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Supportive and hindering factors to a sustainable implementation of ICT in schools

Abstract

This study utilizes a school improvement and school development perspective to identify supporting and hindering factors contributing to long-term and sustainable ICT implementation in schools and classrooms. The nature and impact of these factors are examined in six schools in Germany. These six schools were drawn from the German follow-up study (2006–2007) of the IEA Second Information Technology in Education Study, Module 2 (SITES M2, 1999–2002) funded by the German Research Foundation (DFG). This qualitative and quantitative follow-up study was conducted five years after SITES M2. An instrument to measure the sustainability of ICT implementation was developed and charted for the six schools over the 5-year period. At the same time, the supportive factors and obstacles of ICT integration were determined on the school basis to combine both the degree of success in implementing ICT sustainably and the specific factors in each school. The study concludes by outlining the most important factors on different school levels, which are necessary for long-term and sustainable ICT implementation in the sampled schools and classrooms. Above all, the success in implementing digital media sustainably appeared to be associated with the way that schools use their radius of operation on the process level, especially how principals perform as school leaders and how ICT use meets the pedagogical aims of the schools.

Keywords

ICT in schools; Sustainability of innovation; School development process; Longitudinal design; Case study

Förderliche und hemmende Bedingungen der nachhaltigen Implementierung von IKT in Schulen

Zusammenfassung

Die in diesem Beitrag dargestellte Studie untersucht aus der Perspektive der Schulentwicklungsforschung die förderlichen und hemmenden Bedingungen für eine langfristige und nachhaltige Implementierung von Informations- und Kommunikationstechnologien (IKT) in Schulen. Diese Studie, die von 2006 bis 2007 in Deutschland durchgeführt wurde, ist als Teil der Fallstudienfolgeuntersuchung zur IEA-Studie

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SITES M2 (SITES M2, 1999–2002) konzipiert, die von der Deutschen Forschungsgemeinschaft (DFG) gefördert wurde. Sie fokussiert auf den Schulentwicklungsverlauf der Implementierung digitaler Medien in sechs Fallschulen und erhebt in diesen Schulen nach einer Zeitspanne von fünf Jahren qualitative und quantitative Daten zum Innovationsprozess und zu den Bedingungsfaktoren dieses Prozesses. Gleichzeitig wird ein auf theoretischer und empirischer Grundlage basierendes Instrument zur Messung der Nachhaltigkeit der Innovationen für die Fallschulen entwickelt und schulweise ausgewertet. Als Ergebnis der Studie werden so die wichtigsten Faktoren auf den verschiedenen Ebenen von Schule identifiziert, die für eine nachhaltige Implementierung in den Schulen der Stichprobe wirksam sind. Die Befunde zeigen, dass Schulen dann besonders erfolgreich sind, wenn sie ihren Handlungsspielraum auf der Schulebene effektiv nutzen, die Schulleitungen die Innovationen durch ein innovationsbezogenes Führungsverhalten unterstützen und ein Zusammenhang zwischen dem Einsatz von IKT im Unterricht und den pädagogischen Zielen der Einzelschule hergestellt und in den Schulen verbreitet, akzeptiert und umgesetzt wird.

Schlagworte

Digitale Medien in Schulen; Nachhaltigkeit von Innovationen; Schulentwicklungsprozesse; Längsschnitt; Fallstudien

1. ICT use in German schools

Owing to the impact of technological developments, our society is in a transition towards an information or knowledge-based society (Anderson, 2008). From this, challenges have arisen in education (Voogt & Knezek, 2008) leading to new tasks for schools and a duty to provide all children and young people with equitable opportunities to participate in our society (OECD, 2010). However, the implementation of information and communication technology (ICT) has proved more challenging than was initially assumed when it first appeared on the educational agenda in the 1960s (Tearle, 2004). Even today, the regular use of ICT by the majority of teachers and students within a school is still not commonplace. From a German perspective, the comparatively small number of computers in German schools and their infrequent use (Schulz-Zander & Eickelmann, 2009) triggers the special interest of further research.

It is important to improve the frequency of use of ICT in classrooms. Large-scale studies such as PISA (Programme for International Student Assessment) and PIRLS (Progress in International Reading Literacy Study) have found that ICT is not pervasive (Eickelmann, 2010; Schulz-Zander, Eickelmann, & Goy, 2010; Senkbeil & Drechsel, 2004; Senkbeil & Wittwer, 2007). A literature review shows that the problems concerning successful ICT implementation have been of interest in several countries (Groff & Mouza, 2008). Moreover, the ‘explosion of IT tools and resources’ (Cox, 2008) within recent years has been an ongoing problem for schools all over the world.

This paper presents a new research approach and includes findings from a German follow-up study (2006–2007) of the Second Information Technology in Education Study, Module 2 (SITES M2, 1999–2002), which was coordinated and conducted by the IEA (International Association for the Evaluation of Educational Achievement).

This German follow-up study over more a five-year period is one of the first studies of the sustainability of ICT-integration. Funded by the German Research Foundation (DFG), its methodology mainly focuses on the process level of school. The research is driven by the question: Which factors in schools support or hinder the sustainable and long-term integration of ICT into teaching and learning?

2. State of the art – factors contributing and hindering ICT use in schools

Ever since ICT applications were first implemented in schools, factors supporting or hindering ICT integration have been considered in empirical studies (European Commission, 2006; International Society for Technology in Education, 2007; Law & Chow 2008; Lee, Cerreto, & Lee, 2009; Pelgrum & Anderson, 1999; Pelgrum, 2001; Preston, Cox, & Cox, 2000; Schulz-Zander, 2004; Venezky & Davis, 2002). In order to grasp the complexity of the relevant factors, different approaches for systemization of these factors have been developed, e.g. by distinguishing between material factors and immaterial factors. Whereas material factors refer to the access to technology in schools, immaterial factors relate to school organization and teacher variables (British Educational Communication and Technology Agency, 2003; Eickelmann & Schulz-Zander, 2006; Pelgrum, 2001; Schaumburg, 2003). This approach creates a better understanding of school development processes and indicates that school effectiveness is determined by factors that relate to each school's context, input and processes (Ditton, 2000; Scheerens, 2000). Whereas the *context level* encompasses factors related to the administrative, the socio-regional level and cooperation with external partners, the *input level* of schools focuses on the school's intake in terms of personnel and financial conditions, teacher and student variables and curricula. The *process level* comprises two sub-dimensions: firstly, the school level includes aspects such as the school management, school culture, cooperation structures, and personnel development. Secondly, the classroom level includes the quality of teaching, the appropriateness of methods and media use, the motivation and the effective use of learning time (see also Slavin, 1994).

Above all, single schools have different constellations regarding context and input levels. They have to address the factors in these levels in order to reach their pedagogical aims and maximize the school's effectiveness (Bonsen, Bos, & Rolff, 2008). In this sense, school effectiveness not only focuses on student performance and student's competences, but also in the literal sense of "effectiveness" as "goal

attainment” (Scheerens, 2000, p. 19). Therefore, for schools that aim to implement digital media in teaching and learning, the questions are firstly whether they do aim for this goal and secondly which factors support or hinder the attainment of that goal. Research into factors for ICT implementation in schools has tended to focus on the introductory phase of new ICT applications, rather than on sustainable and long-term implementation. However, from a school improvement perspective, sustainable implementation is more important. This follow-up study is the first time that long-term sustainability of innovation has been considered for ICT implementation at schools.

Factors concerning ICT integration on the input level of schools

A review of previous studies towards technology introduction or the introduction of new technological applications in schools shows that existing research mainly looks into the availability of ICT infrastructure (e.g. measured in student-computer ratios) and teacher variables. The availability and access to technologies seem to be obvious and vital for using ICT in schools (e.g. Deaney & Hennessey, 2007; Pelgrum, 2008). Teacher variables have been examined in more detail in a number of studies: the analysis of Law and Chow (2008) on the basis of the IEA-study SITES 2006 (Second Information Technology in Education Study, Module 3, 2004–2008), as well as other studies, showed that the age of the teachers and the use of digital media do not correlate. Nevertheless, teachers differ in motivation, computer experience and familiarity, innovativeness, personal beliefs and attitudes towards the usefulness of ICT for teaching and learning (e.g. Ertmer, 2005; Ertmer et al., 2009; Tondeur, Coopert, & Newhouse, 2010). On the one hand, the perception of the improvement of student learning outcomes and the perceived student motivation determine teachers’ attitudes towards ICT use for teaching and learning (Teo, 2009). On the other hand, the more the computer-assisted teaching concepts resemble the subjective teaching style, the more likely teachers are to incorporate ICT into their teaching practice (Deaney & Hennessey, 2007; Müller, Blömeke, & Eichler, 2006). Furthermore, teachers’ attitudes are positively correlated with their familiarity with ICT (Christensen & Knezek, 2001, 2008). Together with indicators concerning teachers’ technology access, teachers’ attitudes and competencies account for greater than 90 percent of technology integration into classrooms in the U.S. (Morales, 2006). Even five years later, these indicators explained 40% of variance in computer use by teachers in Swiss schools (Petko, in press). However, findings emphasize that not only teachers’ attitudes and measures of IT-infrastructure explain computer use, but also factors concerning teachers’ technological pedagogical competences and knowledge (TPCK-approach by Koehler & Mishra, 2008).

Factors concerning ICT integration on the process level of schools

Considering process models of change in schools, a sustainable and successful implementation of pedagogical innovation, such as the implementation of ICT into teaching and learning, drops in the last stage of change processes in schools (Fullan, 2001, 2007). Such holistic models of school improvement processes have

been specified and adopted for ICT implementation in schools (e.g. Schnoor, 1998). These models comprise as the first stage for the initiation of ICT implementation by only one teacher or a small group of teachers who attempt to spread the innovation into the curriculum, more subjects or the teaching practice of other educators. Finally, the use of ICT for teaching and learning is integrated into every day teaching. For the very first phase of the innovation process, the current research identifies obstacles and supportive factors on the school level, such as the role of the school principal, aspects of school culture, the level of cooperation between teachers, and additionally pedagogical aspects on the classroom level. The following section elaborates in more detail these factors on the school and on the classroom level.

On the school level, the support of the principals has been found to be the most important and supportive factor for teachers in several studies (Leonard & Leonard, 2006; Tondeur et al., 2010). However, organizational structures and the availability of support from the principal differ in various education systems (Law, Pelgrum, & Plomp, 2008). Furthermore, aspects of school culture, especially with regard to ICT-related teacher cooperation, have great influence on teachers' ICT use (Dexter, Seashore, & Anderson, 2002; Law & Chow, 2008). Such inner-school cooperation enables teachers to improve their ICT-related technological and pedagogical competencies and therefore is a strong contributor to their professional development (see also Looi, Lim, & Chen, 2008). Research in various countries emphasizes the necessity of a strong culture for professional collaboration e.g. in terms of teacher cooperation which should be anchored in school programs as a substantial part of professional learning (Dexter, Seashore, & Anderson, 2002; Kelchtermans, 2006; Law & Chow, 2008; Strudler & Herrington, 2008; Eickelmann, 2010). Furthermore, it turned out that combining the implementation of ICT with other innovations in the school is a supportive factor, e.g. the change of the learning culture in terms of realizing more learner-centered instruction (Krumsvik, 2005). According to Krumsvik, such a pedagogical combination on school level firstly supports the acceptance of ICT use by teachers and secondly, it helps teachers to realize that implementing ICT in teaching and learning is not an exceptional innovation detached from other school development processes.

On the classroom level, the focus is on pedagogical aspects of ICT use. For the development and distribution of pedagogical concepts for ICT use, the limited availability of the teachers' time could still be a hindering factor. This incorporates the issue of learning how to use new technologies within the scope of preparing lessons (Deaney & Hennessy, 2007; Preston, Cox, & Cox, 2000). Furthermore, the lack of specification for ICT in the curricula hinders the development and distribution of learning scenarios with ICT (Deaney & Hennessy, 2007).

Research towards the sustainability of ICT implementation in schools in IEA SITES M2

Regarding research towards the sustainable implementation of ICT in schools, the SITES M2 (Kozma, 2003a; Schulz-Zander, 2005) presented initial findings (Owston, 2003). SITES M2 was a qualitative study on the basis of 174 case studies in 28 countries and the second of three modules of an international comparative research program by the IEA, exploring the use of ICT in schools since the late 1990s (Law, Pelgrum, & Plomp, 2008; Voogt & Plomp, 2010). Owston (2003) brings together factors, which might contribute to the sustainability of ICT integration. Using cross-case analysis of the SITES M2 case studies, he develops a model, which comprises two groups of interdependent factors, the so-called “essential” and “contributing” factors.

The first group encompasses factors that are assumed essential for a sustainable integration of ICT-use in schools (ibid. p. 133) and they could be divided into three subgroups:

1. Support of individuals in the school.
2. Professional development of teachers.
3. Perceived value of the innovation.

The first of these subgroups, *support of individuals in schools*, includes three factors, i.e. the involvement and engagement of teachers, the administrative support, and the support from the students. The latter is of special importance because it influences teachers’ motivation to implement digital media in their lessons. With regard to student support, Owston explains:

Students play a direct role in sustaining the innovation as well. If the innovation affects students positively – for example in terms of improved achievement or attitudes – teachers tend to be motivated to continue with the innovation, look for ways to improve it, and improvise if resources are reduced. (ibid., p. 134)

The second subgroup concerns the *professional development* of the teachers, which has additional impact on their motivation. This includes their participation in further training as well as their informal opportunities to learn. The third subgroup, *perceived value of innovation*, refers to the perception of teachers to experience an additional pedagogical value in the innovation: results show that they tend to support ICT-related innovations in schools if they can identify a positive effect on the students, such as improvement of their achievement or motivation.

The second group of factors identified by Owston, the contributing factors, indicates that they are not as relevant as the essential conditions (ibid. p. 133). This group includes

1. support by groups of persons within and outside the school;
2. support by the innovation champions in the school;

3. financial support; and
4. educational policies.

The first subgroup, the *support by groups of persons within and outside the school*, covers the support by the teaching staff, parents and education authorities. The second aspect concerns the *innovation champions in the school* – people, who have designed and accompanied the innovations in their initial stages and who were motivated to continue their work and to spread the innovation into the teaching and learning in the whole school. The third aspect relates to *financial support*, which is important to provide and maintain the ICT-infrastructure. Lastly, the incorporation of the innovations considered in an overall *concept for educational policy* is conducive.

However, the period of observation of the innovations in the SITES M2 study did not allow for a considered formulation of the condition factors and Owston (2003) outlines that long-term data are required to find out which condition factors are relevant to a sustainable implementation of ICT in schools. The study described in this paper addresses this research gap, and this study is designed as a follow-up study of SITES M2 in Germany and covers a 5-year period.

3. Research questions

This study focuses on the following two research questions:

1. To what degree can sustainable ICT integration into teaching and learning be found in single schools?
2. Which factors on the school input and process level support or hinder the sustainable integration of ICT into teaching and learning?

By addressing these questions directly and designing for the first time a study that joins these both strands by using a long-termed perspective, the study aims to clarify the factors that determine sustainable and successful ICT implementation. By this, it aims to provide knowledge about activating parameters to enhance teaching and learning with technology. Furthermore, the study aims to develop a tool to assess the sustainability of ICT-implementation in order to answer the first question and thus clarify the concept of ‘sustainability’ itself.

4. Data and methods

Phase models for the implementation of innovations in schools (Rogers, 2003; Fullan, 2007) imply a longer period of observation in order to describe the whole innovation process until the innovation is implemented sustainably. This follow-up study of the German SITES M2 recognizes the applicability of phased models. This

study was conducted five years after SITES M2. Looking back on the five years between both studies and focusing on ICT-related school development processes, this follow-up study identifies to what extent the schools that took part in the SITES-M2-study succeeded or failed in continuing to implement ICT into their teaching and learning and it examines supportive and hindering factors for this development.

This study is designed as a follow-up study based on longitudinal case studies. This means that case studies have been carried out over two survey periods and the data sets are connected by addressing the same sample, considering the first sets of data and its analysis successively with the second data collection accompanied by appropriate modification of instruments (Schulz-Zander & Eickelmann, 2008).

Case studies belong to the basic design of qualitative research (Flick, 2000) and the term itself signifies a number of approaches (Creswell, 1998; Fuhs, 2007). The literature distinguishes between single-case and multi-case studies (Yin, 1994). The follow-up study presented here uses a multi-case approach and focuses on the comparison of the cases to identify differences and similarities by means of cross-case analyses (Miles & Huberman, 1994). This approach facilitates both case-oriented and variable-oriented strategies of examination with the aim to get sound and holistic understanding of the innovational processes in the single schools and the commonalities they share. Therefore, this is an *instrumental* case study approach, because it also focuses on the analysis of underlying issues, relationships and causes that can be used to generalize the results, or at least get more holistic insights beyond the individual case (Kozma, 2003b, p. 22; Stake, 1995). Nevertheless, Mayring (2000) seeks a continual recourse to the case in its entirety and complexity, during the entire process of analysis. To grasp this complexity, the current study uses the strengths of qualitative as well as quantitative data to answer the research questions (Bos & Koller, 2002, p. 282). Altogether, the study uses three of four different types of triangulation defined by Denzin (1978; Denzin & Lincoln, 2005) to increase the quality of the study and guarantee reliability and validity. Firstly, data triangulation was realized by addressing different groups of persons (students, teachers, principals, and IT coordinators) and resources (e.g. school documents). Secondly, investigator triangulation of the study involves the carrying out of each interview and the coding of qualitative data and open-ended questions by at least two researchers, including the control for the inter-rater reliability with Cohen's kappa for at least .75 (Bortz & Döring, 2002). Thirdly, the methodological triangulation comprises the already mentioned mixed-methods approach, as well as the triangulation within a method, such as analyzing different types of qualitative data, e.g. interviews, school documents and the existing narrative case reports from *SITES M2*.

Altogether, qualitative data have been analyzed with content analysis procedures (Mayring, 2000). The categories for the coding of supportive and obstructive factors were developed from the theoretical background of school research literature, as well as from inductive categories (Bos & Tarnai, 1989). This ended up in a set of categories comprising the schools' context level (administrative level, so-

cial and regional background of the school and external partners), the input level (e.g. curricula, attitudes and structural, personal, material and financial conditions and teacher and student variables), and the process level. The latter is according to Scheerens (2000) and Ditton (2000) subdivided into the school and the classroom level. Consequently, aspects examined on the school level, such as school leadership, cooperation inside the schools, staff policy, and school culture, were included into the set of categories. With regard to the classroom level, factors concerning the quality of learning, the appropriateness of classroom practice with ICT, students' motivation and the effective use of time for learning are important in school research literature (Slavin, 1994, adopted e.g. by Ditton, 2000) and therefore were included in the set of categories.

The quantitative data were explored by means of descriptive analysis, by multivariate methods of analysis, such as factor analysis regarding teacher cooperation or the perception of the utility of ICT support and infrastructure. In addition, classification of teachers by latent class analysis as an advanced method to cluster subsamples of teachers based on their estimations regarding hindering and supportive factors of pedagogical use of ICT in their schools, presented as dichotomous items, was calculated.

Sample of the study

The sample of the study is a subsample of six schools of the German follow-up study to SITES M2 (Schulz-Zander & Eickelmann, 2008). The SITES M2 schools had formerly been selected by a national panel in each of the 28 SITES M2 national research centers, which used a set of international criteria provided by the international steering committee of SITES M2 (Kozma, 2003b). These criteria concern analytic dimensions like the pedagogical change with ICT, e.g. showing evidence of "significant" change in the roles of teachers and students, the crucial role of technology in teaching and learning itself as "significant" contribution to change, "positive" student outcomes and the "potential" probability of sustainability and transferability of the pedagogical changes (ibid., p. 27). For the presented in-depth analysis concerning the abovementioned research questions and the schools' ICT-related school development processes, two schools of each level (primary, lower and upper secondary), that participated again in the German follow-up study of SITES M2, were chosen as a subsample. After the new data collection in 2006, the research team selected these six schools for in-depth analyses, because they had developed very differently, as described below in more detail.

As to the individual level, the study gathered data from the schools' principals, the schools' IT coordinators, from all students of the last academic year level (which is Grade 4 for primary, Grade 10 for lower secondary and Grade 12 for upper secondary schools), and from teachers who used ICT in their lessons as well as from those who did not. As to the ICT-using subsample of teachers, the follow-up study referred to those teachers who had been nominated as "innovative teachers" by the school principal in the SITES M2, being most involved in ICT-related pedagogical change. In case that these teachers could not be available for the follow-

up study, the principals nominated another person who met the criterion. In some cases, the principals nominated two teachers: the SITES M2 teacher and another teacher who turned out to be equally or even more innovative in the meantime. To get the most holistic insight into the school development process over the observation period, the research team decided to follow the principals' suggestions and therefore interviewed two "innovative teachers".

Instrumentation of the study

As to the instrumentation, the German follow-up study adopted the instruments of SITES M2. For this, questionnaires and interview guides for semi-structured interviews have been modified, extended and updated. Moreover, the new study added a teacher and student questionnaire to assess long-term outcomes of ICT-use and to reach a higher number of persons, in order to get a holistic and most differentiated view on the schools' development. These new questionnaires partly consist of previously validated scales or scales from other studies (e.g. SITES 2006), which take school improvement, as well as ICT-related aspects into account (see Figure 1).

Figure 1: Overview of qualitative and quantitative instruments of the follow-up study

Qualitative Interviews	Questionnaires	Documents
School principal	School principal	Narrative reports of SITES M2
IT coordinator	IT coordinator	
Innovative teachers using ICT (*)	All teachers All students (grades 4, 10, 12)	School programs
Other teachers (*)		Media concepts of participating schools
Students		Homepages of schools

Note. Instruments previously applied in SITES M2 (updated and modified) highlighted within a frame.
 (*) Wherever possible, those teachers were chosen who had been interviewed in SITES M2.

a) Questionnaires

The main aim of the *student questionnaire* was to get reliable information based on Likert-scale items about the pedagogical use of computer technologies in the classroom, the frequency and distribution of computer use in the subjects and by teachers. Furthermore, data on self-efficacy, computer-related self-concept and students' background (e.g. age, gender, books at home) was gathered.

With regard to the first research question, the most important parts of the *teacher questionnaire* investigated teachers' ICT-use, ICT-related school culture, cooperation and pedagogical aims. Furthermore, questions concerning the role of the principal, teachers' attitudes towards the change of teaching and learning

with ICT, their subjective perception and satisfaction with the provision, access and maintenance of ICT-equipment, as well as professional development measures within and outside the school were addressed. As to the hindering factors (second research question), a list of obstacles to ICT-use in terms of dichotomous items was included (see Table 5). Furthermore, teacher characteristics (e.g. age, gender, qualifications, and years of teaching) and teaching assignment were ascertained to understand the teachers' feedback on questions concerning their estimation of pedagogical and ICT-related school factors.

The *principal questionnaire* gave insights into ICT-related school development, the integration of ICT in school programs and professional development. Furthermore, principals were asked to estimate the frequency and distribution of ICT-use in their schools. All items were Likert-scale items, except for some open-ended questions concerning (1) the pedagogical aims of the school related to ICT use and (2) information on funding programs.

IT-coordinators, provided details about the IT-equipment, first and second level of support, as well as their insights into pedagogical practice and problems arising at the intersection of technology and pedagogy, through the *IT-coordinator questionnaire*. Items were presented in Likert-scale type, except for open-ended questions on special information concerning (1) the description of important ICT-related school development and (2) problems concerning ICT-use for teaching and learning.

b) Semi-structured interviews

In addition, semi-structured interviews were addressed to the principals, teachers (two subgroups: (a) the so-called innovative teachers/ICT-users and (b) the non-ICT-users), students and the schools' IT coordinators. Altogether, 30 interviews with regard to ICT-use in the school and its development, hindering and supportive factors, the role of the school principal and cooperation were included in the in-depth analysis presented here.

c) Analysis of school documents

Beyond this, school documents (school programs and school websites) of all schools and the case-related SITES M2 reports were analyzed by means of qualitative content analysis, using the following four categories:

1. Information and statements in school documents regarding ICT implementation as an overall aim of the school (e.g. as a special pedagogical profile or focus).
2. Information and statements regarding the change of learning with ICT.
3. Information with respect to factors concerning the ICT implementation in the schools (e.g. problems documented in the SITES M2 case report).
4. Other Information and statements related to the implementation of ICT in the school (e.g. figures and description concerning the IT-equipment, announcement of ICT-related promotion respectively funding program, etc.).

All qualitative and quantitative instruments in the follow-up study were tested in a field trial before use.

Methodology

In order to measure the success of ICT implementation in the case study, a theory- and data-based instrument comprising 16 indicators with 4 values (0 to 3 points each) was developed (see Table 1). This methodological approach refers to what Mayring (2000) calls a “scaling structure analysis” as a special form of content analysis for which data is estimated on an ordinal scale (ibid., p. 92). The indicators were grouped into the five fields of school improvement concerning digital media (Schulz-Zander, 1999):

1. Organizational development
2. Development of teaching and learning
3. Professional development
4. Development of ICT-related cooperation
5. Technological development

Indicators concerning the *organizational development* comprise: (1) the inclusion of digital media into school programs, (2) the linking of media use to pedagogical aims of the school, (3) the ability to cope with problems regarding ICT implementation, (4) the current stage within the innovation process, and (5) the sustained success of former ICT-related innovations, such as the classroom practice observed in SITES M2.

Indicators concerning the *development of teaching and learning* focus on (6) the application of ICT in various subjects, (7) the application of ICT among the teaching staff, (8) the frequency of ICT-use and (9) general changes in the culture of learning. Concerning the *professional development*, the perceived availability and utility of professional development and training measures for teachers and the participation in such programs were observed and estimated (indicator 10). Furthermore, inter-school cooperation and cooperation with external partners concerning ICT aspects were identified and assessed (11 and 12) on the *development of ICT-related cooperation* indicator level. The survey of the *technological development* consists of the perceived satisfaction with IT-equipment (13), the objective evaluation of IT-equipment compared to national means (14) and the availability and perception of technical support within the school (15 and 16).

Table 1: Outline of an instrument to measure the sustainability of ICT integration in schools

Sustainability indicators	Values	Data base for scaling the values
<i>Indicators regarding the schools' organizational development according to ICT</i>		
1. Embedment of the pedagogical use of ICT into school programs or media concepts	Not at all (0); mentioned (1); outlined and partly transformed into practice (2); outlined clearly and broadly practiced (3)	Interview transcripts, school documents (e.g. school programs), principal questionnaire
2. Connection between ICT-use and general pedagogical aims of the school	None (0), existing (1), clear (2), central (3)	Interview transcripts, school documents, principal questionnaire
3. Organizational capability to solve problems regarding ICT integration	Problems could not be solved at all (0); could be partly solved (1); most of them could be solved (2); for all problems solutions are worked out (3)	Interview transcripts, SITES M2 reports; teacher questionnaire; ICT-coordinator questionnaire
4. Phase of innovation	No evidence for relevance of ICT (0); ICT-related innovations still rely on single persons (1); ICT-use is part of everyday teaching and learning for some persons or subjects (2); ICT is part of teaching and learning for the whole school and is not seen as an innovation any longer (3)	Interview transcripts, ICT-coordinator questionnaire
5. Promotion of the innovation 'ICT integration'	No promotion at all (0); partly evidence for promotional activities (1); promotion on different levels (2); wide-spread and effective promotion of the innovation	Interview transcripts, principal questionnaire
<i>Indicators regarding the development of teaching and learning with ICT</i>		
6. Continuation of the innovative pedagogical practice examined in SITES M2	No longer existing (0); still sometimes in practice (1); still in practice on a regular base (2); further developed	Interview transcripts
7. Dissemination of ICT-use into subjects	No ICT-use in any subject (0); ICT-use mainly in one subject (1); in some (2); in every or nearly every subject (3)	Interview transcripts, ICT-coordinator questionnaire; principal questionnaire
8. Dissemination of ICT-use into teaching staff	No ICT-use by any teacher (0); ICT-use by some teachers (1); by more than half of teaching staff (2); by at least three quarters of the teaching staff (3)	Interview transcripts, ICT-coordinator questionnaire; principal questionnaire, teacher questionnaire

	Sustainability indicators	Values	Data base for scaling the values
9.	Frequency of ICT-use	Never (0); occasionally (1); often (2); very frequently/regularly (3)	Interview transcripts, student questionnaire; ICT-coordinator questionnaire
10.	Change of learning culture with ICT (e.g. presence of more student-centered or project-based learning)	None (0); only in a few projects or by some teachers (1); greater number of projects/teachers (2); widely and systematically (3)	Interview transcripts, student questionnaire; teacher questionnaire ; ICT-coordinator questionnaire
<i>Indicator regarding ICT-related professional development</i>			
11.	Professional development (offer, participation and utility of measures)	Not sufficient (0); rather insufficient (1); sufficient (2); operative and useful (3)	Interview transcripts, teacher questionnaire; ICT-coordinator questionnaire
<i>Indicators concerning the development of ICT-related cooperation</i>			
12.	ICT-related cooperation with external partners	Never (0); occasionally (1); often (2); very frequently/regularly (3)	Interview transcripts, principal questionnaire; ICT-coordinator questionnaire
13.	ICT-related inner-school cooperations	Never (0); occasionally (1); often (2); very frequently/regularly (3)	Interview transcripts, principal questionnaire; ICT-coordinator questionnaire, teacher questionnaire (especially a scale named "ICT-related teacher cooperation", see Table 2)
<i>Indicators on the level of technological development</i>			
14.	Perception of the quality of and access to IT-equipment (subjective)	Not sufficient (0); rather insufficient (1); sufficient (2); operative and useful (3)	Interview transcripts, ICT-coordinator questionnaire, teacher questionnaire (especially a scale named "Teachers' satisfaction with IT-infrastructure")
15.	Quality of and access to IT-equipment (compared to the national average, objective estimation)	Far below the nation-wide average (0); below (1); on average or above (2); outstanding (3)	Interview transcripts, principal questionnaire; ICT-coordinator questionnaire
16.	Technical support (as perceived)	Not sufficient (0); rather insufficient (1); sufficient (2); operative and useful (3)	Interview transcripts, ICT-coordinator questionnaire, teacher questionnaire (especially a scale named "Teachers' satisfaction with IT-support", see Table 3)

All indicators were evaluated for each school after the underlying qualitative and quantitative data had been analyzed case-wise in data matrices. In this context, the

interview data provide the most revealing information to estimate the indicator values for each school. However, in order to compare the situation and the processes, the quantitative data have given the best insights. For this reason, quantitative data, such as responses from teachers and students has been aggregated on school level, e.g. by calculating the mean factor score of a scale as a school score (see Table 2 and Table 3).

Table 2: Scale “ICT-related teacher cooperation”

Statistics	$N = 182$ $\alpha = .83$	$M = 2.10$ MIN = 1	$SD = 0.76$ MAX = 5
Question	How often do you work regularly on the following topics or tasks with other teachers in your school? (teacher questionnaire)		
Scaling	[1] not at all, [2] once a year, [3] several times in half a year, [4] once a month, [5] once a week		
Items	Item	M	SD
	1 Use of ICT in class	2.52	1.08
	2 ICT-infrastructure in the school	2.47	1.02
	3 Teaching concepts for ICT-use	2.11	0.99
	4 Development of teaching and learning materials for use of ICT in class	1.90	0.99
	5 Providing information and materials via the school intranet	1.56	0.86

Table 3: Scale “Teachers’ satisfaction with IT-support”

Statistics	$N = 162$ $\alpha = .72$	$M = 2.17$ MIN = 1	$SD = 0.75$ MAX = 5
Question	Which IT-support do you get in your school regarding the instructional use of ICT? (teacher questionnaire)		
Scaling	[1] not at all, [2] once a year, [3] several times in half a year, [4] once a month, [5] once a week		
Items	Item	M	SD
	1 On request, I get technical support even during the lesson.	2.23	1.03
	2 I get prompt technical support if technical problems arise during a lesson.	2.10	0.82
	3 In my school, I get support for selecting appropriate hard- and software.	2.21	0.83

To give an example, based on the teacher data, questionnaire scales concerning the ICT-related inner-school cooperation (Table 2; Schulz-Zander & Eickelmann, 2010) and a scale concerning the satisfaction with IT-support in the schools (Table 3) have been developed. The factor score for each school was implied into the scoring of the relevant sustainability indicator (here: indicator 13 respectively indica-

tor 16, see Table 1) by ranking the factor scores of all schools, in order to find evidence whether a single school performed well or struggled. Following the approach of scaling structure analysis (e.g. Mayring, 2000) as a special form of content analysis, the values of each school were added and compared to a maximum score of 48 (= 16 x 3, using all 16 indicators with a maximum score of 3 for each, see Table 5). Two researchers estimated the values of these indicators independently. The estimations were controlled for inter-rater reliability in terms of Cohen’s kappa at minimum .80. For all deviations in terms of different values, the two coders found the finally assigned value consensually.

5. Empirical findings

Regarding the first research question, the most noticeable observation was that the surveyed schools developed very differently within the same period. All schools started with an innovative pedagogical approach and high motivation to integrate ICT in teaching and learning, but only a few schools had been successful in realizing this aim (see Table 4). In particular, three of the schools gave evidence for a successful and sustainable ICT integration, whereas three schools reported that they struggled to continue to implement ICT.

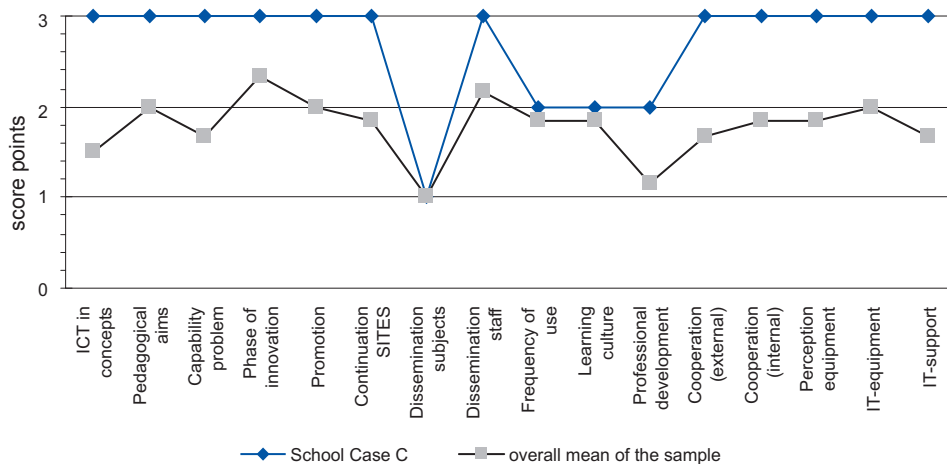
After the scoring process, case schools A and E were classified as ‘more sustainable’ regarding their efforts in ICT integration, as they both reached 38 of 48 points (see Table 4). By way of example, the primary school “case A” had been very successful in implementing digital media in its school program (3 out of 3 points on indicator 1, see Table 1). Furthermore, the school had developed a clear concept on how to use ICT for teaching and learning (3 out of 3 points on indicator 2), in outlining media literacy in terms of an interdisciplinary competence and as an essential aim of schooling. The most outstanding success of this school was that it succeeded on indicator 4 “phase of innovation” (see Table 1). Case A was the only school in the whole sample with evidence that ICT integration was no longer an innovation and was now implemented in every day teaching and learning by all teachers. New innovations, like a support program for gifted students, stood out with the focus of school improvement processes at the time of the follow-up study.

Table 4: Total sustainability scores of the six in-depth analyses of school cases based on scaling structure analysis

	Case A (primary school)	Case B (primary school)	Case C (lower secondary school)	Case D (lower secondary school)	Case E (upper secondary school)	Case F (upper secondary school)
Total points of all 16 sustainability indicators (max. score =48)	38	14	43	17	38	20

The most successful school (case C) in this study achieved 43 out of 48 points with three out of three points in almost every field (see Table 4 and Figure 2). The most outstanding supporting factor in this school was that the principal managed to link the innovation “ICT integration” to other aims of the school, such as the promotion of self-regulated learning. Furthermore, he succeeded in acquiring external cooperation partners, which both guaranteed the financial resources for up to date IT-equipment and contributed to ICT-related knowledge. He also had been very effective in staff development strategies: He established ICT-related coaching systems, where teachers used messages with questions and qualification offers on a white-board in the teachers’ lounge. Additionally, he recruited teachers who were supposed to use ICT competently in terms of technical proficiency and who had previous experience in using ICT for teaching and learning. Besides, the school used its radius of financial autonomy to convert one teacher position into a position for an IT-expert to provide first level support, which turned out to be supportive, too.

Figure 2: Assessment of sustainability indicators for School C compared with the overall mean of the sample



The principal of this school comments on this successful ICT-related school development process, as follows:

Looking back at the last five years, the fascination of the computer as a machine has been replaced with its everyday use, with a focus on supporting learning in general and supporting students’ independent and self-directed learning. (Principal, school C)

Schools B, D and F had much lower scores on the sustainability scale (Table 5). By way of example, the primary school “case B” struggled, because the school principal relied too much on a single teacher as a promoter of ICT-use. When this “innovation champion” left the school two years after SITES M2 data collection, there

was no more support for school-wide ICT integration. This circumstance overlapped with other factors, such as a substandard IT-infrastructure and a missing vision for the relationship between ICT-use and the school's pedagogical aims.

As to school D, to give another example, a set of factors undermined the promising beginnings of ICT-related school development: The position of the school principal had been unoccupied for more than two years and the teachers described these years as a period of time in which nearly all school-wide innovations stopped. Furthermore, the school administration within the school's region equipped all schools with special computer labs, but at the same time prohibited to allocate computers in the classrooms. This did not suit to the prior pedagogical approach to computer use of the school, for which the flexible use of computers and their use in personalized learning scenarios played an important role, therefore resulting in resistance, as well as de-motivation across the teaching staff.

Commonalities between schools which succeeded in sustainable ICT integration

To answer the second research question, the cross-case analysis aimed to identify commonalities between the successful schools. For this analysis, at first the successful schools of the sample were identified by selecting those that reached a comparably high score on the sustainability scale (Table 1 and 4). To identify supportive factors within these schools, a three-step-analysis was undertaken:

First step: Case-based identification of supportive factors.

Second step: Consensual identification of the most important and relevant factors for the single cases.

Third step: Comparison of the different case-related and relevant factors and identification of shared factors between the three successful schools.

The results show that the schools shared the following eight commonalities:

Common essential supportive factors on the school level:

1. The principals in the successful schools had strong leadership skills, which they used to promote ICT-use, and had a sound understanding of the potential of ICT to enhance learning.
2. The schools had established cooperation with external partners to raise funding, e.g. companies or education authorities to participate in ICT-related funding programs.
3. The schools realized intra-school cooperation (e.g. coaching systems or de-privatization of classroom practice), which was integrated into school concepts and culture. This way, the computer-related and pedagogical knowledge of the teaching staff was improved.
4. They developed concepts to cope with new digital trends, e.g. implementation of new staff development schemes with the establishment of private-public partnerships and by turning teacher positions into positions for technical staff when necessary.

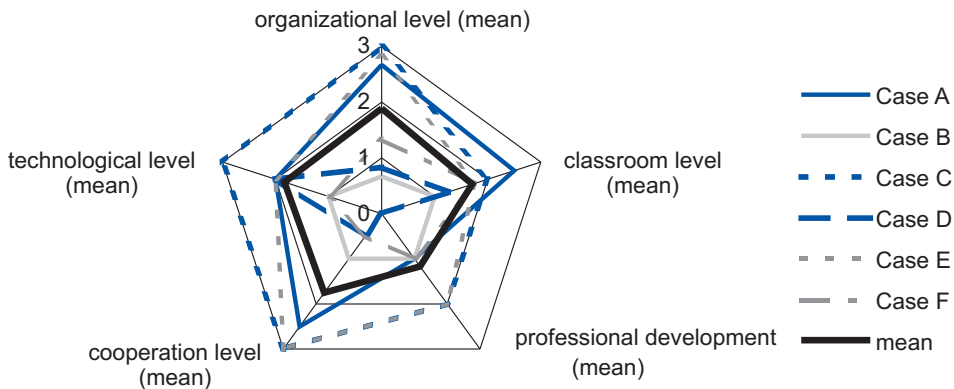
5. They used their radius of operation on the process level to cope with problems and challenges regarding ICT-implementation and did not externalize problems.

Common essential supportive factors on the classroom level:

6. The successful schools disseminated ICT's potential to enhance learning within the whole school, e.g. use of ICT to support personalized learning.
7. They closely linked ICT-use to existing and prospective pedagogical aims, such as language support for students with a migration background. By this, the schools' IT-infrastructure was carefully selected, in order to address these aims (e.g. equipping students with portable devices or locating computers in the classroom to support individualized learning).
8. They disseminated ICT into teaching and learning by integrating technology into compulsory school programs and curricula.

To exemplify one aspect as an overall pattern of results, the importance of cooperation is described in more detail. When comparing the cooperation level, including cooperation with partners (2.) and inner-school cooperation (3.), to the other levels of ICT-related school development (organizational, classroom, professional development, and technological level, see Table 1), it appears that the mean values of all five indicators aggregated on the specific level lie close together (see Figure 3). This is clarified in the following diagram where the graph for the mean values in the star diagram is an almost regular pentagon (thick black line).

Figure 3: Sustainability scores of the schools: means aggregated on five different school levels



However, the spread of the mean values on the single five levels varied with the largest spread of 2.5 for the cooperation level. Furthermore, interestingly the schools that were successful in integrating digital media more sustainably, i.e. cases A, C and E, scored highly on this level (2.5 or 3), whereas the other case schools had settled for low scores (0.5 or 1). Therefore, the cooperation level of ICT-related

school improvement reflects a prominent discriminatory power between successful and less successful schools, at least for the sample of this study.

Commonalities between schools which failed to implement ICT sustainably

To identify crucial hindering conditions, the less successful schools, which reached a comparable low score on the sustainability scale, were analyzed (see Table 4). Again, a three-step cross-case analysis of factors resulted in identifying commonalities between the less successful schools and their school improvement processes. These commonalities refer to the *school- or the classroom level* and therefore were assigned to the schools' process level.

Common hindering factors on the *school level*:

1. When funding was available, these schools did not develop long term strategies to integrate digital media into learning and teaching.
2. The school principals relied too much on individuals, such as 'innovation champions' and did not succeed in disseminating ICT-use. By this, the gap between teachers' technological pedagogical knowledge widened and in some cases, where the innovation champions left the schools, the required knowledge was no longer available.
3. They failed to develop holistic support structures for ICT-use that covers both pedagogical and technological aspects.
4. The schools reported teacher variables as hindering factors for ICT integration, especially lack of acceptance. They missed perceived value of ICT-use by focusing on limited competencies in technical and pedagogical ICT use.

Common hindering factors regarding the *classroom level*:

1. The schools could not clearly disseminate the potential of ICT-use to enhance learning. This became obvious in cases where only some teachers used ICT for teaching and learning aiming to address the needs of their students (e.g. the need for special language support), while other teachers pointed out that their students' needs and background were rather obstacles than reasons for computer use.
2. The schools have focused on teaching ICT competencies, instead of using ICT to enhance learning. For example, they organized courses on how to use a word processing or spreadsheet software, instead of relating their application to content or suggesting an overarching pedagogical approach.
3. They have not developed concepts to use the potential benefits of ICT to achieve their pedagogical aims.

To emphasize the relevance of teachers' proficiency as an important result of the study, this aspect is exemplified in more detail. Teacher variables were important both in successful and in less successful schools. This leads to the assumption that there might be groups or classes of teachers, which outline similar factors, despite their belonging to a specific school. This conjecture is considered by a la-

tent-class-analysis based on the teacher survey (for more methodological issues see Lazarsfeld & Henry, 1968; McCutcheon, 1987). Obstacles to ICT-use are presented in Table 5 using data from the teacher questionnaire.

Table 5: Obstacles to computer use (teacher perspective, $N=180$)

	Percentage of teachers who agree
My school does not have the required peripheral equipment (e.g. printers, scanners).	48.5
My school does not have the required ICT infrastructure.	41.2
I do not have the sufficient time to develop and implement the activities and plan lessons.	38.2
IT-equipment is old and too slow.	37.6
I do not think one teacher is enough in computer-supported instruction.	32.1
IT-equipment is not reliable but flaky.	29.1
I do not have the necessary ICT-related pedagogical skills.	23.0
I do not have the required technological skills.	19.4
My students do not have access to the required ICT tools outside the classroom.	19.4
My school does not have good quality programs.	18.2
I do not know how to integrate ICT into teaching and learning.	17.0
I do not know how to identify which ICT tools will be useful (selection criteria are missing).	17.0
I am afraid of vandalism when using ICT with students.	15.2
I do not have sufficient confidence to try new approaches alone.	13.3
My school lacks digital learning resources and adequate software.	12.1
My students do not possess the required ICT skills.	10.3
I do not consider ICT useful for teaching and learning.	7.9

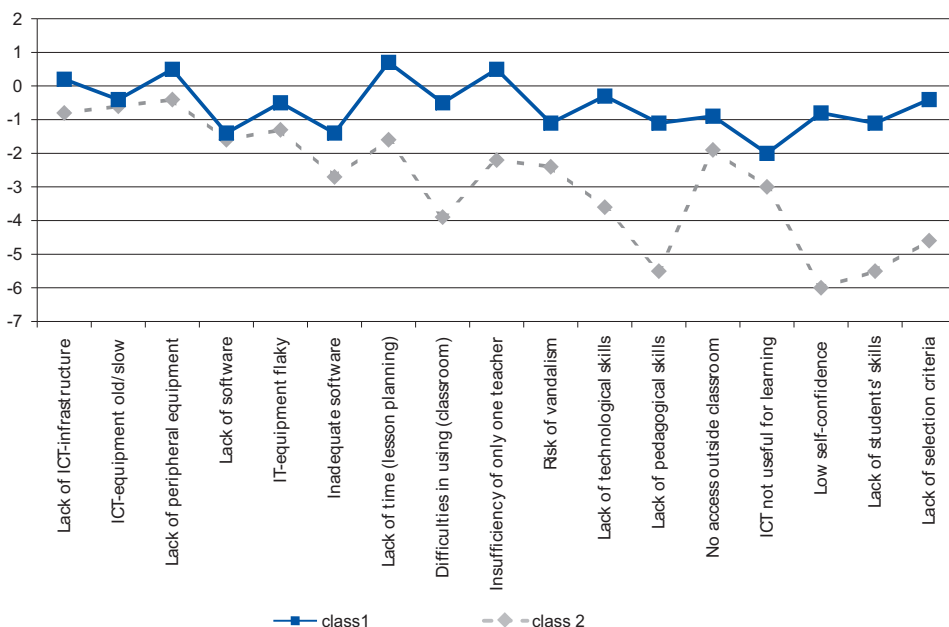
All these 17 items were included simultaneously in a latent-class-analysis. As shown in Table 6, the lowest Bayesian Information Criterion (BIC), which has been minimized for the best model fit (see Rost, 2004; von Davier, 2000), was found for the two-class-solution and therefore fits best to the empirical data.

Table 6: Model fit statistic for the conducted latent-class-analysis

	1-class solution	2-class solution	3-class solution	4-class solution	5-class solution	6-class solution	7-class solution
BIC	2935.08	2789.36	2807.80	2858.80	2910.81	2963.20	3030.57

Note. The lowest BIC value indicating the best model fit is set in boldface.

Figure 4: A typology of teachers and their perception of hindering factors concerning ICT-use. (N=180, class 1 (upper graph): 58% of the teachers)



The latent class analyses thus revealed two types of teachers (Figure 4). Above all, both types (class 1 and class 2) are equally concerned on the lack of ICT infrastructure and ICT-related support in their schools. However, the *first group of teachers* (class 1, upper graph) includes teachers with a self-recognized need to develop skills and competencies in order to use ICT in every-day classroom teaching. For all these teachers, overcoming the hindering factors was more difficult than for teachers in the other group, because the whole graph in Figure 4 lies above the graph of class 2. Teachers in class 1 admit that they do not have the required pedagogical and didactical skills to use ICT for teaching and learning. The *second group of teachers* (class 2) show more confidence in using ICT and reported better technological and didactical skills and knowledge. To sum these findings up with regard to the research question, the results of the latent-class analysis emphasize that some teachers acknowledge the lack of computer skills, technological pedagogical content knowledge, and what one might call ‘computer-related self-proficiency’, as

barriers to ICT use. Nevertheless, successful schools tend to overcome these barriers by taking several measures, such as supporting teacher cooperation and professional development. The less successful schools fail in disseminating the existing competencies within the teaching staff and therefore struggle to overcome barriers on the individual teacher level, as already reported above as a commonality in less successful schools.

6. Discussion and conclusions

The aim of the study presented was to investigate factors that support or hinder the sustainable and long-term ICT implementation in schools. The underlying theoretical approach of this study sought to analyze these research desiderata from a school development perspective (e.g. Fullan, 2007; Ditton, 2000) led to the identification of supportive and hindering factors on the school and the classroom level.

Although the theoretical background led to the assumption that factors on context, input and process levels are relevant for ICT implementation, the main finding of this study is that factors on the process level are most crucial. With regard to this, relevant differences between schools were found on the two sub-dimensions of the process level: the school level and the classroom level. The way schools in this study's sample act and re-act on these levels creates differences between them and influences sustainable implementation of ICT. On this level this study, like previous research (e.g. Leonard & Leonard, 2006; Tondeur et al., 2010), revealed that the support of the school principal and his or her leadership skills are crucial for the implementation of ICT. Moreover, the schools' cooperation with external partners, the intra-school cooperation, the development of concepts to cope and to re-act to new digital trends – which is one of the most important new findings revealed in this study – and the overall radius of operation to cope with problems on the process level, have been found to be most supportive. Whereas the failing to continue to develop pedagogical concepts when funding was available and/or the reliance on 'innovation champions', turned out to hinder schools. Moreover, the absence of holistic support structures for ICT-use in the school, related to both pedagogical and technological aspects were identified as hindering factors, particularly the lack of acceptance and appreciation of the value of ICT-use for teaching and learning and missing competencies in technical and pedagogical use of ICT.

There are two main *theoretical implications* from this study. Firstly, although the theoretical background led to the assumption that factors on the context, input, and process levels are relevant for ICT implementation, the study revealed factors on the process level of schools are crucial. It became obvious that schools that used their radius of operation succeeded, while others with comparably good starting situations that did not develop adequate strategies failed. Secondly, from a school improvement perspective, the implementation of digital media is a special innovation for schools in which the most challenging task for the school is the

rapid change of the innovation itself. It might happen that one innovation process has not been completed (e.g. the implementation of one-to-one computing) when the next one (e.g. the applications of Web2-technologies) has already begun. To cope with this challenge, schools have to develop appropriate strategies and, coming back to the first issue, they have to focus on the process level because this is their only scope for action.

Regarding the *practical implications* of the study, the presented study was motivated by the notion that computers and Internet were designed to be integrated into schools; reasons supporting or hindering their integration have been considered in empirical studies. However, previous studies have rarely been helpful to improve the frequency of computer use in schools. Although we knew why schools struggled during the initial phase of implementing digital media and we know how to react to this, we did not know what helped to maintain the efforts at the beginning in order to implement ICT sustainably into teaching and learning. Now, the results of this study, by outlining supportive and hindering factors, provide some guidance on the practices that schools could undertake in order to make their efforts operative.

However, further actions are required to integrate ICT within the whole education system so as to support schools to prepare students for the 21st century. That needs to go beyond single school practice. A key aspect missing is training for subject-related pedagogical approaches, as illustrated in the focus of research concerning TPCK (Technological Pedagogical Content Knowledge, see Koehler & Mishra, 2008). Furthermore, there is a need for comprehensive teaching of computer and information literacy, as it is for example studied in the current computer-related IEA-study ICILS 2013 (International Computer and Information Literacy Study, 2010-2014; Fraillon & Ainley, 2009). There is also a need for integrating ICT into teacher education (see also Davis, 2010; Williams, Foulger, & Wetzel, 2009) and curricula. As to teacher training in particular, it appears to be sensible to integrate lectures and seminars on the topics of school improvement and change processes in schools, with regard to ICT implementation as a special type of innovation in schools (see e.g. Finley & Hartman, 2004). Furthermore, reconsidering the special situation in Germany, the results of former studies and the analyses presented here outline that there is still a need for support by the policy and administration levels. This support should focus on:

1. Developing and improving school (media) concepts.
2. Support on the policy level, e.g. by developing curricula and teacher education.
3. Provision of in-service pedagogical training towards ICT-use for teaching and learning.

Finally, as to *methodological implications*, the study showed that the approach of gathering long-term data by conducting longitudinal case studies in qualitative research is important in order to examine processes in educational settings. The limitations of such studies include that their results do not allow for generalization. At first sight, the research outcomes are comparably low considering the immense

amount of work and time invested. This effort is only justifiable if one uses the outcomes of the study for further research. Using the main outcomes of the study, further research could apply the list of supportive and hindering factors for sustainable implementation of ICT in schools, to transfer it into Likert-scale items and collect data from a larger sample. Furthermore, the list of sustainability indicators could serve as a draft for a quantitative instrument, transferred into Likert-scale items to measure the degree of sustainable implementation of ICT in schools. Such an instrument was missing before this study.

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