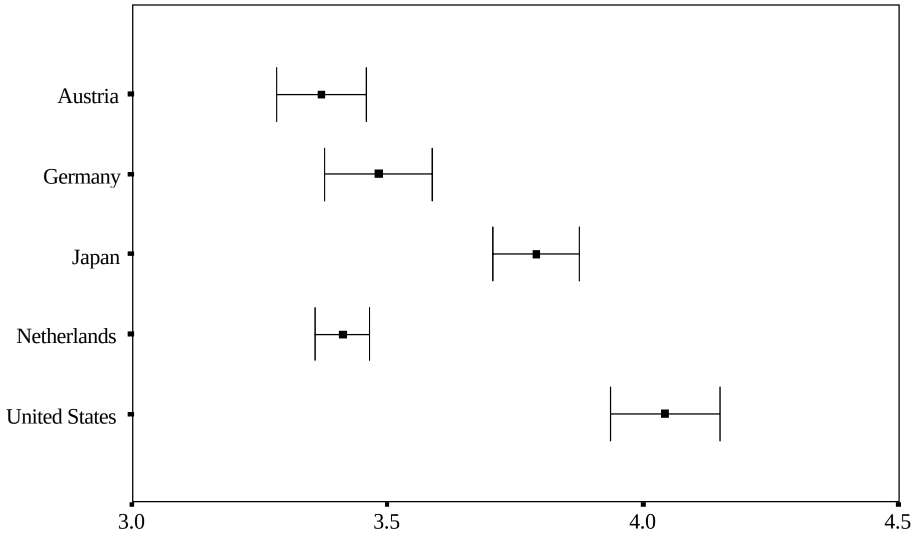


Figure 4.16 Mean score on relevance scale for computer use including the 95 percent confidence interval

As mentioned before, a policy for the introduction of computers provides a school with a framework for action. From this point of view it is important to look at the percentage of schools that have such a policy. A distinction is made between three types of schools:

a. schools with an internal school policy;
b. schools that do not have their own (internal) school policy for computer use but carry out a policy provided by an external agency such as the state government or the national government;
c. schools without any policy for computer use.

Figure 4.17 depicts the percentage of schools of each of these three groups across countries. The results show that the Dutch schools most frequently have an internal school policy for computer use and at the same time the Netherlands has the lowest percentage of schools with solely an external policy for computer use. The majority of the Austrian schools indicate that the use of computers is the result of an external policy. In the United States we find the lowest percentage of schools with a policy on computer use.

Knowing that the United States started as one of the first countries in the world with the introduction of computers (Figure 4.6), this result could indicate that many US-schools have finished their implementation process. In other words, this result could indicate that computer use in these US-schools (without a policy) has stabilized and does not need the attention of a special policy any longer.

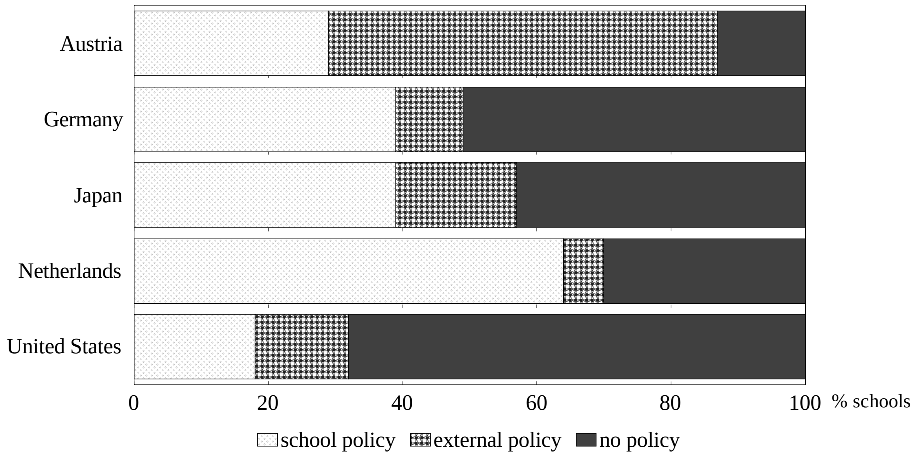


Figure 4.17 Percentage of schools having a policy for instruction with computers initiated by the school or external board

Other aspects influencing the ongoing process of implementation are evaluation activities and information exchange. Figure 4.18 depicts these aspects across countries and shows that more than 50 percent of the schools in Austria, the Netherlands and the United States apply evaluation activities such as assessing how computers are actually used in classes. In Germany and Japan these evaluation activities occur at less than 40 percent of the schools. In all countries, except Japan, information exchange about the use of computers exists in the majority of the schools, either among teachers within the school or with teachers from other schools.

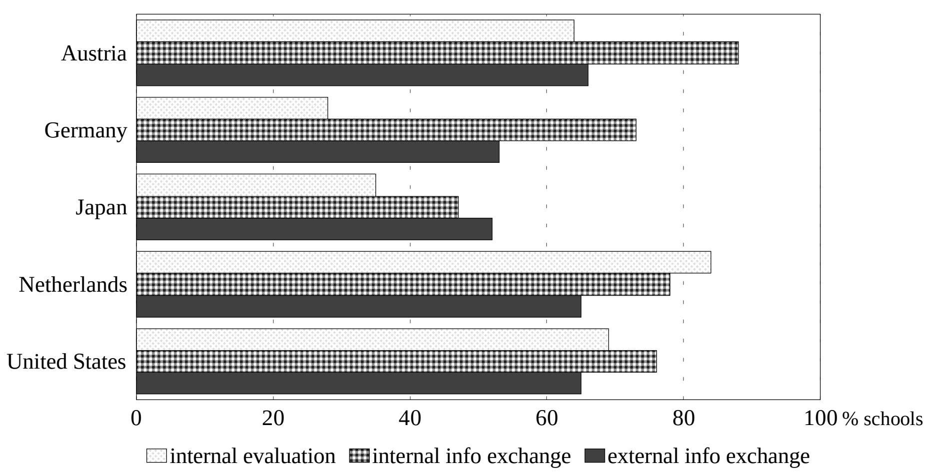


Figure 4.18 Percentage of schools with evaluation activities or information exchange

Computer use in classrooms

Implementation of computer use in schools ultimately results in changes in the individual educational practice of teachers. This means that outcomes of the implementation process have to become visible in the degree of computer use by teachers during lessons. The amount of computer use by teachers combined with the results computers have for students determine the success or failure of the implementation process. The outcome of the implementation process in this study is restricted to the extent of computer use by teachers. Student results are only indirectly seen by looking at the perceived educational impact teachers indicate computers have on their students.

For the secondary schools in the Netherlands Figure 4.19 presents a curve indicating computer use in grade 7, 8 and 9 in four subjects: mathematics, science, mother tongue and computer education. The index for this figure is derived as follows.

The percentage of lower secondary schools that have access to computers is shown on the horizontal axis. It can be seen, for example, that 87 percent of the Dutch secondary schools had access to computers in 1989 and 100 percent in 1992.

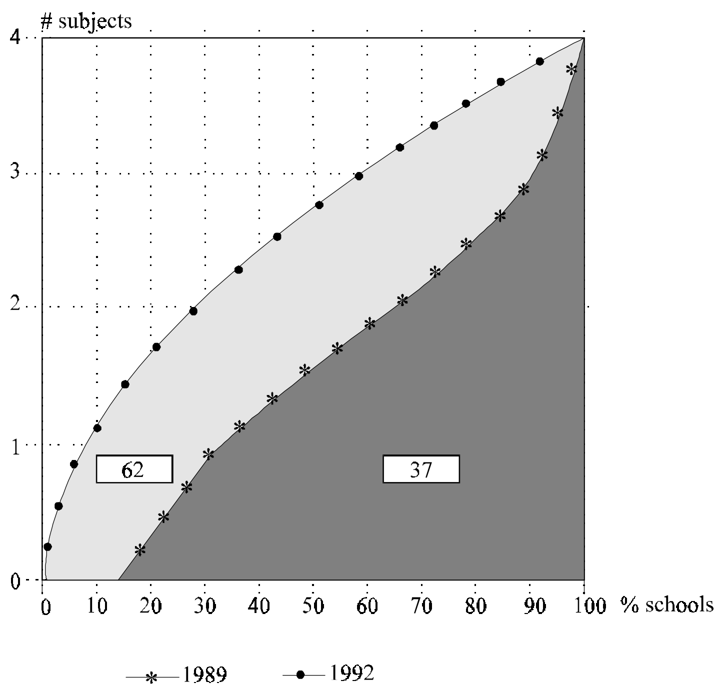


Figure 4.19 Index for computer use in Dutch secondary schools in 1989 and 1992

The percentage of schools using computers for educational purposes in each of the four subjects is indicated on the vertical axis. Thus, the larger the shaded area on the right-hand side of the curve, the higher the proportion of schools that have computers and that actually use these for educational purposes in the four major subjects. Based on the curve determined by the access and use of computers for educational purposes, a yield score of computer implementation is calculated. By using five measuring-points the yield score is calculated by the fourth grade polynoom of the curve. The yield score represents the surface of the shaded area. Figure 4.19 shows for the grades 7, 8 and 9 that the percentage of Dutch schools using computers in one or more of the four main subject areas has increased substantially from 37 in 1989 to 62 in 1992.

When looking from an international perspective at the growth of computer use in the same period, an increase of computer use in Japan and Germany is found that is comparable to the situation in the Netherlands (see Figure 4.20). In 1989, computer use in the United States was far ahead of the other countries. During the period 1989-1992 only a minor increase of computer use took place in the US-secondary schools. In 1992, this resulted in the situation that the computer-use-gap between the United States and other countries has become smaller and the most widespread computer use in 1992 is found in Austria.

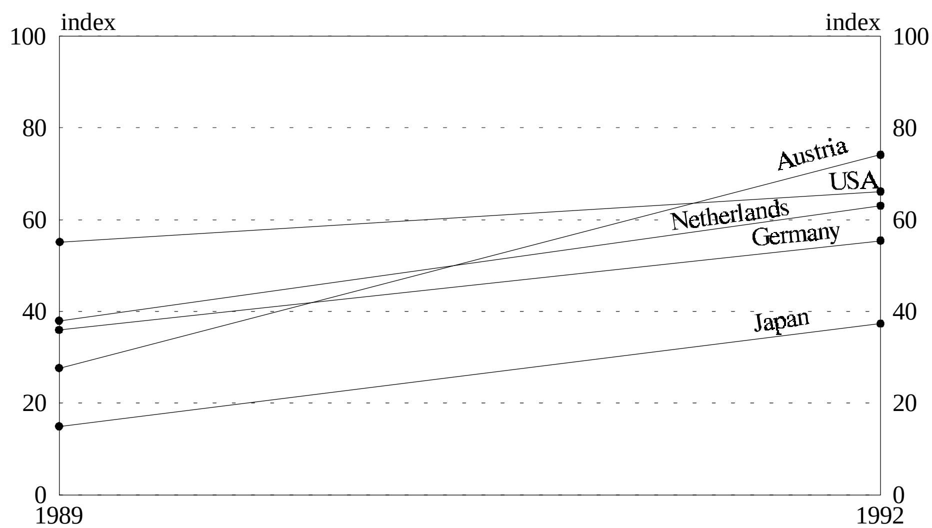


Figure 4.20 Degree of computer use over the years represented by an index concerning the subjects mathematics, science, mother tongue and computer education in the grades 7, 8 and 9

Although the Figures 4.19 and 4.20 record a notable growth of the Dutch schools that use computers in four major subject areas in the grades 7, 8 and 9, it has to be noted that these figures do not give an indication of the nature or the actual amount of usage.

Concerning the amount of use, a distinction can be made between implementation width and implementation depth. Implementation width refers to the number of teachers using computers. Implementation depth refers to the amount of time that computers are used during lessons. When looking at the number of teachers using computers (width), it is important to make a distinction between implementation width at school level (across departments) and implementation width at department level (within departments).

Longitudinal analyses of the increase of computer use during the period 1989-1992 show that the percentage of lower secondary schools that included the subject of computer education on the schedule of one of the first three grades increased from 84% to 94%. As can be seen from Figure 4.21 the increase of lower secondary schools with at least one teacher who uses the computer during lessons has at least doubled in each of the studied existing subjects.

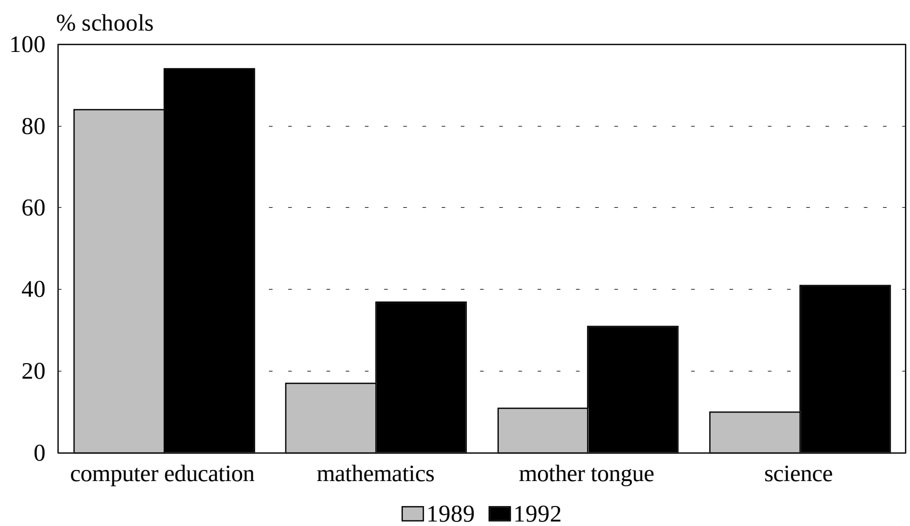


Figure 4.21 Percentage of secondary schools with at least one teacher in the grade range 7 - 9 in thesubjects mathematics, science or mother tongue

This increase can almost entirely be attributed to teachers who work within a department in which in 1989 no other teacher had yet made use of the computer (Figure 4.22). Although there is an increase of implementation width at school level, the growth of computer use is not related to what is called implementation width at department level. The growth is caused by individual teachers who are the first users within their department (Brummelhuis & Plomp, 1994a). The consequence of this type of growth is that computer use is not getting integrated in the curriculum of a department but remains related to the interest of an individual teacher.

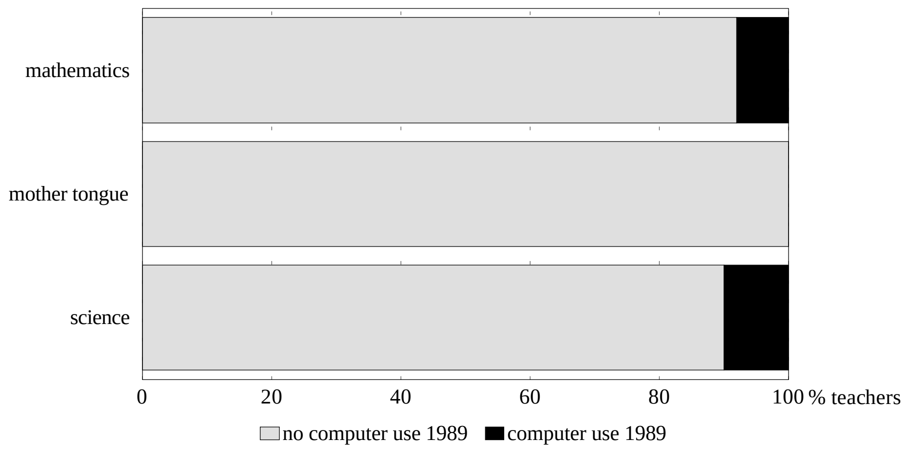


Figure 4.22 Percentage of teachers who started using computers for teaching aims in the period 1989-1992 within existing subjects in the second grade of secondary education in break down by experience of computer use of their colleagues within the department

Only a small percentage of teachers frequently use computers during their lessons. As illustrated in Figure 4.23, almost all teachers in existing subjects use the computer incidentally. Computer use in existing subjects in Dutch lower secondary education can thus be characterized as an activity that very much depends upon the individual teacher and is not embedded in the curriculum or department. Results from other studies confirm that this is not only the case in the Netherlands: for instance, in the UK the use of computers in education also depends strongly upon the interest of individual teachers (Watson, 1993).

Figure 4.23 Extent of computer use by at least one teacher in the grade range 7 - 9 in the subjects mathematics, science or mother tongue

Concerning the nature of computer use the computer coordinators as well as teachers were asked to indicate how frequently computers are used by students in various ways. The results show that most emphasis in computer use is given to drill and practice for instructional purposes and the use of general application programs such as a word processor. It has to be noted that more than 80 percent of the computer using teachers use the computer less than 20 lesson hours per year (Brummelhuis & Plomp, 1993a).

Based on the results with respect to computer use at Dutch lower secondary schools in 1992, it can be concluded that the degree of computer use at school level is primarily determined by the number of subjects in which computers are used. The amount of time that students work with computers within each of the existing subjects as well as the variation in approaches of computer use is very limited.

Discussion of findings

In the previous sections an overview is presented of the degree of computers use in Dutch lower secondary schools and other aspects relevant for the introduction of computers. The selection of these aspects is based on the review of theories on educational change that was discussed in Chapter 2. The findings presented in this chapter are relevant for a good understanding of the developments over time. Furthermore, it gives an overview of several other aspects of computer use in the Netherlands compared to the situation in other countries.

Although the descriptive data presented in this chapter are adequate for providing an overview of aspects of computer use, they do not provide insight in the interrelatedness of these aspects. This means, the presented findings do not answer the question why certain schools use computers in their educational practice to a greater extent than others. It is known from previous studies on educational change (see Chapter 2) that the success or failure of educational change is not determined by one factor. To understand why some schools are more successful in implementing computers than others, it is necessary to study the factors that may influence on the degree of computer use as an interrelated system. Therefore, analyses are conducted that take the interrelatedness of factors into account. The results of these analyses are presented in the next two chapters.

Summary

Since the early eighties the Dutch government has provided a policy aimed at stimulation of the use of computers in education. As a result of these stimulation programs, all Dutch secondary schools nowadays possess computer hardware. In 1992, compared with schools in other countries, secondary schools in the Netherlands were in the possession of a relatively diverse set of software for subject areas. However, the practical usability of a number of the available programs was rated by teachers as unsatisfactory.

Although during the period 1989-1992 the number of computer using teachers has increased substantially, this increase primarily concerns individual teachers within a department in which the computer up to then had not been used for teaching aims. The policy for lower secondary schools during this period focused on further integration of computer education in the curriculum and the integration of information technology elements in existing subjects. The results show that computer use is mainly restricted to the new subject computer education and teachers in other subjects use the computer only incidentally.

5

Developing the Exploratory Structural Model

As concluded in Chapter 2, a large number of factors influencing the process of successful innovation in education can be identified, but little is known about the interrelatedness of these factors. Due to the lack of a specified theory or model on the implementation of computers in education that can be evaluated by means of a confirmatory LISREL analysis, exploratory analyses were carried out on the Dutch Comped data set of 1989.

A primary reason for applying exploratory analyses is the lack of an *a priori* specification of the underlying structure of the measures. The exploratory analyses are aimed at developing a (hypothesized) structural equation model on the implementation of computers in education in order to identify the influencing factors on the outcome variable and the way these factors are interrelated with each other. Subsequently, confirmatory analyses are applied to evaluate the exploratory model. Approaches for confirmatory analysis are only appropriate for models that are nearly completely specified. Although confirmatory analysis provides methods for model revision, these methods are more appropriate for 'fine tuning' of the model instead of large-scale respecification. In general, the phase of confirmatory analyses is preceded by exploratory analyses. Model building is an iterative process in which three stages can be distinguished: building, testing and, if necessary, rebuilding (Keeves, 1994). Each of these stages in model building is represented in this study. This chapter describes the results of model building by means of exploratory analyses and the following chapter provides the results of testing as well as rebuilding of the model.

Several computer programs, like LISREL (LInear Structural RELations; Jöreskog & Sörbom, 1989a, 1993a) and EQS (Bentler, 1989) have incorporated the principles of structural equation modeling. For the analyses carried out in this study LISREL version VII (Jöreskog & Sörbom, 1989a) has been used (which was the most recent version available at the time the exploratory analyses were conducted) as well as LISREL version VIII (Jöreskog & Sörbom, 1993a), which became available in 1993. In LISREL version VIII the traditional LISREL statements as well as the new command language SIMPLIS can be applied. A check has been done that both LISREL versions and command languages produce identical findings when using the Dutch data set.

The first section of this chapter provides a short introduction to the key concepts of structural equation modeling. In the subsequent sections of this chapter, the results of the exploratory analyses on model building for the implementation of computers in education are described.

Introduction to structural equation model building

Structural equation modeling is a statistical approach for describing a complex structure underlying a set of observed variables. Such models explain how the observed variables and latent variables (hypothetical concepts that cannot be observed directly) are related to one another and offer the opportunity to express these relations diagrammatically or mathematically via a set of equations. The term structural equation modeling conveys two important aspects: (a) the processes under study are represented by a series of structural (regression) equations, and (b) these structural relations can be modeled to enable a clear conceptualization of the theory under study.

The hypothesized model underlying a dataset can be tested statistically in a simultaneous analysis of the entire system of variables to determine the extent to which it is consistent with the data. More concrete, the model is tested to determine the extent to which it accounts for the covariation between the observed variables. If goodness-of-fit is adequate, the model argues for plausibility of postulated relations among variables; if it is inadequate, the tenability of such relations is rejected. This means that causal relationships are not ‘proved’ by a model in any definite sense, but are only considered as more or less reasonable relative to alternative specifications (Jöreskog & Sörbom, 1989a).

Three characteristics of structural equation modeling make this methodology very useful for the problems studied in the present investigation. First, many other multivariate procedures are essentially exploratory or descriptive in nature, so that testing of causal hypotheses is not always appropriate. Second, structural equation models provide estimates of measurement error in the observed variables, and can incorporate both unobserved (latent) and observed variables. This in contrast to most other multivariate procedures that are incapable of either assessing or correcting for measurement error (Byrne, 1994). Third, the use of structural equation modeling has the advantage that it makes the interrelations among variables that are derived from theory explicit (Tuijnman & Keeves, 1994).

Key concepts

Most theories in educational research are formulated in terms of theoretical or hypothetical concepts (also called constructs or latent variables) which cannot be observed or measured directly. Examples of latent variables applied in this study are ‘teacher readiness’ and ‘perceived relevance of computer use’. Because latent variables are unobservable, their measurement must be obtained indirectly. For this reason it is necessary to define the latent variable in terms of aspects thought to represent the latent variable. By example, the latent variable 'perceived relevance of computer use' is measured in this study in terms of three items expressing the expectations of the principal that computers will increase productivity, increase student achievement and optimalize learning. Within the context of structural equation modeling, the observed variables serve as indicators of the underlying construct (the latent variable) that they are assumed to represent.

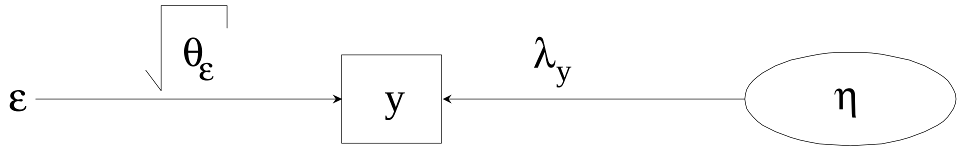
The links between the latent variables and their observed indicators are indicated by the measurement model. This model specifies how the latent variables or hypothetical constructs are measured in terms of the observed variables, and it describes the measurement properties in terms of validity and reliability of the observed variables (Jöreskog & Sörbom, 1989a).

Furthermore, the structural model depicts the links among the different latent variables under study and describes the causal effects and the amount of unexplained variance. A full latent variable model that specifies direction of causes from one direction only is called a recursive model. This means that in a recursive model the latent variables are ordered in such a sequence that each variable depends only on previous variables (Jöreskog & Sörbom, 1989a). In general, it is highly unlikely to end up with a perfect fit between the observed data and the hypothesized model. The discrepancy between the two sets is called the residual variance.

LISREL notation

Structural equation models can be depicted in a path diagram. By convention observed variables are shown in boxes and indicated by the character y, while latent variables appear in ellipses and are indicated by the Greek character η (eta). The observed variable y acts as indicator of the underlying latent variable (η). For a simple measurement model with one observed y-variable this is depicted in Figure 5.1.This figure also shows that the observed variable is associated with an error term ε (epsilon).

As stated before, this section is only meant to provide a short introduction in the key concepts of structural equation modeling. More detailed information about the theories and principles of structural equation model building is given in Alexander & Clifford (1995); Bollen (1989); Hayduk (1987); Loehlin (1992); and Jöreskog & Sörbom (1989a, 1993a).



LISREL variables:

y observed variable

ε measurement error of variable y

η latent variable

LISREL model:

The LISREL parameters λ_y (path coefficient from η-variable to y-variable) and θ_ε (error term of y-variable) are defined by the following relationships:

$y = \lambda_y \eta + \varepsilon$

$\lambda_y = \sigma_{(y)} \sqrt{r}$

$\theta_\varepsilon = \sigma^2 (y) - \lambda_y^2 = \sigma^2 (y) (1 - r)$

where (1) σ^2 (y) = the variance of y,

(2) r = the reliability coefficient for y,

(3) ε and η are assumed to be uncorrelated

Figure 5.1: Path diagram for a simple measurement model with one observed variable y

The measurement model: constructs and their variables

The selection of influencing factors or constructs involved in this study is based on the framework presented in Chapter 2 (Figure 2.1). The information used to measure the constructs was taken from the questionnaires to which the school principals, different groups of teachers, and resource persons acting as computer coordinator in schools responded.

Several constructs (latent variables) could have been measured by six or more indicators (observed variables). It was decided to use the three highest loading indicators per construct because of two reasons.

First, the specification of each additional measure would influence model stability by increasing the number of degrees of freedom in the model substantially. Secondly, good validity could also be achieved when less than six indicators were used.

The first step in the selection of indicators was to examine the frequency distributions and standard deviations of the relevant items. Observed variables lacking in variance or suffering from other serious deficiencies of measurement were excluded. An attempt to improve the distributions of highly skewed variables was made early in the study by applying transformation procedures. This was done to achieve as closely as possible a normal distribution of scores. Another activity was to recode all measures in a positive direction. The method of principal component analysis was used to select and exclude observed variables with confounded measurement. Data reduction also occurred in a later stage when one-factor scores were estimated in order to identify and delete variables with insufficient reliability. An overview of the complete set of items used for model building is included in Appendix 1.

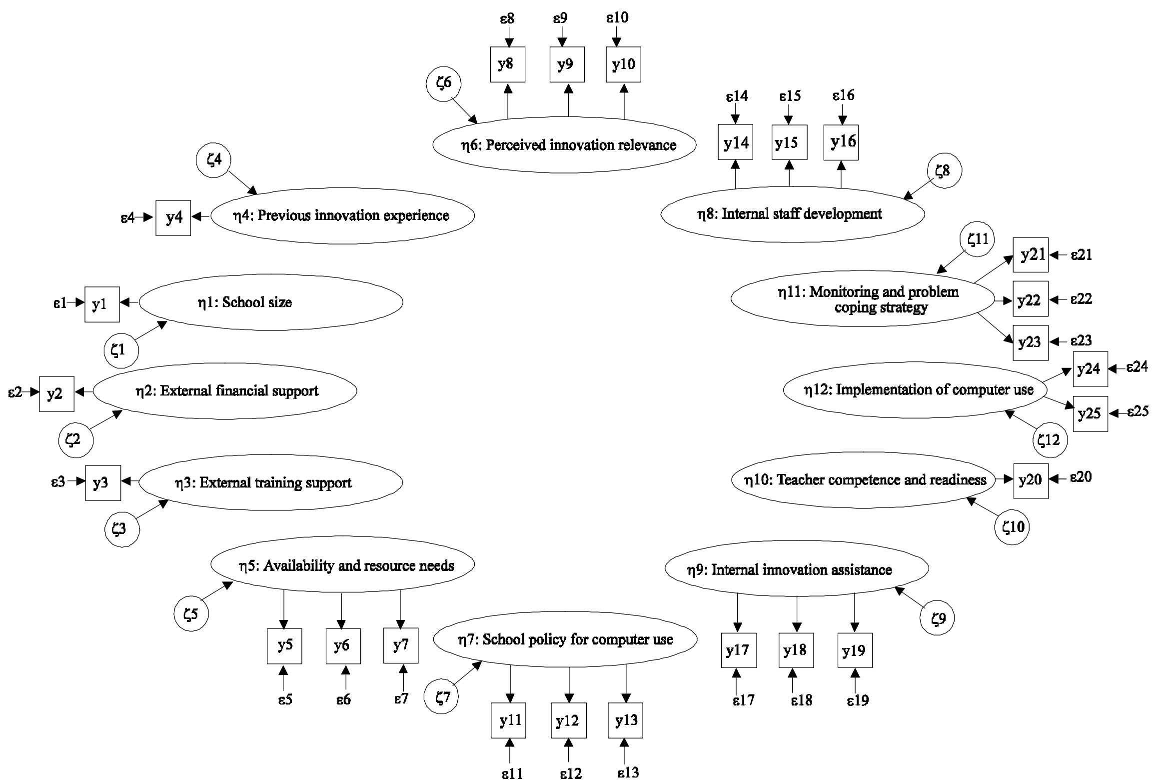
Missing values on constructs that are measured with a set of items were imputed on the basis of response pattern matching. For the imputation procedure of missing values the PRELIS computer program was used (Jöreskog & Sörbom, 1989b, 1993b). PRELIS is a statistical program for multivariate data screening and data summarization. This program is a preprocessor to the LISREL program. For the computation of the correlation matrix that was used as input for the LISREL analyses, cases with missing values after the imputation procedure were pairwise deleted.

The computation of optimal correlations among the variables was also done by using the PRELIS program. Polychoric and polyserial correlation coefficients were calculated for variables classified as being ordinal or continuous. However, chi-square tests of normality showed that this approach was not admissible for certain variable pairs; product moment correlations were computed in these cases. The resulting correlation matrix is included in Appendix 2.

A brief description of the applied set of constructs (η1-η12) and their associated observed variables (y1-y25) is given below and is graphically depicted in Figure 5.2. In terms of the conceptual model depicted in Figure 2.1 (Chapter 2), the constructs η1-η4 belong to exogenous preconditions, η5-η11 to endogenous adoption and implementation conditions, and η12 refers to the implementation outcome.

Although the conceptual model justifies to specify the four exogenous preconditions as x-variables, such a model has the limitation that it can not handle correlated measurment errors between the exogenous preconditions (x-variables) and the other variabels included in the model (y-variables). In order to allow for correlated error terms between all variables, it was necessary according to the LISREL guidelines to specify the model in terms of y-variables (Jöreskog & Sörbom, 1989a).

In addition to the LISREL symbols explained in Figure 5.1, it has to be noted that each latent factor (η) being predicted by structural equations has a disturbance term that is indicated in Figure 5.2 by the character ζ (zeta).



Construct η_i	y_i	Observed variable
η_1	y_1	School size
η_2	y_2	External financial support
η_3	y_3	External training support
η_4	y_4	Previous innovation experience
η_5	Availability and resource needs	
	y_5	need more powerful computers
	y_6	need network for disk storage
	y_7	need more tool software
η_6	Perceived innovation relevance	
	y_8	computers increase productivity
	y_9	computers increase achievement
	y_{10}	computers improve learning
η_7	School policy for computer use	
	y_{11}	priorities for instructional use
	y_{12}	prescribe soft- and hardware
	y_{13}	instruction with computers

Construct η_i	y_i	Observed variable
η_8	Internal staff development	
	y_{14}	course in application programs
	y_{15}	course in computer programming
	y_{16}	subject-specific course in computer use
η_9	Internal innovation assistance	
	y_{17}	software support to teachers
	y_{18}	instructional support to teachers
	y_{19}	organizational support to teachers
η_{10}	y_{20}	Teacher competence and readiness
η_{11}	Monitoring and problem coping strategy	
	y_{21}	internal information exchange
	y_{22}	external information exchange
	y_{23}	internal evaluation of computer use
η_{12}	Implementation of computer use	
	y_{24}	number of subjects with computer use
	y_{25}	number of teachers using computers

Figure 5.2 Measurement model for influencing factors on the implementation of computer use

η1 *School size*. This variable is based on the number of students enrolled in school (y1).

η2 *External financial support*. One item of the school questionnaire that was completed by the principal is used as an indicator of the financial support given by the government (y2).

η3 *External training support*. This variable involved 10 items with respect to staff development and training received from external agencies, such as computer manufacturers, software producers, other businesses and educational support institutions. Factor analyses showed that these 10 items underlay the same dimension and could be represented by a scale score (y3) having a reliability of 0.78. The information for this variable was provided by the principal.

η4 *Previous innovation experience*. Only one item is available to measure this construct. It is derived from the school questionnaire and based on an item asking for the year in which computers were first introduced in the school. The item thus measures the number of years of experience schools have had with computers in education (y4).

η5 *Availability of infrastructure and resource needs*. Three items measuring the urgency of the need for additional hardware and software are used as indicators of availability of infrastructure and resource needs on the assumption that schools well supplied with, for example, computer hardware, will assign a low priority to the purchase of new equipment. The three items used in the analysis are: the need for more powerful computers (y5), the need for a network for shared disk storage(y6), the need for more tool software (y7). The information is provided by the computer coordinator.

η6 *Perceived innovation relevance*. This variable is based on three items of the school questionnaire. These express the expectations of the principal that computers will increase productivity of students (y8), increase student achievement (y9), and optimalize learning (y10).

η7 *School policy for computer use*. Three items form this construct. These measure whether a school has determined a policy with respect to the means and ends of computer use: whether the school shall give priority to the use of computers for instruction (y11); whether the school prescribes which hardware and software should be used by teachers and students (y12); and whether all students have to acquire some experience with computers before their graduation (y13). This policy information was provided by the principal of the school.

η8 *Internal staff development*. The information on this variable comes from the computer coordinator. Three items are employed. These measure whether there is training available for teachers in the school with respect to: a course on the use of application programs (y14); a course in computer programming (y15); and a course on how to use computers for teaching in specific subjects (y16).

η9 *Internal innovation assistance*. Subject teachers in schools were asked whether internal support was available at school level to solve problems arising from: the use of software (y17); the use of computers in instruction (y18); and the organization of the teaching and learning process (y19). This information, which gives an indication of the assistance available to teachers who use computers for instruction, is aggregated to school level by using the highest score of all teachers on each of the items per school.

η10 *Teacher competence and readiness*. Subject teachers were sampled for the subject matter areas computer education, mother tongue, mathematics and science in each sampled school with computer use. As already indicated in Chapter 2, readiness involves the availability of prerequisite knowledge of the individual teacher. In the Comped study teachers, whether user or nonuser, were asked to indicate by checking 'yes' or 'no' whether they had the knowledge or could perform the tasks mentioned in statements on: (a) knowledge of computers and applications [I know ..., 9 items]; (b) the ability to write or adapt software [I can write a program for ..., 5 items]; and (c) the capacity to actually use computers as an aid in instruction [I am capable of ..., 8 items]. A total score was computed per teacher. As this factor indicates the knowledge and skill level available at school, the teacher with the highest score was selected, representing the (maximum) level of computer knowledge available at school (y20).

η11 *Monitoring and problem coping strategy*. Three items of the school questionnaire are employed for measuring whether monitoring procedures are used in the school. These items are based on responses to questions asking whether teachers in the school meet to exchange information and experiences (y21); the schools' exchange of information about the use of computers with other schools (y22); and how often internal evaluation procedures on computer use are applied (y23).

η12 *Implementation of computer use*. This outcome variable is based on information provided by the computer coordinator. As concluded in Chapter 4, computer use in Dutch lower secondary education is primarily determined by individual teachers. The variation in approaches of computer use as well as the amount of computer use is limited for almost all teachers. This means that the amount of time that individual students are exposed to computers is primarily determined by the number of subjects in which computers are used. In this study two indicators are used for measuring the degree of computer use: the number of subjects in which computers are used as well as the number of teachers who use computers.

The variable indicating the number of subjects with computer use (y24) has rank scale scores from 4 to 0 from the highest to the lowest categories. It is based on the use of computers for educational purposes in four subjects, namely computer education, mother tongue, mathematics and science. A value of 0 indicates that, in a given school, computers are not used for educational purposes in any of these four subjects. In contrast, a value of 4 indicates that computers are used for educational purposes in all four subjects. It must be noted that only information with respect to the target grade 8 is used in measuring the number of subjects with computer use, although similar information is also collected on computer use in the adjacent grades. There are two reasons for this decision. First, the items measuring computer use in grades 7, 8 and 9 showed very high correlations. Second, the items involving grade 8 were shown in one-factor models to have the highest reliability.

The second indicator refers to the width of computer use and counts the presence of teachers who use computers within each of the departments (y25).

Reliability of the measurement model

For each latent variable or construct for which there are two or more observed indicators, the LISREL program estimates the measurement errors from the covariances sets among the variables (Jöreskog & Sörbom, 1989a). As illustrated by the measurement model above, this is the case for the following seven constructs: 'availability and resource needs' ($\eta 5$), 'perceived innovation relevance' ($\eta 6$), 'school policy for computer use' ($\eta 7$), 'internal staff development' ($\eta 8$), 'internal innovation assistance' ($\eta 9$), 'monitoring and problem coping strategy' ($\eta 11$) and the outcome variable 'implementation of computer use' ($\eta 12$).

Due to the availability of a single item, a measurement error could not be estimated by the LISREL program for the five remaining constructs. The following strategy was followed to estimate and assign error terms to these constructs. The variables 'school size' ($\eta 1$), 'external financial support' ($\eta 2$) and 'previous innovation experience' ($\eta 4$) are represented by an exact number, subsequently the number of students enrolled in the school, the provision of financial support for computer use, and the number of years of experience that schools have with computers. For each of these variables a reliability of 0.85 is assumed.

From previous research it is known that single-item variables based on respondents' answers to a question tend to be measured imperfectly. Moreover, the reliability is not only influenced by measurement error but also other sources of error, such as sampling error and specification error (Thorndike, 1992). Because it cannot be assumed that these single-item variables are totally free of such errors, it is more reasonable to assign a value to the error term than to ignore the likelihood of error altogether. Following Munck (1979) and Tuijnman (1989), the error terms of these three variables are therefore set at the value of 0.15 units.

The remaining two variables 'external training support' (η3) and 'teacher competence and readiness' (η10) are included in the measurement model as observed variables, but both are actually based on a list of items represented by a scale score. 'External training support' is based on a set of 10 items. The reliability of these items could be estimated by using a scale analysis procedure (Cronbach alpha) and subsequently these findings could be included as fixed values for measurement error in the LISREL program. For the variable 'external training support' a reliability of 0.78 was found.

The same procedure was used for estimating the reliability of 'teacher competence and readiness'. This variable is based on a set of 22 items and showed a reliability of 0.90.

The loadings of the observed variables in measuring their constructs are obtained with the use of the linear structural relations (LISREL) approach and the maximum likelihood method (Jöreskog & Sörbom, 1989a). The squared factor loadings can be interpreted as lower bound estimates of reliability of the measures making up the constructs (Jöreskog & Sörbom, 1993a). The factor loadings and unique variances of the items used to measure the constructs are listed in Table 5.1.

Building the exploratory structural model

After the set of constructs and their corresponding observed variables were established, the next step in the analyses comprised the building of the structural model. The starting point for this phase was a fully recursive model in which the variables were ordered according to the sequence depicted in Figure 2.1 (Chapter 2). This figure assumes the following sequence of variables explaining the outcome variable 'implementation of computer use': first, the set of variables related to the exogenous preconditions (η1: school size; η2: external financial support; η3: external training support; and η4: previous innovation experience); second, the endogenous adoption conditions (η5: resources; η6: relevance and η10: readiness); and third, the endogenous implementation conditions (η7: school policy; η8: staff development; η9: internal innovation assistance; η11: monitoring). The results of the analyses on the data set of 1989 showed that this sequence of variables could not be completely confirmed by the data.

Table 5.1

The measurement model underlying the exploratory analysis of the Dutch Comped data of 1989

Construct	y_i	Item	Factor Loading λ_y	t	Unique Variance θ_ε	t	No items	Notes
η_1	y_1	School size	.85	n.a.	.26	n.a.	1	Assumed α
η_2	y_2	External financial support	.85	n.a.	.26	n.a.	1	Assumed α
η_3	y_3	External training support	.78	n.a.	.40	n.a.	10	Estimated α
η_4	y_4	Previous innovation experience	.85	n.a.	.26	n.a.	1	Assumed α
η_5	Availability and resource needs						3	Estimated *R*
	y_5	need more powerful computers	.78	n.a.	.39	2.85		
	y_6	need network for disk storage	.73	4.41	.46	3.72		
	y_7	need more tool software	.33	4.04	.87	10.55		
η_6	Perceived innovation relevance						3	Estimated *R*
	y_8	computers increase productivity	.76	n.a.	.42	6.89		
	y_9	computers increase achievement	.89	10.13	.19	2.80		
	y_{10}	computers improve learning	.54	8.64	.74	10.48		
η_7	School policy for computer use						3	Estimated *R*
	y_{11}	priorities for instructional use	.72	n.a.	.50	4.53		
	y_{12}	prescribe soft- and hardware	.54	4.86	.71	8.31		
	y_{13}	instruction with computers	.47	4.69	.78	9.35		
η_8	Internal staff development						3	Estimated *R*
	y_{14}	course on application programs	.58	n.a.	.64	9.55		
	y_{15}	course in computer programming	.85	7.93	.28	3.71		
	y_{16}	subject specific course in computer use	.66	7.87	.56	8.25		
η_9	Internal innovation assistance						3	Estimated *R*
	y_{17}	software support given to teachers	.83	n.a.	.33	7.97		
	y_{18}	instructional support given to teachers	.95	6.12	.09	2.17		
	y_{19}	organizational support given to teachers	.73	4.24	.46	9.87		
η_{10}	y_{20}	Teacher competence and readiness	.92	n.a.	.15	n.a.	22	Estimated α
η_{11}	Monitoring and problem coping strategy						3	Estimated *R*
	y_{21}	internal information exchange	.72	n.a.	.48	5.78		
	y_{22}	external information exchange	.59	5.51	.64	7.25		
	y_{23}	internal evaluation of computer use	.79	6.50	.36	3.68		
η_{12}	Implementation of computer use						2	Estimated *R*
	y_{24}	number of subjects with computer use	.91	n.a.	.15	n.a.		
	y_{25}	number of teachers using computers	.50	8.70	.74	10.78		

Legend: n.a. = not applicable; λ_y = factor loading; t = t-value; θ_ε = variances of error

Based on the theoretical consideration that the relation between both sets of endogenous conditions (see Figure 2.1), subsequently referring to adoption and implementation, is '*loosely coupled and interactive' (*Fullan, 1991, p. 64), it was decided to change the order position of the variable 'teacher competence and readiness'. In terms of the framework of Figure 2.1, this variable was mentioned as an 'adoption condition'. Based on the above considerations it was moved to the set of factors labelled 'implementation conditions'. Apparently, the way 'teacher competence and readiness' is operationalized in this study makes it better fitting to the implementation conditions than adoption conditions.

As mentioned before, specifying an exploratory LISREL model is an iterative process of model specification and fit assessment. Large measurement errors that negatively affect the validity of the constructs is the most common problem during the starting phase of model building. If the measurement errors are large, this usually means that significant correlations are also found among the residual variances of the error terms. Therefore, the model has to be modified by changing the measurement model, by removing variables, by allowing an indicator to be associated with more than one latent construct, or by explicitly allowing for correlations among the residuals.

After refining the model several times, the model presented in Figure 5.3 was fitted to the data.

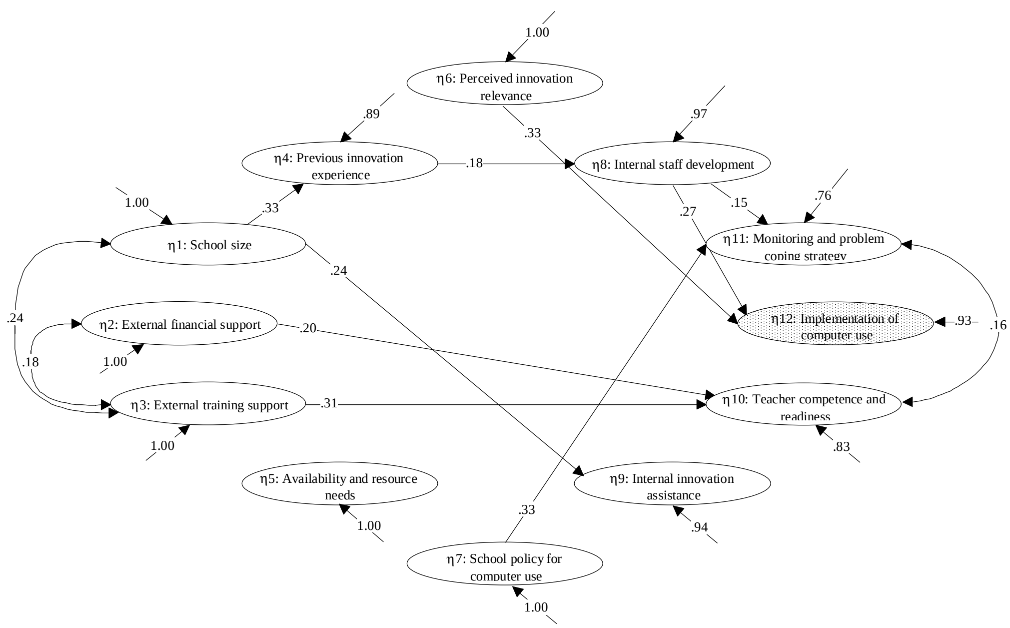


Figure 5.3 Standardized effects on the implementation of computer use in Dutch lower secondary schools in 1989 (exploratory model)

This figure shows the overidentified recursive path model, which means that non-significant path coefficients have been removed. The non-significant paths have been removed one by one in ascending order of significance. One-way arrows are used to indicate the impact of one variable on another. Each path represents a statistically significant standardized regression relationship. The paths not shown in the model failed to reach the five percent threshold level of significance.

The LISREL program provides a number of statistics for estimating model fit. The basic idea in assessing model fit is to determine the degree of similarity between the sample data and the structure specified in the model. Assessment of model adequacy involves a number of criteria, some of which bear on the fit of the model as a whole, and others on the fit of individual parameters. Table 5.2 gives an overview of the most often used goodness-of-fit measures.

Studies on finding the minimum sample needed for LISREL model building indicate that at least 200 cases are required. If the number of cases is smaller, the goodness-of-fit indices may have insufficient power to detect substantial differences (Boomsma, 1983; Hayduk, 1987; Jöreskog & Sörbom, 1989a). As shown in Table 5.2, the number of cases that were used for the exploratory analyses (247) exceeds the lower limit for multivariate analyses.

The overall fit of the model to the data is represented by a chi-square measure for goodness-of-fit. It measures the distance or difference between the sample covariance matrix and the fitted covariance matrix.

Table 5.2
Estimates of the goodness-of-fit of the exploratory model and data

Number of cases	247
Chi-square	261.68
Degrees of freedom	241
Probability	0.17
Goodness-of-fit index	0.93
Root mean square error of approximation (RMSEA)	0.018
90 percent confidence interval for RMSEA	0.0 - 0.032
Number of fitted residuals	25
Unfitted residuals with standardized values ≥ 2.0 or ≤ -2.0	2

Actually, the chi-square is a badness-of-fit measure in the sense that a small chi-square corresponds to a good fit. The fit of a model may be judged acceptable if the chi-square value is close to the number of degrees of freedom (in the present study the chi-square is 261.68 with 241 degrees of freedom), the probability value is greater than 0.10, the goodness-of-fit index exceeds 0.90, the root mean square error of approximation lies below 0.05 and the number of unconstrained residuals with standardized values outside the range from -2.0 and 2.0 is small (Jöreskog & Sörbom, 1993a; Bollen, 1989). The estimates of goodness-of-fit as presented in Table 5.2 indicate that the model adequately fits to the sample data.

Validity of the structural model

It is common practice to test the stability of parameters estimated in structural equation models by cross-validating the results on a split-half independent sample (Reynolds & Walberg, 1991). Instead of employing an artificially created split-half sample, a more elaborate and rigorous approach to cross-validation could be executed in the Comped study because of the availability of data sets from other countries. Data from five different systems (France, Germany, Japan, Switzerland and the United States) were used to test the exploratory model. The measurement model needed minor modifications for some countries but the model could be identified with adequate estimates of goodness-of-fit in all five countries. This means that the measurement model for all five countries included almost the same items as presented for the Dutch model in Table 5.1. Based on this finding, it is concluded that the identified variables serve as predictors of computer use in all studied countries. The structural model for each of the five studied countries is included in Appendix 3.

The findings on the structural models for these countries show variation in terms of the factors that influence the use of computers. According to Tuijnman and ten Brummelhuis (1993), this variation among the countries can be explained by differences in the stage of the innovation process in the different countries and country specific policies for the introduction of computers.

Discussion of findings

Figure 5.3 shows the following substantive findings on the exploratory model for the implementation of computers in education. First, the variables 'perceived innovation relevance' (.33) and 'internal staff development' (.27) are the two variables exerting a direct, significant effect on the implementation of computer use. Second, indirect effects are found from 'school size' and 'previous innovation experience' via 'internal staff development' on 'implementation of computer use'. These results indicate that larger schools seem to have more years of experience with the introduction of computers, which subsequently has a positive influence on the degree of staff development. Internal staff development is measured by the opportunity for teachers to attend different computer courses within schools.

The Dutch model shows only a few direct and indirect relationships on computer use. However, the results do show significant effects from ‘school policy’ and ‘internal staff development’ on ‘monitoring’ as well as from ‘external training support’ and ‘financial support’ on ‘teacher readiness’, but the variables ‘readiness’ and ‘monitoring’ do not significantly influence computer use in 1989.

For fully understanding this exploratory model, it is important to note that in 1989 computers were only to a small extent introduced and integrated in lower secondary schools (see for more details about this Dutch situation, Chapter 4). The measurement model fits adequately to the data of 1989 but a relatively small proportion of the variance (.07) in implementation of computer use is explained by the model. These findings indicate that there must be either a number of additional factors influencing the successful implementation of computer use in Dutch lower secondary schools, or the effects are too weak to measure factors significantly influencing computer use in this phase of implementation.

The results of the confirmatory analyses on data collected in 1992 have to show whether this model is adequate to identify more substantial effects on the implementation of computer use. The results of the confirmatory analyses are presented in the next chapter.

Summary

In this chapter results of analyses aiming at the development of an exploratory model for the implementation of computers underlying the Dutch Comped data of 1989 are presented. These analyses resulted in a hypothesized model that will be tested in a confirmatory analysis on data collected in 1992. The exploratory model shows that, in the early phase of implementation, the degree of computer use in Dutch lower secondary schools is directly influenced by the perceived relevance of computer use and activities on internal staff development. Results of confirmatory analyses have to show whether a greater proportion of variance in the outcome variable can be explained by the antecedent factors of the model when the implementation of computer use in Dutch lower secondary schools is taking place for three more years.

6

Confirming and Refining the Exploratory Model

This chapter describes the results obtained in a confirmatory analysis of the hypothesized model presented in the previous chapter. Confirmatory analysis involves the testing of an *a priori* specified model against data. The confirmatory and exploratory models are measured with identical variables. The exploratory model was developed using data collected from a sample of Dutch lower secondary schools in 1989, while the confirmatory analysis is based on data from a repeated data collection from the same population in 1992.

In the previous chapter it was presumed that the exploratory model explained a small proportion of the variance in the outcome variable due to the small extent of computer implementation in 1989. As shown in Chapter 4, computer use in Dutch lower secondary schools increased substantially from 1989 to 1992. Hence it is expected that a larger proportion of the variance in the outcome variable will be explained in the 1992 model compared to the 1989 model.

Checking a model against empirical evidence is the only means of establishing its validity. According to Keeves (1994), building or exploring a model without testing it is a pointless exercise. As model building is an iterative process, the results of the test against empirical evidence forms the basis for further improvement. Therefore, the second part of this chapter describes a refined model that takes account of the results from the confirmatory analysis of data.

Confirmatory test of the exploratory model

In this section the validity of the hypothesized model on the implementation of computers in education is established by means of a test against empirical evidence. The results of the measurement model are presented first and the findings for the structural model subsequently.

The confirmatory measurement model

The data set used for the confirmatory analysis is derived from the Dutch Comped data collected in 1992. The procedure used for file building was identical to the one applied for the exploratory analysis described in the previous chapter. The applied set of constructs and their indicators are identical as well. This means that the measurement model used for the confirmatory analysis of the 1992 model is entirely identical to the one used for the 1989 model.

Table 6.1

The measurement model underlying the confirmatory analysis of the Dutch Comped data of 1992

Construct	y_i	Item	Factor Loading λ_y	t	Unique Variance θ_ε	t	No items	Notes
η_1	y_1	School size	.85	n.a.	.26	n.a.	1	Assumed α
η_2	y_2	External financial support	.85	n.a.	.26	n.a.	1	Assumed α
η_3	y_3	External training support	.78	n.a.	.40	n.a.	10	Estimated α
η_4	y_4	Previous innovation experience	.85	n.a.	.26	n.a.	1	Assumed α
η_5	Availability and resource needs						3	Estimated *R*
	y_5	need more powerful computers	.80	n.a.	.36	2.17		
	y_6	need network for disk storage	.37	3.47	.87	10.51		
	y_7	need more tool software	.32	3.35	.88	10.91		
η_6	Perceived innovation relevance						3	Estimated *R*
	y_8	computers increase productivity	.93	n.a.	.13	1.93		
	y_9	computers increase achievement	.71	10.13	.51	8.71		
	y_{10}	computers improve learning	.48	7.47	.76	11.26		
η_7	School policy for computer use						3	Estimated *R*
	y_{11}	priorities for instructional use	.67	n.a.	.55	7.94		
	y_{12}	prescribe soft- and hardware	.42	5.79	.82	10.87		
	y_{13}	instruction with computers	.62	7.43	.62	8.96		
η_8	Internal staff development						3	Estimated *R*
	y_{14}	course on application programs	.58	9.31	.66	10.95		
	y_{15}	course in computer programming	.92	n.a.	.16	2.45		
	y_{16}	subject specific course in computer use	.65	9.85	.58	9.69		
η_9	Internal innovation assistance						3	Estimated *R*
	y_{17}	software support given to teachers	.91	n.a.	.17	5.03		
	y_{18}	instructional support given to teachers	.74	15.79	.44	10.51		
	y_{19}	organizational support given to teachers	.86	18.30	.29	8.01		
η_{10}	y_{20}	Teacher competence and readiness	.92	n.a.	.15	n.a.	22	Estimated α
η_{11}	Monitoring and problem coping strategy						3	Estimated *R*
	y_{21}	internal information exchange	.73	n.a.	.51	8.16		
	y_{22}	external information exchange	.79	9.63	.41	7.02		
	y_{23}	internal evaluation of computer use	.61	10.27	.64	9.53		
η_{12}	Implementation of computer use						2	Estimated *R*
	y_{24}	number of subjects with computer use	.92	n.a.	.15	n.a.		
	y_{25}	number of teachers using computers	.48	8.41	.77	11.30		

Legend: n.a. = not applicable; λ_y = factor loading; t = t-value; θ_ε = variances of error

The congruence between both measurement models suggests that possible differences in findings between the corresponding structural models will not be caused by differences in the measurement specifications but are related to the structure underlying the data.

The computation of optimal correlations among the observed variables was done according to the procedure applied to the data set of 1989. The correlation matrix for the variables used in the confirmatory analysis is presented in Appendix 4. The factor loadings and unique variances, which offer indications of reliability and validity, of the variables used to measure the indicators are listed in Table 6.1.

The confirmatory structural model

Based on findings in previous research (described in Chapter 2) as well as the between-country validation of the exploratory model (described in Chapter 5), it was hypothesized that the factors influencing computer use are related to the degree of implementation. This means that the impact and interrelatedness of the factors possibly influencing the implementation of computer use in schools depend on the stage of the innovation. As mentioned in Chapter 2, this proces involves several stages as adoption, implementation and institutionalization. It can be expected that the process of adoption is influenced by a different set of factors than the process of implementation. The findings in other countries in particular showed that the identified variables served as predictors of computer use in all countries, but the extent of interrelatedness varied among countries because of the different stages of implementation in each of the countries (see Chapter 5 and Appendix 3).

In the case of the Netherlands the implementation of computers made substantial progress during the period 1989-1992. Therefore, it is expected that, similar to the differences between countries in 1989, compared to the exploratory model the findings of the confirmatory model will show a different pattern of interrelatedness of factors. This is the reason why the data analyses began with the fully recursive model. Paths which were not statistically significant at the five percent threshold level were removed in ascending order of significance. Figure 6.1 shows the resulting overidentified recursive model fitted to the Dutch data of 1992. Each depicted path represents a statistically significant standardized regression relationship.

The model in Figure 6.1 shows that the antecedent variables explain 26 percent of the variance in the outcome variable. This is almost four times as much as the proportion of variance explained by the exploratory model. This finding confirms the expectation that more variance is explained by the model when the degree of computer use is more advanced.

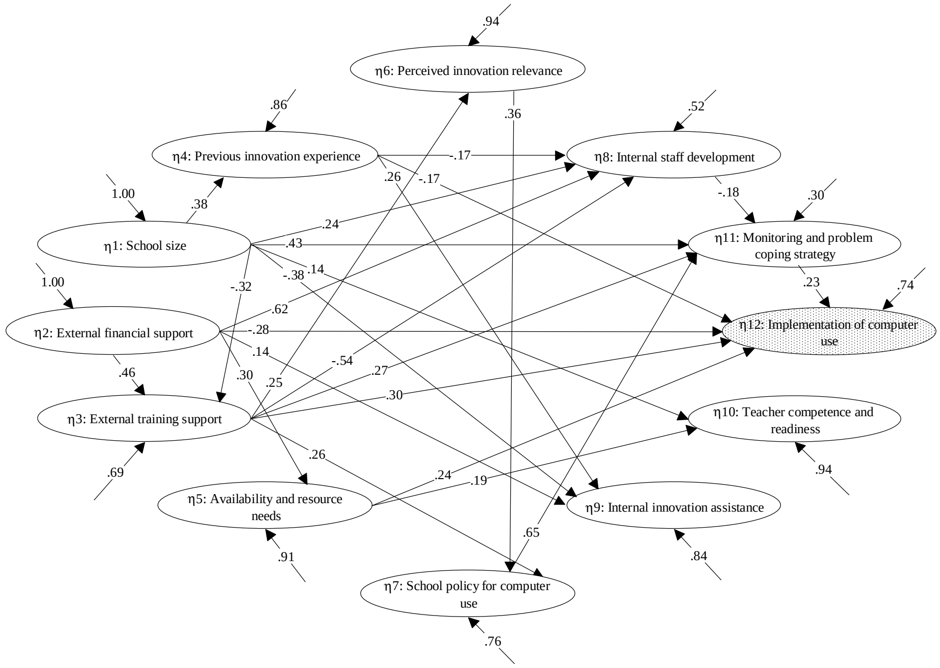


Figure 6.1 Standardized effects on the implementation of computer use in Dutch lower secondary schools in 1992

The statistics in Table 6.2 indicate that the goodness-of-fit of the data to the model is adequate. It can be seen that the model has 227 degrees of freedom and an overall chi-square estimate of 251, which corresponds with a probability value of 0.13. Explanation of this and other statistics are presented in the previous chapter.

Table 6.2

Estimates of the goodness-of-fit of the confirmatory model and data

Number of cases	281
Chi-square	251.53
Degrees of freedom	227
Probability	0.13
Goodness-of-fit index	0.94
Root mean square error of approximation (RMSEA)	0.020
90 percent confidence interval for RMSEA	0.0 - 0.033
Number of fitted residuals	25
Unfitted residuals with standardized values ≥ 2.0 or ≤ 2.0	4

Also other goodness-of-fit statistics indicate that the confirmatory model adequately fits to the sample data of 1992. The goodness-of-fit index exceeds 0.90 and the root mean square error of approximation as well as the corresponding 90 percent confidence interval lies below 0.05. It can be concluded that the exploratory model is adequately reproduced by the confirmatory analyses.

Findings and implications for model building

In this section the results of the structural model will be discussed in order to identify those variables contributing to the explanation of implementation of computer use in Dutch lower secondary schools in 1992. Subsequently, variables with a meaningful contribution to the implementation of computer use will be included in a simplified model that will be tested against the same data of 1992. This means that variables without a meaningful direct or indirect influence on implementation of computer use will be excluded from the simplified model.

The path coefficients in Figure 6.1 indicate that five indicators have a direct significant effect on the outcome variable ‘implementation of computer use’ (η12). Positive effects on computer use are found for ‘monitoring and problem coping strategy’ (η11: 0.23), ‘availability and resource needs’ (η5: 0.24), and ‘external training support’ (η3: 0.30).

The variables ‘previous innovation experience’ (η4: -0.17) and ‘external financial support’ (η2: -0.28) exert a negative influence on the implementation of computer use. This means that schools which started early with the introduction of computers are no longer the forerunners in computer use in 1992. This effect was already found in other countries (see Chapter 4) and it seems that also within a country at school level the forerunners of the 1980s have become the laggards of the early 1990s. This could be explained by the fact that when the first schools started with the introduction of computers it was often initiated by individual enthusiastic teachers. As concluded in Chapter 4, many lower secondary schools did not succeed in involving other teachers in the use of computers. Despite the number of years of experience with computer use in these schools, the implementation of computers has been an activity that very much depended on the individual teacher and often did not get embedded in the curriculum. It can be concluded that the years of experience of computer use do not seem to be an indicator for the degree of implementation of computers at school level.

The direct negative effect from ‘external financial support’ on ‘implementation of computer use’ indicates that providing finances to schools does not directly stimulate the actual use of computers. Beside this negative path the variable ‘external financial support’ (η2) has several positive effects on other variables. The path on ‘external training support’ (η3: 0.46) is noteworthy as the latter subsequently positively influences ‘implementation of computer use (η12: 0.30). This means that the provision of ‘external financial support’ only exerts a positive effect on the implementation of computers in combination with other measures such as ‘external training support’.

In addition to this causal chain, the model also shows a link between ‘external financial support’ (η2), via ‘availability and resource needs’(η5), to ‘implementation of computer use’ (η12). This indicates that the provision of finances to schools with an actual need for hardware and software contributes to the implementation of computers.

A third causal chain between ‘external financial support’ (η2) and ‘implementation of computer use’ (η12) has substantial paths via ‘external training support’ (η3), ‘perceived innovation relevance’ (η6), ‘school policy for computers’ (η7), and ‘monitoring and problem coping strategy’ (η11). The variables belonging to one or more of these causal chains illustrate the interrelatedness of factors influencing the implementation of computers.

It can be seen from Figure 6.1 that ‘school size’ (η1) has negative path coefficients towards ‘external training support’ (η3: -0.32) and ‘internal innovation assistance’ (η9: -0.38). At the same time ‘school size’ (η1) has positive path coefficients towards ‘internal staff development’ (η8: 0.24), ‘teacher competence and readiness’ (η10: 0.24), and ‘monitoring and problem coping strategy’ (η11: .43). Although the latter path could be indicated as meaningful for a causal chain from ‘school size’(η1) via ‘monitoring and problem coping strategy’ (η11) on ‘implementation of computer use’ (η12), the influence of ‘school size’ (η1) in the model is not consistent because of both positive and negative effects. This inconsistency can be explained by the large number of schools that have merged in the Netherlands during the period 1989-1992. As a consequence of the process of school merging the number of lower secondary schools decreased substantially, and at the same time the average school size increased enormously. Given this situation, it was decided to exclude the variable ‘school size’ from the simplified model. When the process of scale enlargement of lower secondary schools has been completed, it might be relevant to include this variable in research projects again.

Compared to the model of 1989 (see Chapter 5), no direct influence from ‘internal staff development’ (η8) on ‘implementation of computers’ is found. This indicates that ‘internal staff development’, measured by the availability of introductory training opportunities in the school with respect to computer use, has a positive influence on the implementation of computers during the starting phase, but this factor loses its influence in a later stage of implementation. The results in

Figure 6.1 show that the availability of 'external training support' (η3) has more impact on the 'implementation of computer use' than 'internal staff development'. It is noteworthy that 'external training support' has a negative path coefficient (-.54) on 'internal staff development'. This negative path could indicate that schools with 'external training support' succeeded in implementing computers in classes more often than schools only providing introductory courses to their teachers, most probably organized by the computer education teacher or the computer coordinator. It can be concluded that 'internal staff development' is not a relevant factor for explaining the implementation of computer use in 1992.

'Internal innovation assistance' (η9) as well as 'teacher competence and readiness' (η10) are the only two variables in the model that do not exert any significant influence on other variables. This means that these two variables in the way they are operationalized in this study, are not crucial for a good understanding and explanation of the implementation of computer use at Dutch lower secondary schools in 1992.

The findings on the confirmatory model show that the following set of variables exert a meaningful direct and/or indirect influence on the implementation of computer use in Dutch lower secondary schools in 1992:

- external financial support (η2);
- external training support (η3);
- availability and resource needs (η5);
- perceived innovation relevance (η6);
- school policy for computer use (η7);
- monitoring and problem coping strategy (η11).

This set of six variables form the basis for testing a simplified model, under the assumption that a comparable proportion of variance explained by the extended confirmatory model can be explained by the factors belonging to the hypothesized simplified model.

Simplified model

The factor loadings and unique variances of the variables belonging to the simplified model are shown in Table 6.3. For reasons of comparability with the previous measurement models, all variables used for the exploratory and confirmatory model are listed in this table.

Table 6.3
The measurement model underlying the confirmatory analysis of the simplified model

Construct	y_i	Item	Factor Loading λ_y	t	Unique Variance θ_ε	t	No items	Notes
η_1	y_1	School size						Not included
η_2	y_2	External financial support	.85	n.a.	.26	n.a.	1	Assumed α
η_3	y_3	External training support	.78	n.a.	.40	n.a.	10	Estimated α
η_4	y_4	Previous innovation experience						Not included
η_5		Availability and resource needs					3	Estimated *R*
	y_5	need more powerful computers	.93	n.a.	.13	0.41		
	y_6	need network for disk storage	.33	2.57	.90	10.57		
	y_7	need more tool software	.27	2.44	.93	11.17		
η_6		Perceived innovation relevance					3	Estimated *R*
	y_8	computers increase productivity	.95	n.a.	.11	1.32		
	y_9	computers increase achievement	.69	9.21	.53	8.52		
	y_{10}	computers improve learning	.49	7.24	.76	11.11		
η_7		School policy for computer use					3	Estimated *R*
	y_{11}	priorities for instructional use	.67	n.a.	.56	7.82		
	y_{12}	prescribe soft- and hardware	.43	5.54	.82	10.75		
	y_{13}	instruction with computers	.60	7.08	.63	9.02		
η_8		Internal staff development					3	Not included
η_9		Internal innovation assistance					3	Not included
η_{10}	y_{20}	Teacher competence and readiness						Not included
η_{11}		Monitoring and problem coping strategy					3	Estimated *R*
	y_{21}	internal information exchange	.65	n.a.	.60	8.69		
	y_{22}	external information exchange	.79	7.97	.38	5.36		
	y_{23}	internal evaluation of computer use	.54	8.72	.71	9.96		
η_{12}		Implementation of computer use					2	Estimated *R*
	y_{24}	number of subjects with computer use	.92	n.a.	.15	n.a.		
	y_{25}	number of teachers using computers	.45	7.81	.78	11.32		

Legend: n.a. = not applicable; λ_y = factor loading; t = t-value; θ_ε = variances of error

The column 'notes' indicates which latent variables are not included in the simplified model. For obvious reasons the factor loadings in the simplified model are almost identical to the measurement model presented in Table 6.1. Minor differences between both models can be explained by the removal of fitted residuals on observed variables due to the exclusion of several latent variables in the simplified model. Compared to the extended model the goodness-of-fit of the simplified model has slightly improved. The probability value increased from 0.13 for the extended confirmatory model to 0.20 for the simplified model. The most substantial difference between both models is the decrease of 21 fitted residuals. This indicates that less variables are beset with correlated measurement errors.

Table 6.4
Estimates of the goodness-of-fit of the simplified model and data

Number of cases	281
Chi-square	102.05
Degrees of freedom	91
Probability	0.20
Goodness-of-fit index	0.96
Root mean square error of approximation (RMSEA)	0.021
90 percent confidence interval for RMSEA	0.0 - 0.040
Number of fitted residuals	4
Unfitted residuals with standardized values ≥ 2.0 or ≤ 2.0	1

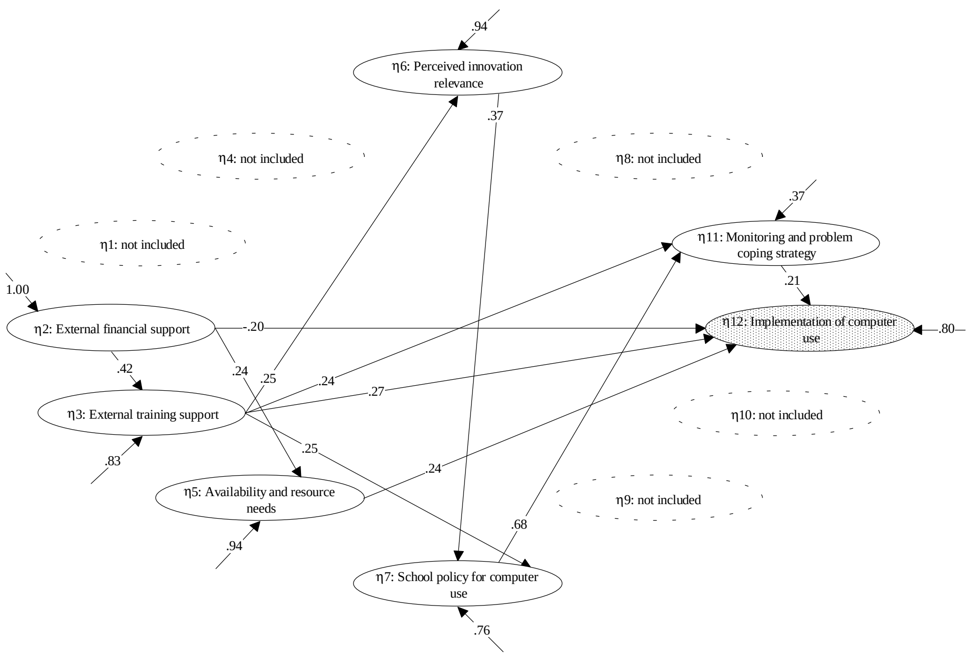


Figure 6.2 Simplified model with standardized effects on the implementation of computer use in Dutch lower secondary schools in 1992

The simplified structural equation model is presented in Figure 6.2. In contrast to the extended confirmatory model, this model shows only variables exerting direct or indirect influence on the implementation of computer use. All path coefficients are almost identical to the measures in the extended exploratory model. The proportion of explained variance in the outcome variable decreased with 6 percent from 26 percent to 20 percent. Compared to the decrease of 5 predictor variables this decrease is rather small. It can be concluded that the simplified model is able to explain the computer use in Dutch lower secondary schools in 1992 more efficiently than the extended exploratory model.

Discussion of findings emerging from the confirmatory analyses

Results emerging from the confirmatory analyses confirm the hypothesized set of constructs underlying the Comped data. Results from the extended confirmatory model (Figure 6.1) show a larger number of significant paths compared to the exploratory model of 1989 (Figure 5.1) and also show more constructs exerting a significant influence on the outcome variable 'implementation of computer use'. These results confirm the hypothesis that the factors influencing computer use are related to the stage at which the innovation has advanced. It is concluded that the factors identified on the basis of theories of educational change do not have equal impact during all stages of the process of introducing computers in education. The stage of computer introduction in Dutch lower secondary schools in 1992 can be characterized as the stage of implementation. At that time almost all schools were putting the intended educational change of using computers for educational purposes into practice.

In the model of 1989 the greatest proportion of variance was explained in the variable 'monitoring and problem coping strategy' (η11). This variable was predicted by two variables explaining 24 percent of the variance. Especially the 'school policy for computer use' (η7) played a modest role in predicting 'monitoring and problem coping strategy'. However, 'monitoring and problem coping strategy' did not exert a significant influence on 'implementation of computer use' (η12) in 1989. The results of 1992 show that the greatest proportion of variance is again explained in the variable 'monitoring and problem coping' (extended confirmatory model: 70%; simplified model: 63%) and now this variable also exerts a meaningful influence on implementation of computer use. Identical to the model of 1989 the variable 'school policy for computer use' is the most important predictor for 'monitoring and problem coping strategy'. Based on the results of 1989 and 1992, it can be concluded that having a school policy is an important factor for the starting phase of implementation as well as for the continuation of the implementation process. The link between 'school policy for computer use' and 'monitoring and problem coping strategy' seems to be meaningful for the whole implementation process and is not limited to a specific phase of innovation such as adoption or implementation.

Knowing that school policy is one of the key factors in the implementation process, it is relevant to identify the variables predicting this factor. In 1989 no significant predictor was found for ‘school policy’. In 1992 two variables exert a significant influence on policy. Both ‘perceived innovation relevance’ ($\eta6$) and ‘external training support’ ($\eta3$) explain 24 percent variance in this variable. In addition, ‘external training support’ plays a role in predicting ‘perceived innovation relevance’.

Looking at the interrelatedness of factors influencing implementation of computer use, the simplified model shows that, with exception of ‘perceived innovation relevance’ and ‘school policy for computer use’, all variables exert direct influence on computer use. Two variables, ‘external financial support’ ($\eta2$) and ‘external training support’ ($\eta3$), have direct as well as indirect influence on the use of computers. In the simplified model it is easy to see that the interrelatedness of factors influencing the implementation of computer use consists of five different causal chains.

In arbitrary order, the first chain involves the paths between ‘external financial support’ and ‘external training support’ on ‘implementation of computer use’. The second chain also includes the path between ‘external financial support’ and ‘external training support’ but continues the impact on ‘implementation of computer use’ via ‘monitoring and problem coping strategy’. The third chain that can be identified consists of the paths between ‘external financial support’, ‘availability and resource needs’ and the outcome variable. The fourth chain is determined by the paths between ‘external financial support’, ‘external training support’, ‘school policy for computer use’, ‘monitoring and problem coping strategy’ and ‘implementation of computer use’. Finally, the fifth chain that influences the implementation of computers starts at ‘external financial support’ and continues via ‘external training support’, ‘perceived innovation relevance’, ‘school policy for computer use’, and ‘monitoring and problem coping strategy’.

The interrelatedness of factors and the identification of different causal chains confirms empirically what is stated by the theory on educational change: the more factors support implementation, the more change will be accomplished in practice. However, it has to be noticed that not all factors determined in the conceptual model have equal impact on the implementation of computer use. As shown by the analysis on the simplified model, 5 out of 11 antecedent variables of the extended confirmatory model could be excluded without a substantial drop in the amount of explained variance in the outcome variable. This means that some of the identified variables as operationalized in this study, do not really contribute to the implementation of computer use in the Netherlands.

It can be concluded from the structural model that the success or failure of educational change is not determined by the availability or absence of an individual factor but is primarily the result of a dynamic process involving interrelated variables. The factors relevant for the degree to which computer use is predicted, depend on the degree of implementation.

Summary

Results of the confirmatory analyses show that the factor structure underlying the Dutch Comped data set of 1992 is identical to the hypothesized structure developed on the Comped data of 1989. The exploratory model could adequately be reproduced by the confirmatory analysis. The findings on the confirmatory model show that six out of eleven antecedent factors identified in the conceptual model have a meaningful direct and/or indirect influence on the implementation of computer use in Dutch lower secondary schools in 1992. This set of six influencing variables on the implementation of computer use form a simplified model. The simplified model is tested on the data of 1992. The findings show that path coefficients are almost identical to the measures in the extended exploratory model and the decrease in proportion of explained variance in the outcome variable is small compared to the decrease of 5 predictor variables.

The results of both the extended and simplified confirmatory analyses show that the interrelatedness of factors influencing the implementation of computer use can be summarized by five different causal chains involving the six variables of the simplified model. From these causal chains it can be concluded that the success or failure of educational change is not determined by the availability or absence of an individual factor but is primarily the result of a dynamic process involving interrelated variables.

7

Summary and Discussion

This chapter includes two sections. The first section provides a summary of the key findings of the study while in the second one implications for educational policy, school practice, and further research are discussed. The findings of this study have to be placed in the perspective of model building. In educational research it can be helpful to develop models and to examine them systematically in order to advance theoretical understanding. Existing theories are not only important for the manner in which the data are to be analyzed. They may also suggest hypotheses and offer indications for the variables on which data have to be collected. As illustrated in the previous chapters, structural equation modeling is a tool for assisting in decisions about questions whether a hypothesized model is consistent with the empirical evidence. In case the model is not consistent with the data, either doubt may arise about the validity of the hypothesized model in which case the model has to be modified or the data are insufficiently suitable to answer the research questions posed. Results presented in this book illustrate that a model including a set of factors derived from theories on educational change fits the available data on implementation of computer use in education. However, as Tuijnman & Keeves (1994) state 'it is important to recognize that the consistency of a model with the data collected does not furnish *proof* of theory, but it may provide *support* of theory' (p.4340).

Summary of the key findings

The central theme of this study is the implementation of computers in education. Two research questions determine the focus in this study. These questions are:

- To which degree are computers used in Dutch lower secondary schools compared to the use in other countries?
- What factors influence the implementation of computers in Dutch lower secondary schools, and how important are these in predicting computer use?

Findings on the first question are described in Chapter 4, while the analyses on factors influencing computer use are presented in the Chapters 5 and 6. A summary of the major findings on each of the questions is presented in the next two paragraphs.

Degree of computer use

The degree of computer use is examined in a time-related as well as an international comparative perspective. Over-time comparisons for the period 1989-1992 show that the percentage of computer using schools, where teachers use computers in the subject computer education as well as in common subjects such as mother tongue, science and mathematics, increased substantially. However, this increase primarily concerns teachers within a department in which the computer up to then had not been used for instructional purposes by that teacher and his or her colleagues. Most of the lower secondary schools use computers in a new subject 'computer education'. This is in accordance with the Dutch policy for the implementation of computer use in lower secondary schools. Formulated in the early 1980s this policy aimed at introducing the use of computers via a separate subject then referred to as 'computer education'. In other subjects, only a small percentage of teachers frequently use computers during their lessons. Emphasis is given to drill and practice and the use of general application programs such as a word processor. The findings show that the conditions applied for the introduction of computer use as a separate subject are not sufficient to realize the integration of computer use in other subjects than 'computer education'. Additional activities are required to realize the use of computers as a medium supporting the learning activities of students.

Growth

When studying the growth of computer use in the period 1989-1992, the percentage increase of computer use in the Netherlands is comparable to that of Japan and Germany (see Chapter 4). In 1989, computer use in the United States was far ahead of the other studied countries. Based on a yield score with a range from 0 to 100, computer use in Dutch lower secondary schools increased from 37 in 1989 to 62 in 1992. During this period only a minor increase of computer use took place in the US-secondary schools; from 55 in 1989 to 66 in 1992. This minor increase can be explained by the theory of diminishing growth (the further you get, the more difficult it will be to achieve additional gain), but it resulted in the situation that the gap in computer use between the United States and other countries has become considerably smaller in 1992. Future studies are needed to show whether the rate of increase of computer use in Dutch lower secondary schools will slow down in the same way as apparently happened in the United States during the early 1990s.

Hardware

When examining computer use in Dutch lower secondary schools from an international comparative perspective it is noteworthy that the countries which started in the early 1980s with the introduction of computers in education (i.e., United States and the Netherlands), 10 years later were faced with often an often 'old-fashioned' infrastructure for information technology. The results show that with respect to the infrastructure for information technology as described in Chapter 4, Dutch lower secondary schools were ahead in the early 1980s, but became the laggards of the early 1990s. Countries which started relatively late with the introduction of computers, such as Austria and Japan, have at present more powerful computers than the countries which started early.

Software

In studying the diversity of the software programs available in the schools, it appeared that compared with other countries Dutch lower secondary schools have achieved the widest range of software products. This can be seen as an achievement of the Dutch stimulation policy, which determined the provision of all secondary schools with a set of software programs. Despite the high degree of availability of software in Dutch schools, in no other country is the lack of usable software and problems related to the integration of software in instructional practice experienced as being a hindrance in the implementation process as frequently as in the Netherlands. The explanation for this apparent contradiction appears to lie in the lack of practical usability of the programs that are available in the schools. According to teachers it takes too much time to prepare lessons in which the available programs can be tuned to the curriculum. It can be concluded that courseware development for computer use as an aspect of existing subjects needs to be tuned to the curriculum and integrated in textbooks in order to facilitate the implementation of computer use at school level as well as classroom level.

Dutch policy aims

An assessment of the effectiveness of Dutch stimulation policies since the early 1980s, as conducted in this study, shows that the following results have been achieved in the early 1990s:

- the establishment of an infrastructure for information technology in lower secondary schools (even though this infrastructure is relatively out of date);
- the implementation of a new subject (computer education) aimed at enabling all students to become familiar with information technology;
- incidental computer use in the subjects already part of the curriculum by a relatively small number of teachers.

Although the policy for the period 1989-1992 was aimed at broadening computer usage within the common subjects, in a substantial number of schools this aim was not realized in terms of embedding computer use in the curriculum of other subjects than 'computer education'. To change the situation that computer use in existing subjects strongly depends upon the interest of individual teachers, additional policy measures and corresponding support activities are necessary. This study offers some insights for devising strategies for improving scope and breadth of computer use. Indications for improvement of implementation can be derived from factors explaining the degree of computer use as mentioned below.

Factors explaining the degree of computer use

A set of factors was identified from theories on educational change expected to influence computer use in education. Subsequently, relationships were hypothesized and represented by a conceptual model. This model, shown in Figure 2.1, involves four frame factors: exogenous preconditions, endogenous adoption conditions, endogenous implementation conditions, and implementation outcomes. In this study, the implementation outcome refers to the degree of computer use at Dutch lower secondary schools. Each of the frame factors includes one or more variables which are described in Chapter 5. In this study, as in many social and behavioral studies, two basic problems had to be solved. The first problem concerns the question which indicators can be used for measuring the variables identified in the conceptual model. The second problem concerns the sequence of causal relationships among the constructs and the relative explanatory power of such relationships. To handle these problems the LISREL methodology was applied.

Stage of innovation

The findings show that, due to the increase of computer use during the period 1989-1992, more significant paths could be identified in the confirmatory model of 1992 as compared to the exploratory model of 1989. In the model of 1992 many constructs exert a significant influence on the outcome variable ‘implementation of computer use’. These results confirm the hypothesis based on the between-country comparisons of 1989, namely that the factors influencing computer use are related to the stage of innovation achieved by a school. It can be concluded that factors identified by the theories of educational change do not have equal impact during all stages of the innovation process of computer use in education.

The stage of computer use in Dutch lower secondary schools in 1989 can best be characterized as adoption or early implementation. For this stage two variables were found to exert a direct influence on computer use: ‘perceived innovation relevance’ and ‘internal staff development’. In 1992, almost all Dutch lower secondary schools used computers for educational purposes and, therefore, this stage refers to what is called ‘implementation’. The results of the confirmatory analyses on data of 1992 show that six variables contribute to the explanation of computer use in this phase of the implementation process. The influencing variables are: external financial support, external training support, availability and resource needs, perceived innovation relevance, school policy for computer use, and monitoring and problem coping strategy.

Interrelatedness

Testing 11 variables identified in the literature dealing with aspects of educational change (see Chapter 2) for their relevance for an innovation process - such as the implementation of computer use in Dutch lower secondary schools - this study reveals that the stage of implementation reached by schools determines which set of interrelated factors are most important. The interrelatedness of factors influencing the implementation of computer use can be summarized by five different causal chains among the six variables (external financial support, external training support, availability and resource needs, perceived innovation relevance, school policy for computer use, and monitoring and problem coping strategy). Most of the identified chains include the combination of support at national level (external to the school) and support at school level. This indicates that the implementation of computers in schools is not solely determined by support activities on either a national level or the school level but is most effective when external support reinforces school activities. The findings also show that the success or failure of implementing computers in education is not determined by the availability or absence of one individual factor but is primarily the result of a dynamic process involving a set of interrelated variables.

Perceived relevance of the intended innovation is the only factor exerting a significant influence during both the adoption and implementation stage. It is concluded that 'perceived innovation relevance' is, because of its duration of impact, expected to be one of the most crucial factors for successful implementation of new technologies in education. This finding, however, needs to be confirmed in subsequent research.

Implications for educational policy

The benefits of information and telecommunication technologies for educational purposes have been proclaimed for a long time. Although the applications based on these technologies develop rapidly, some key questions still go unanswered. This is the question of the effectiveness and actual benefits of the use of these technologies (Rodriguez-Roselló, 1993). Recently, several research projects started, for example ARTICULATE (1992), as part of the European Community's DELTA program (Development of European Learning through Technological Advance) in an attempt to answer this question. The results of the study presented in this book show the importance of the perceived relevance of the use of information technology and the provision of information about the benefits of computer use.

However, it is also concluded that the factors involved in this study can predict the degree of computer implementation only with a considerable risk of error. Educational innovations in general, but certainly in the field of information technology, are often part of a complex set of innovative activities such as technological innovations, economic innovations, and institutional innovations.

The role of information technology

Educational aims for information technology can be subdivided according to three different ways of using information technology: object, aspect and medium (Ministry of education, 1992a). Object use refers to learning about information technology and is often organized in a specific subject such as 'computer education' or 'informatics'. Information technology as an aspect is aimed at learning to handle specific applications of information technology as part of vocational training or job preparation. Information technology as medium for teaching refers to the use of information technology to improve and facilitate learning. A specific innovation can be aimed at more than one approach. This is also shown in the case of the Netherlands where the introduction of computers in lower secondary education started with the aim of introducing information technology as an 'object' (computer education) while it was broadened in a later stage to the use of information technology as a 'medium' or a 'tool'. The findings in this study show that in contrast to the potentialities of computers, they are mainly used by teachers to replicate an existing practice. Until now, the computer did not change the existing curriculum and didactical methods in a fundamental way. At this moment, tool use in lower secondary schools is often a substitute for existing drill and practice oriented learning activities.

Flexible learning

Most potential didactic models or learning environments that computers allow for, are not implemented in schools. Nevertheless, technology proceeds and computer hardware and software are becoming so sophisticated and powerful that computers are now being combined with other technologies to form promising new interactive multimedia for learning. Interactive multimedia refer to the combination of video, sound text, animation and graphics and the computer is used to tie these components together. Potential learning environments supported by new information and communication technologies range from the traditional one-to-many teaching model like educational television to the one-to-one learning model where the tutor is replaced by the computer through computer based instruction, simulations, CD-I or even where the tutor is present at a distance through audio and/or video two way communication. In addition, more and more potential benefits of computer use are claimed for learning higher-order thinking skills, for managing and manipulating information, and for creating text, graphics and music. The central concept of such a new learning environment supported by technology can be indicated by ‘flexible learning’ (Brande, 1993). Flexible learning enables learners to learn when they want (frequency, timing, duration), how they want (mode of learning), and what they want (that is, learners can define what constitues learning to them). Also the term ‘distance’ can be added to this concept (flexible distance learning) referring to the cases where the learners can choose where they want to learn (at home, at an institution, at a company, at a training center, etc.). In the short term, flexible distance learning seems to be most relevant for training in the sector of adult education (both employed and unemployed adults), but pilot studies also demonstrate the feasibility and relevance of these new ways of learning, for instance, for young children living in remote areas (Sullivan, Jolly, & Tompkins, 1994; Means, Schlager, & Poirier, 1994).

Lifelong learning

It is not yet known in which way computers and telecommunications will influence future learning at schools, but learning in future will surely be heavily supported by technology. Indications for these changes can already be found in the field of vocational training where the rapid economic changes have led to an increased demand for a continuing education provision or lifelong learning (OECD, 1994b). The growing training needs ask, according to the Comission of the European Communities (Brande, 1993), for learning situations responding to *flexibility* (adaptability to different needs), *accessibility* (learning when and wherever suits best) and *support* (an adequate infrastructure to assist learners). It is assumed that these criteria can be met by applying new information and communication technologies.

Schools of the future

Recognizing that the implementation of new information and communication technologies will be an important issue in the short term as well as in the long term, it is relevant to learn from lessons concerning the implementation of computers in education as described in this book. Although some argue that optimal use of the potential benefits of computers ask for a new learning paradigm in which learning is brought out of its embedded position in the current school system (Branson, 1987), the implications described below take the existing school system as starting point for further development and implementation of computers in schools. Implications on the following aspects are discussed subsequently: monitoring educational change, a top-down versus a bottom-up strategy, and transfer of findings.

Monitoring

Policy makers as well as educators have long speculated about why some reform efforts succeed better than others (Firestone & Corbett, 1988). The results presented in this study show for the case of the implementation of computers use in education that influencing factors do not operate as separate entities. Instead, they interact in complicated patterns. For policy makers in the field of education and innovation the findings of this study indicate that it is important to recognize that the number of significant influences and the varied ways in which they can interact in different stages of the process of educational change are so great that predictions about how an implementation process will proceed can only be made with a considerable risk of error. This finding stresses the importance of monitoring the implementation process. Characteristic for this approach is the systematic and regular procedures for data collection in order to determine the progress of the process (Husén & Tuijnman, 1994). Besides, monitoring provides help to correct mistakes. If policy makers, developers, and educators do not take the lessons learned during the introduction of computers seriously, interactive multimedia or any other new technology are unlikely to have more success in realising their potential benefits in schools. The implementation of information technology in education does not work according to a simplistic model in which the availability of an infrastructure automatically leads to the adoption and implementation of new strategies for teaching and learning offered by these tools. Effective implementation depends on the combination of different factors reinforcing each other as in an interrelated system. The more uncertainty there is about the prediction of the output of an innovation, the more important is the monitoring of how well or poorly a change is coming about.

Top-down versus bottom-up

As part of the review of literature on educational change (Chapter 2) a distinction was made between two different types of initiators of educational change: policy makers representing a strategy of educational change labelled as ‘top-down’, and teachers representing a strategy called ‘bottom-up’. The findings in this study show that most of the identified causal chains on the implementation of computer use involve both ‘top-down’ and ‘bottom-up’ elements. This means that for a successful implementation elements of both strategies are necessary. It can be concluded that both strategies are interrelated and can strengthen the outcome of the implementation process. An illustrative example of the interrelatedness of ‘top-down’ and ‘bottom-up’ elements is found in this study for the variable ‘external financial support’ (see Figure 6.1). The provision by the Dutch government of financial support to all schools to stimulate computer use can be seen as a top-down measure. The impact of this variable shows a direct negative effect on the intended implementation of computer use, but exerts a positive influence on the outcome in combination with other ‘top-down’ measures (external training support) and ‘bottom-up’ variables (‘perceived innovation relevance’, ‘school policy for computer use’, and ‘monitoring and problem coping strategy’). It can be hypothesized that the lack of success of innovations characterized by a top-down policy is caused by the deficiency of ‘bottom-up’ elements in the implementation process. From this point of view the decentralization (the ‘movement’ towards devolution of responsibilities from the central state to other stakeholders) in The Netherlands and other countries (OECD, 1994a), namely shifting the planning and support for implementation of educational change to the individual school and subsequently withdraw ‘top-down’ support, may result in the same lack of success as the previous policy dominated by ‘top-down’ measures. Educational change thus seems to be most successful when there is an *interaction* between local school conditions (which are denoted in the conceptual framework depicted in Figure 2.1 as ‘endogenous adoption conditions’ and ‘endogenous implementation conditions’) and the broader context (in the conceptual framework indicated by ‘external preconditions’).

Transfer

The results presented in the previous chapters might also be useful for policy makers in those countries where the introduction of computers in society started recently and where the educational system is not yet influenced on a large scale by this development. In these countries, the information on the factors that influence the implementation of computer use might be taken into account in an early stage of strategy and policy development. However, it has to be noted that the impact of variables is not only determined by the stage of implementation but is also influenced by country specific policies and the possible influence of different cultures.

Implications for school practice

Although the results show that it is not possible to identify one factor as determining the degree of implementation, it can be inferred from the results that the perceived relevance of an innovation is a crucial variable that affects the success of educational change.

Perceived relevance

Perceived relevance can be seen as a precondition for the commitment of people to the intended change. The importance of this variable is explained because of its influence at all levels of an educational hierarchy. Both the minister of education and the school principal, each on their own 'level', command the authority and resources to provide the services and supplies needed for operating the intended educational change at classroom level. These agents also have the means to develop a reward structure that might encourage teachers to cooperate with the reform effort. In other words, they can provide pressure as well as support, and both are necessary for successful implementation (Fullan, 1994a). The findings on the confirmatory LISREL analyses show that an increase of the perceived relevance of the innovation by the principal has a positive influence on the policy measures taken at school level aimed at integration of the intended change in school practice. At teacher level, perceived relevance is crucial as well. The availability of new information technology and its technical possibilities is in itself not a reason for educational change. However, the availability of good examples illustrating the relevance and added value of the use of new technologies for instructional purposes can be important for both the adoption and implementation of future innovations in this field. This finding also indicates the importance of the beliefs and behaviors of teachers and stresses the central role of the teacher in the implementation process. From the teachers' perspective the role of the computer is primarily determined by the question what can be done with these tools and how appropriate the use of these media is in a given educational setting and teaching (or pedagogical) approach. As such, the use of new technologies as a tool or medium for educational purposes is not so much stimulated by solely the availability of an infrastructure.

Skills and knowledge

The current use of computers in Dutch secondary schools can be characterized by a new delivery system for convential content. For instance, students write essays on a word processor instead of by hand or on a typewriter; drills similar to those in workbooks are presented by the computer. These forms of computer use do not demand changes in the curriculum. However, available computer-based tools often assist learning in another way than formerly was done by teachers. Programs check spelling and grammar, solve arithmetic problems and make graphs of data and functions, for instance. The use of these tools in education raises questions about the skills and knowledge involved. Should some skills no longer be taught now that the task can be done electronically? Will using these tools improve students' learning or interfere with their learning? Information and communication technology offer the opportunity to specify the curriculum in a way that was not possible before. Maybe not today or tomorrow, but the enormous variety of educational applications in information and communication technology will ultimately bring at least two issues into scope. The first issue concerns a reconsideration of the entire existing curriculum. Secondly, the question is whether the institution of the school is still the best way to educate young people, when information technology makes new forms of mediated human interaction and new kinds of intelligent devices possible (Walker, 1994). The challenge for schools and their teachers is to integrate information and communcication technology in their teaching practices in order to provide learning opportunities that match the interests and abilities of students.

Implications for further research

In social sciences many techniques are available for descriptive research and some of them are applied in Chapter 4 of this book. A limitation of the approach of descriptive research is the lack of inferences about effects, benefits and influences among variables (Cook & Campbell, 1979). This limitation can be overcome by applying structural equation models that represent the structure of cause and effect relationships among latent variables or between latent variables and observed variables. As illustrated in Chapters 5 and 6, these models can be useful tools in educational research, but they also have their shortcomings. In this section implications are discussed from both a theoretical and methodological perspective.

Theoretical implications

The conceptual model used for this study is a set of frame factors. Factors influencing the outcome were divided in exogenous and endogenous factors (Chapter 2). As concluded in the section about ‘implications for educational policy’, exogenous factors such as technological innovations, economic innovations and institutional innovations, may be relevant for a better understanding of the implementation of computers in education. Especially for studies aimed at comparing educational outcomes across countries it is relevant to take those factors into account that are external to the school and represent the country specific context. However, it has to be noted that not all theoretically relevant variables are incorporated in this study. The decision to specify a particular construct in the model was influenced by theoretical considerations, the results obtained in previous research and by the currently available data. It is recommended to improve the current model in future research or develop a research program that systematically tests other theoretical relevant variables and is searching for improvement of the current set of observed variables. Possible factors, besides the already mentioned exogenous factors, might be related to endogenous factors at teacher or student level (e.g., teacher commitment and classroom practice).

Even though a confirmatory procedure was employed in this study, it has to be noted that the model like the one presented in this study, is intended only to approximate reality. The model provides a means to examine and evaluate the implementation process of computers in education. Future research and further elaboration of the model would not only offer a means of examining the validity of the model, but would also make it possible to test empirically the central hypothesis that distinctive stages of the innovation process are influenced by a changing set of interrelated factors. Although the idea of implementation and of factors affecting actual use seems simple enough, the research findings in this study confirm that this concept is '*exceedingly elusive'* (Fullan, 1994a).

Methodological implications

Theoretical constructs have to be identified by means of observed variables. Although LISREL takes the reliability of the observed variables into account, not all variables applied in the model under study have a high reliability. Future studies could examine whether and how the measurement model can be improved. Special attention should be given to the measurement of the latent variables which were removed in the simplified model. These variables were removed for statistical reasons, due to lack of influence on the outcome variable, but this lack of influence is possibly due to a poor operationalization of the constructs. Poor identification of variables can also be caused by statistical problems such as effects of discrete measurements of a continuus variable, and departures from assumptions of normality. If the assumptions are inappropriate, there is a risk of spurious factors being estimated (Munck, 1992). In order to identify the degree and the impact of the problems related to the applied model, it is necessary to apply these models in future studies and systematically test alternative measurement models as well as structural models.

Usefulness and dangers

It is important to recognize that a 'model' is not synonymous with 'theory'. A model is aimed at testing hypothesis developed from earlier studies and from substantive theories. Model building is a strategy that can be employed in research for providing a statistical summary of the data with a heuristic value in the development of theory (Keeves, 1994). Model building is especially useful for testing interrelations between variables. However, there is the danger of oversimplification which means that in the process of abstraction the model is built with a degree of simplification that is extended too far. Furthermore, the danger of model building can be that the model is insufficiently specific and therefore caution is needed for placing too much weight on the findings as having identified the complete causal process.

The greatest danger in model building is developing a single model without testing the model through the use of empirical evidence. Model building, data collection and the testing of the model are integrated activities. The structure of the model influences the data to be collected, and the data are essential for the verification of the model and the estimation of its parameters. The position that an educational researcher needs to collect his or her own data before a hypothesized model can be tested, does not always have to be taken because the availability of precollected data is immense, and these data are often useful for testing constructs or (parts of) hypothesized models. The growing availability of large national and international archived data sets of educationally relevant information offers more and more opportunities for secondary analysis. Applying data for secondary analysis fits well in the iterative process of model building.

Samenvatting

Achtergrond en vraagstelling

In het midden van de jaren tachtig besluit de Nederlandse overheid om alle scholen voor voortgezet onderwijs te voorzien van computerapparatuur, programmatuur en ondersteuning ten behoeve van de invoering van computers in het onderwijs. Op dat moment beschikken nog maar weinig scholen voor voortgezet onderwijs over computers en de leraren die proberen de computer voor onderwijsdoeleinden in de klas te gebruiken, behoren tot de pioniers op dit gebied. Deze eerste gebruikers van computers voor onderwijsdoeleinden worden gekenmerkt door hun enthousiasme over de mogelijkheden die de computer als hulpmiddel in de klas naar verwachting te bieden heeft en hun bereidheid op eenvoudige machines (P2000, C64, MSX) toepassingen voor onderwijsdoeleinden te ontwikkelen.

Nadat alle scholen voor voortgezet onderwijs in de periode 1984-1988 zijn toegerust met apparatuur (acht 16-bit PC's in een netwerk en twee 'stand-alone' PC's), programmatuur (een startpakket met tien verschillende computerprogramma's) en scholing (verplicht gesteld voor drie docenten per school, onder wie tenminste één vrouw) ligt in de periode 1989-1992 het accent op implementatie. Tegen deze achtergrond van een overheidsbeleid dat gericht is op het stimuleren van computergebruik in het onderwijs dient de vraagstelling voor onderhavig onderzoek te worden bezien. Deze vraagstelling is tweeledig:

a) In welke mate worden computers gebruikt in de eerste drie leerjaren van het voortgezet onderwijs en hoe verhoudt zich de Nederlandse situatie tot die in andere landen?
b) Welke factoren zijn van invloed op de implementatie van computers bij scholen voor voortgezet onderwijs en wat is de invloed van deze factoren op de mate van computergebruik?

Dataverzameling

Voor het in kaart brengen van het computergebruik is in 1989 en 1992 met subsidie van het SVO (Instituut voor Onderzoek van het Onderwijs) door het Onderzoek Centrum Toegepaste Onderwijskunde (OCTO) van de Universiteit Twente een grootschalig onderzoek uitgevoerd naar de stand van zaken op het gebied van computergebruik in het voortgezet onderwijs. Dit onderzoek is onder de naam COMPED (COMPuters in EDucation) uitgevoerd en maakte deel uit van een internationaal vergelijkend onderzoek onder auspiciën van The International Association for the Evaluation of Educational Achievement (IEA). Aan het COMPED-onderzoek hebben naast Nederland meer dan 20 andere landen deelgenomen. De gegevens voor dit onderzoek zijn bij een steekproef van scholen verzameld met behulp van schriftelijke vragenlijsten die ingevuld zijn door directies, computercoördinatoren en docenten. De directie is bijvoorbeeld gevraagd naar het schoolbeleid; de computercoördinator naar de op school aanwezige apparatuur en programmatuur; en de docenten naar het feitelijke computergebruik in de klas en de ondersteuning die zij daarbij hebben gehad. Meer gedetailleerde gegevens over de opzet van het onderzoek alsmede een overzicht van het aantal verstuurde en geretourneerde vragenlijsten is opgenomen in hoofdstuk 3.

Computergebruik in het voortgezet onderwijs

Uit de onderzoeksgegevens komt naar voren dat sinds 1990 alle scholen voor voortgezet onderwijs in het bezit zijn van computerapparatuur. Volgens de gegevens van 1992 beschikken de scholen over gemiddeld 24 computers die vooral gebruikt worden tijdens de lessen informatiekunde. Leraren die lesgeven in andere vakken zoals Nederlands, wiskunde of natuurkunde, maken bij hun lessen weinig gebruik van de computer. Bij veel scholen bleef in 1992 het computergebruik beperkt tot een enkele leraar die het leuk vindt om de leerlingen af en toe met de computer te laten werken. Als maat voor computergebruik op schoolniveau is een index gehanteerd met een waardenbereik van 0 tot 100, waarbij de maximale waarde aangeeft dat op alle scholen voor voortgezet onderwijs de computer wordt gebruikt in de vier onderzochte vakgebieden: informatiekunde, Nederlands, wiskunde en natuurwetenschappelijke vakken. Het computergebruik bij scholen voor voortgezet onderwijs is in de periode 1989-1992 volgens deze index gestegen van 37 naar 62. De toename van het aantal scholen met computergebruik bij de onderzochte vakgebieden is vooral toe te schrijven aan individuele docenten, terwijl door andere docenten uit die vaksecties nog niet met computers wordt gewerkt. Het betreft vooral docenten uit de vakgebieden Nederlands, wiskunde en natuurwetenschappen. Het computergebruik bij andere vakken dan informatiekunde heeft bij de meeste scholen het karakter van een docentgebonden activiteit die niet verankerd is in het curriculum van de school. Zoals het bijna vanzelfsprekend is dat alle docenten binnen een vaksectie dezelfde lesmethode gebruiken, geldt dit zeker niet voor de inzet van de computer als hulpmiddel bij het lesgeven. De mate waarin leerlingen in aanraking komen met computers tijdens andere lessen dan informatiekunde is daardoor meer afhankelijk van de docent dan van het curriculum dat de leerling aangeboden krijgt.

Internationale vergelijking

Het gebruik van computers op de Nederlandse scholen voor voortgezet onderwijs is vergeleken met de situatie in Duitsland, Japan, Oostenrijk en de Verenigde Staten. Terwijl in 1989 het computergebruik op scholen voor voortgezet onderwijs in de Verenigde Staten het meest wijdverbreid was, zijn in 1992 de verschillen van Duitsland, Oostenrijk en Nederland ten opzichte van de USA veel kleiner geworden. Bezien over de vijf onderzochte landen komt in 1992 binnen de vakgebieden informatiekunde, moedertaal, wiskunde en natuurwetenschappen het meeste computergebruik voor in Oostenrijk. Computertoepassingen voor onderwijsdoeleinden komen relatief het minst voor in Japan, hoewel er aanwijzingen zijn dat deze ‘achterstand’ snel ingelopen zal worden. Opmerkelijk is dat de landen die in de begin jaren tachtig behoorden tot de koplopers bij de invoering van computers in het voortgezet onderwijs, waaronder Nederland en de Verenigde Staten, in 1992 over de meest verouderde apparatuur beschikken. Dit in tegenstelling tot de landen die het laatst gestart zijn met de invoering van computers, zoals Oostenrijk en Japan, waar de meeste scholen over moderne en krachtige computers beschikken. Hieruit blijkt dat de scholen na de eerste apparatuuraanschaf veelal niet in staat zijn gebleken de verouderde computers te vervangen door moderne apparatuur.

De beschikbaarheid van computerprogrammatuur is bij Nederlandse scholen voor voortgezet onderwijs in vergelijking met andere landen het grootst. Opmerkelijk daarbij is dat het gebrek aan bruikbare programmatuur in geen enkel van de andere onderzochte landen zo vaak als een knelpunt wordt genoemd als op de Nederlandse scholen. De verklaring voor deze schijnbare tegenstelling moet worden gezocht in de geringe praktische bruikbaarheid van de programmatuur die aan alle scholen voor voortgezet onderwijs beschikbaar is gesteld. Een overzicht van beschrijvende gegevens over verschillende aspecten van computergebruik is opgenomen in hoofdstuk 4.

Beïnvloedende factoren

Onderzoeksresultaten van eerder uitgevoerd onderzoek laten zien dat factoren die van invloed zijn op de invoering van computers in het onderwijs, meestal dezelfde zijn als de factoren die in de literatuur over andere onderwijsinnovaties genoemd worden. Voor het empirisch identificeren van factoren die van invloed zijn op het computergebruik in het onderwijs is gebruik gemaakt van een conceptueel raamwerk bestaande uit 11 mogelijk beïnvloedende factoren. Dit conceptueel raamwerk (beschreven in hoofdstuk 2) heeft als uitgangspunt gediend voor een verklaringsmodel waarvan het meetmodel is ontwikkeld op basis van de dataset van 1989. Hierbij is gebruik gemaakt van de LISREL-methodologie waarvan de principes beschreven zijn in hoofdstuk 5. Het ontwikkelde model is getoetst in een confirmatieve analyse waarvoor de dataset van 1992 is gebruikt. De resultaten laten zien dat in 1989, wanneer de meeste scholen voor voortgezet onderwijs nog aan het begin van het invoeringstraject staan, het computergebruik via een tweetal factoren direct wordt beïnvloed: ‘gepercipieerde relevantie’ en ‘interne deskundigheidsbevordering’. De confirmatieve analyse laat zien dat het verklaringsmodel ook op de dataset van 1992 adequaat kan worden geïdentificeerd. In 1992, wanneer ten opzichte van 1989 de implementatie van computergebruik op schoolniveau aanmerkelijk is toegenomen, hebben 6 van de 11 in het model opgenomen factoren een betekenisvol direct of indirect effect op de mate van computergebruik. Deze factoren zijn:

- externe financiële ondersteuning;
- externe scholingsondersteuning;
- beschikbaarheid van apparatuur en programmatuur;
- gepercipieerde relevantie;
- schoolbeleid voor computergebruik;
- monitoring en strategie voor het oplossen van knelpunten.

De bovengenoemde set van beïnvloedende factoren vormt tezamen met de afhankelijke variabele ‘mate van computergebruik’ de bouwstenen voor een vereenvoudigd verklaringsmodel. Dit vereenvoudigde verklaringsmodel is eveneens getoetst op de data van 1992 en de resultaten laten zien dat de verwijdering van 5 beïnvloedende factoren uit het oorspronkelijke model slechts een beperkte afname in de proportie verklaarde variantie tot gevolg heeft. Dit betekent dat van de 11 onderzochte factoren, de eerder genoemde zes factoren de belangrijkste zijn voor het verklaren van de mate van computergebruik bij de scholen voor voortgezet onderwijs anno 1992. De onderlinge samenhang tussen de zes beïnvloedende factoren komt tot uitdrukking via vijf verschillende causale ketens die elk invloed uitoefenen op de mate van computergebruik. Een overzicht van deze ketens is weergegeven in de onderstaande tabel.

Tabel 1

Overzicht van causale ketens ter verklaring van de implementatie van computergebruik bij scholen voor voortgezet onderwijs in 1992

externe financiële ondersteuning	externe scholingsmogelijkheden	beschikbaarheid van apparatuur en programmatuur	gepercieerde relevantie	schoolbeleid voor computergebruik	monitoring en strategie voor het oplossen van knelpunten	implementatie van computergebruik
x →	x →	→	→	→	→	x
x →	→	x →	→	→	→	x
x →	x →	→	→	→	x →	x
x →	x →	→	→	x →	x →	x
x →	x →	→	x →	x ⇒	x →	x

Toelichting: → gestandaardiseerd effect ≥ .20 en < .50
⇒ gestandaardiseerd effect ≥ .50

De volledige beschrijving van het meetmodel en de resultaten van de exploratieve analyse zijn te vinden in hoofdstuk 5. De confirmatieve analyse op zowel het volledige model als het vereenvoudigde model is beschreven in hoofdstuk 6.

Betekenis van resultaten

Wanneer de balans wordt opgemaakt van het Nederlandse overheidsbeleid dat sinds het begin van de jaren tachtig gericht is geweest op het stimuleren van computergebruik in het voortgezet onderwijs, dan kan worden vastgesteld dat in het begin van de jaren negentig, (wanneer de periode van zogenoemde brede stimulering wordt afgesloten) de volgende resultaten zijn bereikt:

- alle scholen voor voortgezet onderwijs beschikken over een infrastructuur voor informatietechnologie;
- er is een nieuw vak (informatiekunde) ingevoerd dat er op gericht is alle leerlingen in het voortgezet onderwijs vertrouwd te maken met informatietechnologie;
- bij andere vakken dan informatiekunde wordt op veel scholen gebruik gemaakt van de computer, maar het betreft slechts een relatief klein aantal leraren dat de computer incidenteel gebruikt als hulpmiddel bij het lesgeven.

Hoewel het beleid voor de periode 1989-1992 gericht was op verbreding van computergebruik in andere vakken dan informatiekunde, dient te worden vastegsteld dat ondanks de toename van computergebruik op schoolniveau, binnen vaksecties nog nauwelijks sprake is van systematisch computergebruik en verankering in het curriculum. Om in de toekomst alsnog de beoogde veranderingen te realiseren zijn aanvullende maatregelen vereist. Hierbij verdient het aanbeveling rekening te houden met de factoren die in deze studie zijn geïdentificeerd als zijnde verklarend voor de mate van implementatie. Verwacht mag worden dat de kennis uit deze studie over de invoering van computers in het onderwijs ook relevant is voor de invoering van nieuwe onderwijskundige toepassingen op het gebied van communciatie- en informatie-technologie, zoals multi-media applicaties en teleleren.

Een vergelijking van de factoren die de mate van computergebruik in 1989 en 1992 beïnvloeden, laat zien dat de mate waarin de onderscheiden factoren invloed hebben, samenhangt met het stadium waarin het invoeringsproces verkeert. Deze bevinding is overeenkomstig de resultaten van analyses waarbij het gehanteerde verklaringsmodel is toegepast op data uit vijf andere landen. Geen van de onderscheiden factoren is volledig bepalend voor de mate van computergebruik. Het is de onderlinge samenhang tussen factoren die bepalend is voor de mate van computergebruik. De resultaten van de analyses maken zichtbaar dat onderwijsverandering een dynamisch proces is waarvan het succes niet wordt bepaald door de aanwezigheid of afwezigheid van één enkele factor.

De gepercipieerde relevantie van computergebruik is de enige factor die zowel in de adoptiefase (1989) als in de implementatiefase (1992) significant bijdraagt aan de mate van computergebruik bij scholen voor voortgezet onderwijs. Een toelichting op verdere implicaties voor zowel beleid, schoolpraktijk als vervolgonderzoek is opgenomen in hoofdstuk 6.

Appendices

Appendix 1

Wording of the items used for the measurement model

<table>
<tr><th>Variable</th><th>Item</th><th>Respondent</th></tr>
<tr><td>η_1</td><td>School size</td><td></td></tr>
<tr><td>y1</td><td>How many male and female students are in grade 7, 8, 9, respectively in total in your school?

GENDER
number of male students   number of female students

Grade 7 ____________ ____________
8 ____________ ____________
9 ____________ ____________

TOTAL
IN SCHOOL ____________ ____________</td><td>principal</td></tr>
</table>

<table>
<tr><th>Variable</th><th>Item</th><th>Respondent</th></tr>
<tr><td>η2</td><td>External financial support</td><td></td></tr>
<tr><td>y2</td><td>
Effective use of computers in schools is a difficult proposition. Schools may need support on several areas:
- financial support for acquisition and maintenance of hardware and software, specialized teacher training, teacher aids, etc.;
- technical expertise and information for selecting and applying hardware and software, and software development or adjusting software to the school situation;
- training of teachers for integrating computers in the curriculum, and organizing their use within the school;
- other instructional support for helping teachers to improve their use of computers.

Many groups or agencies OUTSIDE the school might be expected to be able to provide schools with support in their use of computers.

Indicate for each group or agency whether they have provided your school with important support in different support areas (important means: the use of computers would have clearly been different without their support).
For each group or agency circle all that apply or none

<table>
<tr><th></th><th colspan="5">Support areas</th></tr>
<tr><th>Group</th><th>financial</th><th>technical expertise</th><th>teacher training</th><th>other instructional</th><th>none</th></tr>
<tr><td>Ministry of Education</td><td>❑</td><td>■</td><td>■</td><td>■</td><td>■</td></tr>
</table>

Note: ❑ = item used for this variable
</td><td>principal</td></tr>
</table>

<table>
<tr><th>Variable</th><th>Item</th><th>Respondent</th></tr>
<tr><td>$\eta 3$</td><td>External training support</td><td></td></tr>
<tr><td>y3</td><td>
Effective use of computers in schools is a difficult proposition. Schools may need support on several areas:
- financial support for acquisition and maintenance of hardware and software, specialized teacher training, teacher aids, etc.;
- technical expertise and information for selecting and applying hardware and software, and software development or adjusting software to the school situation;
- training of teachers for integrating computers in the curriculum, and organizing their use within the school;
- other instructional support for helping teachers to improve their use of computers.

Many groups or agencies OUTSIDE the school might be expected to be able to provide schools with support in their use of computers.

Indicate for each group or agency whether they have provided your school with important support in different support areas (important means: the use of computers would have clearly been different without their support).
For each group or agency circle all that apply or none

<table>
<tr><th></th><th colspan="5">Support areas</th></tr>
<tr><th>Group</th><th>financial</th><th>technical expertise</th><th>teacher training</th><th>other instructional</th><th>none</th></tr>
<tr><td>Ministry of Education</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
<tr><td>Local education authorities</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
<tr><td>Teachers of other schools</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
<tr><td>Parents</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
<tr><td>Universities (teacher training) colleges</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
<tr><td>Teacher/other associations</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
<tr><td>Business and industry</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
<tr><td>Support institutions</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
<tr><td>Local/regional resource Center</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
<tr><td>Other (specify)</td><td>■</td><td>■</td><td>❑</td><td>■</td><td>■</td></tr>
</table>
Note: ❑ = items used for this variable
</td><td>principal</td></tr>
</table>

Variable	Item	Respondent
η4	Previous innovation experience	
y4	In what year were computers first used by your school for teaching and/or learning activities?	principal

Variable	Item					Respondent
η5	Availability and resource needs					
	How high a priority have the following kinds of computer-related expenditures in your school's current plans? *Indicate the importance of each kind of expenditure. If a kind of expenditure is not part of the plans, please circle 'not important'*					computer coordinator
		Importance				
	Kind of expenditure	not important	slightly important	important	very important	
y_5	more powerful computers	❏	❏	❏	❏	
y_6	computers networked for shared disk storage	❏	❏	❏	❏	
y_7	more tool software (word processors, database, and graphing programs, etc.)	❏	❏	❏	❏	

Variable	Item						Respondent
η6	Perceived innovation relevance						
		strongly disagree	slightly disagree	uncertain	slightly agree	strongly agree	principal
y8	using computers in class leads to more productivity of students	❏	❏	❏	❏	❏	
y_9	the achievement of students can be increased when using computers for teaching	❏	❏	❏	❏	❏	
y_{10}	computers are used for teaching and learning activities in order to improve student achievement in the school	❏	❏	❏	❏	❏	

Variable	Item	Respondent
η7	School policy for computer use	
	Some schools establish specific policies regarding different aspects of computer use. For each of the policy areas described below, indicate whether your school has established any policies in that area.	principal
y_{11}	❑ priorities for particular types of instructional uses over others	
y_{12}	❑ a policy that prescribes the use of certain software or hardware	
y_{13}	❑ a policy that prescribes the content of an introduction to computers course or unit	

Variable	Item	Respondent
η8	Internal staff development	
	Which of the following kinds of staff development is readily available for the teachers of your school and also organized by the school?	computer coordinator
y_{14}	❑ using general computer application programs (e.g., word processors, spreadsheets, database)	
y_{15}	❑ computer science course, programming	
y_{16}	❑ using computers in specific subjects	

Variable	Item	Respondent
η9	Internal innovation assistance	
	In which areas can you get support from each of the following person(s)/agencies, in case you encounter problems in using computers?	teachers

Person/agency	Support areas: hardware	software y_{17}	instruction y_{18}	organization y_{19}
school administration	■	❑	❑	❑
other teachers	■	❑	❑	❑
computer coordinator in the school	■	❑	❑	❑

Variable	Item
y_{17}	software support given to teachers
y_{18}	instructional support given to teachers
y_{19}	organizational support given to teachers

Note: ❑ = items used for this variable

Variable	Item			Respondent
η10	Teacher competence and readiness			
	Please indicate below what you have learned so far about computers.			teachers
	For each particular statement, please circle 'yes' or 'no'			
y20	*I know . . .*			
		yes	no	
	Several advantages of computer use for instruction	❑	❑	
	The difference between a word processor and a desktop publishing program	❑	❑	
	Criteria to judge the quality of a printer	❑	❑	
	The trends in hardware development in the past 20 years	❑	❑	
	What 'file extensions' are	❑	❑	
	What a 'loop' means in programming	❑	❑	
	What a 'relational database' is like	❑	❑	
	What a 'bit' is defined as	❑	❑	
	The difference between 'RAM' en 'ROM'	❑	❑	
	I can write a program for . . .			
	Adding up numbers	❑	❑	
	Using arrays	❑	❑	
	Sorting data on a disk drive	❑	❑	
	Sorting data into a certain sequence	❑	❑	
	Printing the complete ASCII character set	❑	❑	
	I am capable of . . .			
	Exchanging data between different types of computers	❑	❑	
	Copying files from one disk to another	❑	❑	
	Editing documents with a word processor	❑	❑	
	Loading a data set from a disk drive	❑	❑	
	Creating a database file	❑	❑	
	Evaluating the usefulness of software for my lessons	❑	❑	
	Adapting instructional software to my needs	❑	❑	
	Writing courseware for my own lessons	❑	❑	

Variable	Item					Respondent
η11	Monitoring and problem coping strategy					
	How often has each of the following activities related to the use of computers taken place at your school during this school year?					principal
		not at all	some weeks	most weeks	every week	
y_{21}	teachers in the school met to exchange information about the use of computers	❏	❏	❏	❏	
y_{22}	we exchanged information about the use of computers by teachers and students with other schools	❏	❏	❏	❏	
y_{23}	we assessed how computers were being used	❏	❏	❏	❏	

<table>
<tr><th>Variable</th><th>Item</th><th>Respondent</th></tr>
<tr><td>η12</td><td>Implementation of computer use</td><td></td></tr>
<tr><td>y24</td><td>For each subject below indicate in which grade at least one teacher at your school currently uses computers
‘Computer use’ means using it with a class on at least several occasions during the school year.
<table>
<tr><th>Subject</th><th colspan="3">Grade</th></tr>
<tr><th></th><th>7</th><th>8</th><th>9</th></tr>
<tr><td>Computer education/informatics</td><td>■</td><td>❑</td><td>■</td></tr>
<tr><td>Mathematics</td><td>■</td><td>❑</td><td>■</td></tr>
<tr><td>Science, e.g. physics, chemistry, earth science life science, physical geography</td><td>■</td><td>❑</td><td>■</td></tr>
<tr><td>Mother tongue</td><td>■</td><td>❑</td><td>■</td></tr>
</table>
Note: ❑ = items used for this variable</td><td rowspan="2">computer coordinator</td></tr>
<tr><td>y25</td><td>How many teachers teach each of the following subjects and how many of them use computers in that subject?
‘Computer use’ means using it with a class on at least several occasions during the school year. Enter the total number of teachers for each subject and the number of those teachers that use computers.
<table>
<tr><th>Subject</th><th>number of teachers</th><th>number of teachers using computers</th></tr>
<tr><td>Computer education/informatics</td><td>________</td><td>_________</td></tr>
<tr><td>Mathematics</td><td>________</td><td>_________</td></tr>
<tr><td>Science, e.g. physics, chemistry, earth science, life science, physical geography</td><td>________</td><td>_________</td></tr>
<tr><td>Mother tongue</td><td>________</td><td>_________</td></tr>
<tr><td>Foreign language</td><td>________</td><td>_________</td></tr>
<tr><td>Social studies, e.g., history, geography, civics, economics</td><td>________</td><td>_________</td></tr>
<tr><td>Other (specify)</td><td>________</td><td>_________</td></tr>
</table></td></tr>
</table>

Appendix 2

Polychoric and polyserial correlations between observed variables included in the model of 1989

	y1	y2	y3	y4	y5	y6	y7	y8	y9	y10	y11	y12	y13	y14	y15	y16	y17	y18	y19	y20	y21	y22	23y	24y	y
y1	1.00																								
y2	-.09	1.00																							
y3	.19	.17	1.00																						
y4	.26	.02	.15	1.00																					
y5	-.03	-.07	-.10	.04	1.00																				
y6	.14	-.13	-.01	.12	.58	1.00																			
y7	.15	-.11	.13	.17	.23	.23	1.00																		
y8	.03	.02	-.00	-.10	-.03	-.07	-.04	1.00																	
y9	.00	-.01	-.03	.01	-.08	-.17	-.05	.69	1.00																
y10	-.05	-.08	-.13	.05	-.13	-.13	.06	.41	.43	1.00															
y11	.09	-.00	.07	.07	-.03	.03	-.02	.13	.22	.03	1.00														
y12	.04	.03	.04	.12	-.09	-.05	-.07	.12	.08	.13	.36	1.00													
y13	.06	-.10	.05	.07	-.04	-.02	.01	.08	.01	.12	.32	.27	1.00												
y14	.25	.03	.00	.10	-.03	.04	.02	.02	-.07	.00	.03	-.03	.01	1.00											
y15	.11	.06	-.02	.14	-.07	-.03	-.05	.10	-.03	.10	.07	-.05	.04	.50	1.00										
y16	.06	.11	-.04	.05	-.06	-.02	-.04	.03	-.14	.03	-.11	-.02	-.05	.37	.52	1.00									
y17	.16	.04	-.02	.03	-.05	-.01	-.01	.01	-.04	-.02	-.13	.01	-.00	.03	-.05	-.07	1.00								
y18	.11	-.06	.01	.12	.01	.04	.04	.02	.01	.08	-.10	-.00	-.04	-.04	-.03	-.05	.79	1.00							
y19	.17	-.16	.13	.04	.02	.12	.08	-.01	-.07	-.04	-.07	-.09	-.00	-.10	-.13	-.18	.60	.69	1.00						
y20	-.05	.21	.25	.12	-.03	-.05	-.02	.03	-.05	.13	-.03	.04	.04	-.05	-.03	-.03	-.05	.03	-.02	1.00					
y21	-.12	-.07	.07	.01	.05	.01	.04	.14	.21	.21	.21	.14	.12	.04	.13	.07	.04	.03	.01	.11	1.00				
y22	-.04	.09	.07	.06	-.07	.03	-.09	.15	.12	.26	.15	.12	.11	.01	.09	.11	.06	.09	.09	.20	.43	1.00			
y23	.07	.01	.12	.27	.01	.09	.02	.20	.25	.25	.23	.20	.11	.02	.10	.16	.03	.13	.16	.16	.56	.34	1.00		
y24	.12	-.05	-.01	.11	-.10	-.04	.03	-.01	-.11	.18	.04	.01	.11	.11	.27	.07	.03	.07	.08	-.03	.02	.06	.04	1.00	
y25	.10	-.08	-.02	.14	-.07	.03	-.08	.11	-.01	.11	-.01	.06	.15	.13	.23	.10	.02	.10	-.04	.05	.03	.10	-.03	.49	1

Appendix 3

Cross-validation of the exploratory model on 1989 data of:
France, Germany, Japan, Switzerland and the United States
(from: Tuijnman and Brummelhuis, 1993)

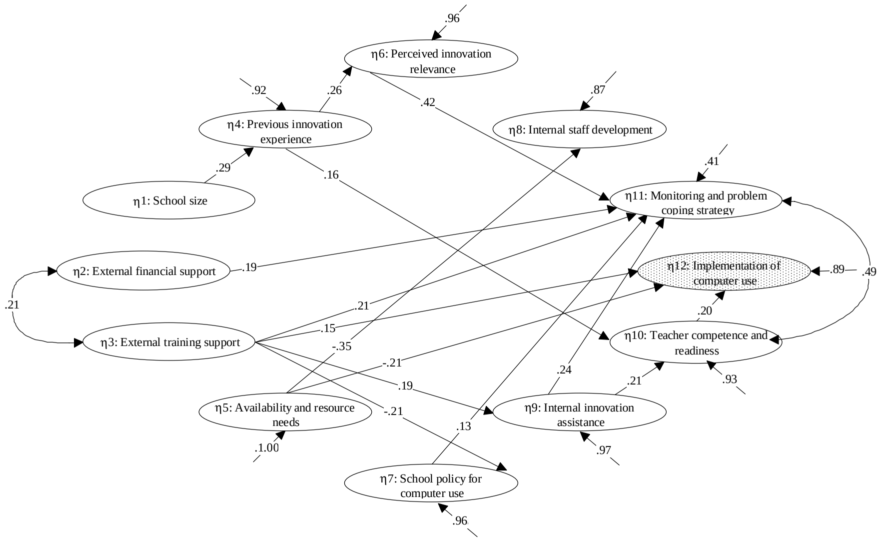


Figure a: Standardized effects on the implementation of computer use in FRANCE

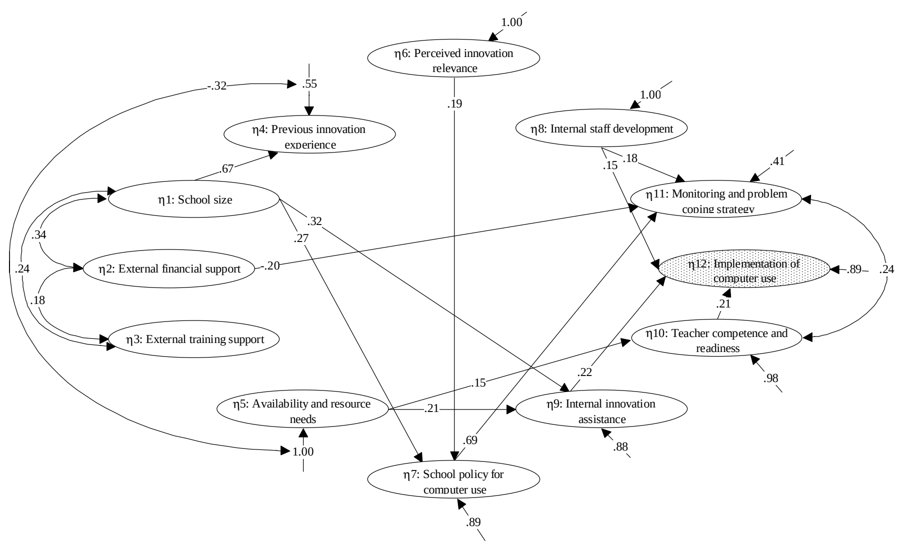


Figure b: Standardized effects on the implementation of computer use in GERMANY

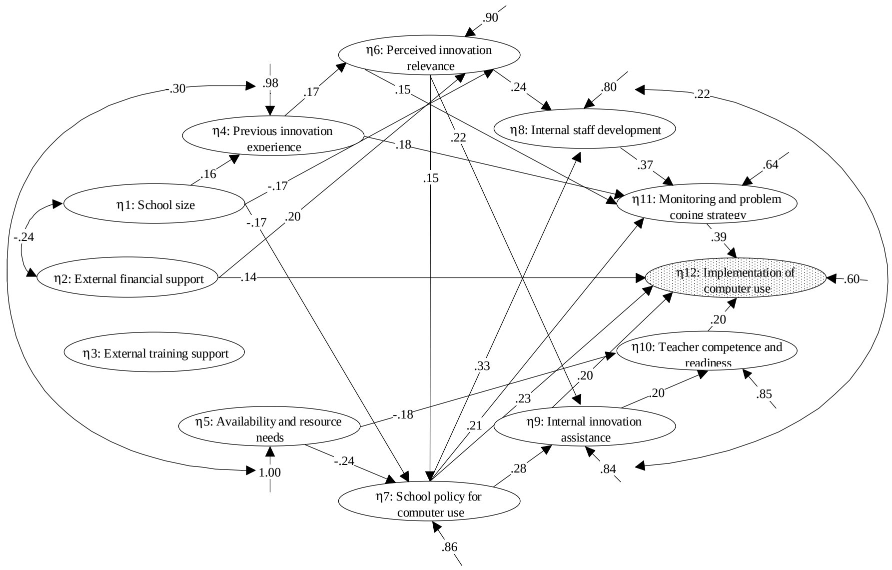


Figure c: Standardized effects on the implementation of computer use in JAPAN

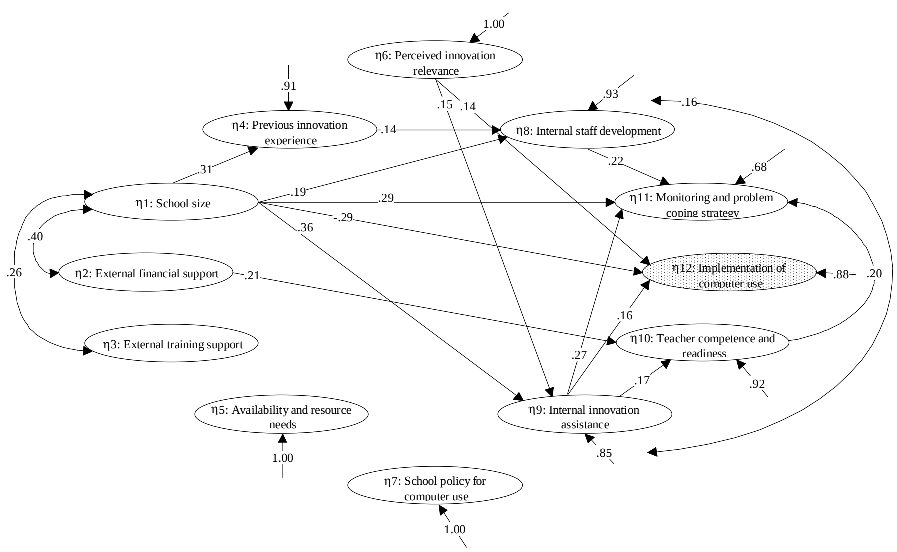


Figure d: Standardized effects on the implementation of computer use in SWITZERLAND

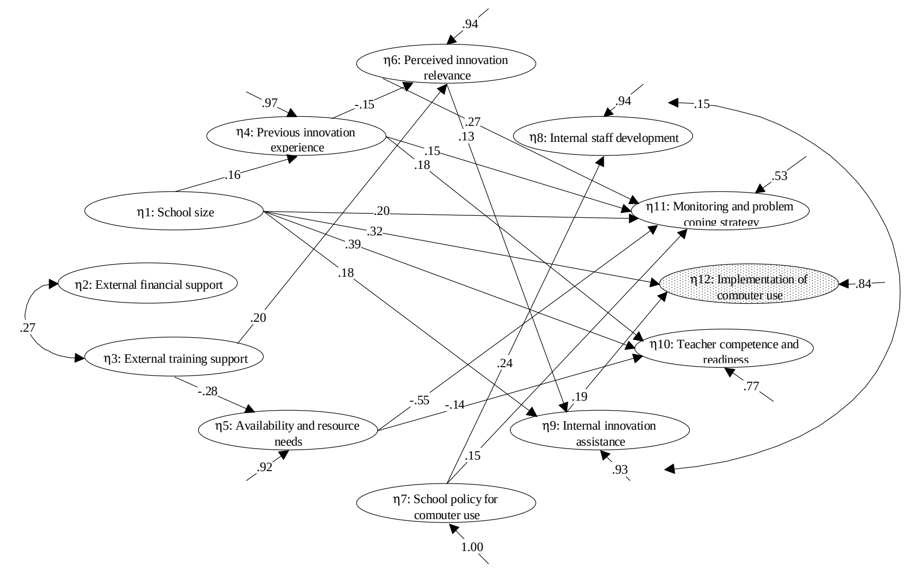


Figure e: Standardized effects on the implementation of computer use in the UNITED STATES

Appendix 4

Polychoric and polyserial correlations between observed variables included in the model of 1992

	y1	y2	y3	y4	y5	y6	y7	y8	y9	y10	y11	y12	y13	y14	y15	y16	y17	y18	y19	y20	y21	y22	y23	y24	y25
y1	1.00																								
y2	-0.04	1.00																							
y3	-0.19	0.28	1.00																						
y4	0.26	0.01	-0.08	1.00																					
y5	-0.02	0.19	0.11	-0.07	1.00																				
y6	0.06	0.04	-0.02	0.02	0.30	1.00																			
y7	-0.14	0.09	0.09	-0.08	0.26	0.14	1.00																		
y8	-0.08	0.08	0.16	0.09	-0.02	-0.09	0.04	1.00																	
y9	0.00	0.18	0.17	-0.09	0.04	-0.19	0.02	0.65	1.00																
y10	-0.04	0.12	0.15	0.07	0.13	-0.04	-0.02	0.46	0.34	1.00															
y11	-0.15	0.12	0.17	0.02	0.05	-0.02	0.06	0.27	0.22	0.18	1.00														
y12	-0.12	0.11	0.16	0.08	0.03	-0.09	0.12	0.18	0.09	0.11	0.32	1.00													
y13	-0.13	0.07	0.12	0.01	0.09	-0.04	-0.06	0.22	0.16	0.20	0.43	0.21	1.00												
y14	0.17	0.14	-0.20	-0.07	0.05	-0.02	0.02	-0.17	-0.10	-0.11	-0.15	-0.11	-0.05	1.00											
y15	0.23	0.03	-0.19	-0.03	0.09	0.06	0.04	-0.05	-0.12	0.00	-0.07	-0.04	0.02	0.54	1.00										
y16	0.05	-0.18	-0.10	0.04	-0.08	-0.14	0.03	-0.05	-0.11	-0.05	-0.03	-0.11	-0.05	0.38	0.60	1.00									
y17	-0.20	0.10	0.08	0.10	0.03	0.07	0.03	0.02	0.02	-0.01	0.14	-0.10	0.16	0.07	-0.02	0.00	1.00								
y18	-0.07	0.09	-0.05	0.07	0.13	0.10	0.03	-0.08	-0.06	0.11	-0.01	-0.21	0.12	0.01	-0.09	-0.05	0.68	1.00							
y19	-0.25	0.11	0.06	-0.02	0.08	0.06	0.15	0.05	0.03	0.10	0.13	0.03	0.14	0.01	0.04	0.02	0.77	0.61	1.00						
y20	0.12	0.12	0.05	-0.07	0.13	0.10	0.12	-0.01	-0.03	-0.02	0.06	0.01	-0.01	0.01	0.04	-0.07	-0.04	-0.08	-0.01	1.00					
y21	0.12	-0.07	0.17	0.10	0.07	0.01	0.00	0.17	0.25	0.10	0.31	0.19	0.30	-0.09	-0.20	-0.11	0.14	-0.01	-0.01	0.07	1.00				
y22	-0.08	0.09	0.29	-0.01	0.12	-0.01	0.04	0.29	0.18	0.18	0.38	0.28	0.37	-0.21	-0.20	-0.11	0.00	-0.04	0.06	-0.01	0.47	1.00			
y23	0.06	0.07	0.22	0.11	-0.02	-0.10	-0.07	0.26	0.17	0.11	0.21	0.14	0.26	-0.16	-0.19	-0.03	0.04	0.02	-0.14	-0.02	0.55	0.43	1.00		
y24	-0.08	0.00	0.23	-0.14	0.23	0.06	-0.02	0.09	0.07	0.18	0.09	0.04	0.21	-0.07	-0.14	-0.17	-0.06	0.03	-0.02	0.12	0.20	0.25	0.15	1.00	
y25	-0.02	0.01	0.06	-0.11	0.02	0.02	-0.10	0.06	0.12	0.03	0.13	0.03	0.24	-0.11	-0.12	-0.13	-0.03	0.06	-0.07	0.09	0.19	0.11	0.07	0.44	1.00

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