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An Integrative Model for the Dynamics of ICT-based Innovations in Education

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Abstract

Empirical evidence underlines the importance of ICT-based innovations in education for at least two reasons: They prepare for a future workplace in a knowledge society increasingly dependent on ICT and furthermore, they support student-centred learning processes. However, adoption of ICT in educational organizations in general as well as of specific ICT-based innovations varies broadly across nations, as there are many different influencing factors with strong interdependencies. In order to better understand the dynamics of innovations in education, in this article we expose to discussion an integrative model based on a combination of models of individual and organizational adoption processes and their interplay with a socio-economic environment. The authors propose this concept of an "educational innovation system" to analyse differences in the diffusion of ICT-based innovations across countries and to better understand educational policies and their impact on classroom practice.

Keywords:

Education policy, innovation research, educational technology

Introduction

As the entire educational process is centred in communication and information, any tools and resources that help to communicate, and to create, disseminate, store, and manage information have been adopted in education systems (e.g. Cuban 1986; Blurton 1999; OECD 2006). Today, ICT-based innovations are relevant in the context of education for at least two main reasons: First of all, future workplaces in a knowledge society increasingly depend on ICT and therefore its use is regulated by curricula (e.g. OECD 1996). Media and information literacy in this respect is a basic competence for participation in the knowledge society (e.g. Jenkins 2007). Additionally, ICT-based innovations are also seen as a new means for teaching in a variety of subjects to support student-centred learning processes (e.g. Kozma 2003).

Rather indirectly, nevertheless important, as an increasingly time-consuming leisure activity, ICT usage plays an important role in childhood development and in the ways social networks are knit among children and adolescents. This in turn moulds - at least partly - formal and informal learning processes. Efforts by public institutions like schools to increase ICT skills and media literacy are generally preceded by children growing up within their 'computer culture.' Although highly disputed, some researchers suggest calling this generation 'digital natives' (Prensky 2001a,b; Palfrey & Gasser 2008). This observation still lacks an empirical foundation, as Selwyn (2009) pointed out: "At best the 'evidence base' for much of the digital native literature is rooted in informal observation and anecdote" (p.371). Nevertheless, the number of computer literate children is constantly increasing.

However, although education is facing a significant challenge in preparing students and teachers for a knowledge-based society, many teachers still are not prepared to use ICT, and often school buildings, even in OECD countries, are ill equipped to integrate the new information and communication technologies (see UNESCO 1998).

It comes as no surprise that ICT-based innovations in education are studied from the perspective of a variety of different academic disciplines and professional contexts. ICT-based innovations in education are a case in point for a complex process where individual choices, organizational frameworks and educational policies as well as attitudes in the society at large formed in public discourse interferes in several ways. Based on the cultural traditions of the educational systems, the innovation dynamics differ significantly. A mesh of several sub-processes on different levels is at work, which can only be understood by integrating the complimentary findings of various approaches or models respectively. We will introduce the concept of path dependency as one model to explain both the cultural embeddedness as well as dynamics of change.

The correlation of PC usage in classrooms and PC usage in private households as shown in figure 1 exemplifies the complexity of the interdependencies. From the diagram it becomes evident that we can observe in general a statistical correlation. Notably Thailand, Poland, Finland and the USA are in line with the average regression. However, large deviations (e.g. Hungary, Germany, South Korea) also point to the fact that there are other influencing factors. Above all, it is not even clear, whether PC usage in classrooms or PC usage in private households is the dependent variable.

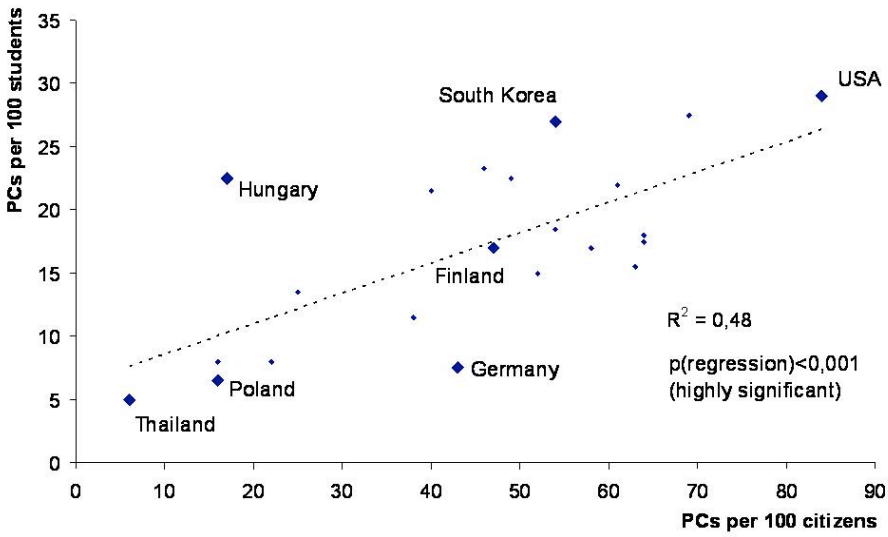

Figure 1: Correlation of PC usage in classrooms (OECD 2006) and PC usage in private households (compilation of data from different sources for 2004 cited in TNS Infratest 2006).

Additionally, adoption of ICT in educational organizations not only differs in terms of scale but also in terms of the adoption rate, as there are many different interfering variables and interdependencies among them.

In order to be able to better understand the dynamics, in this article we build upon a previous research study on the particular field of electronic gaming as an innovation process (Breiter & Kolo 2008). It aims at defining a first sketch of an integrative model based on a combination of models of individual and organizational adoption processes and their interplay within a socio-economic environment. This can deliver a new explanatory model, which brings together existing research based on systems theory on the different levels and adds the interplay between the levels.

Educational innovation systems

We will base our integrative approach on the concept of an 'educational innovation system.' It is aimed at analysing differences in the diffusion of ICT-based innovations across countries and to derive a better understanding of educational policies and their impact on classroom practice. The concept thereby is strongly influenced by the concept of 'national innovation systems' as used to describe the dynamics of innovation processes in general. The concept of national innovation systems was set up to account for the increasing economic role of knowledge. Knowledge, as embodied in human beings (as 'human capital') and in technology, has always been central to economic development. Over the last two decades its relative importance has been more and more recognized, just as its importance is increasing. Investments in knowledge, such as in education and training, are considered key to economic growth (OECD 1996).

The concept of national innovation systems dates back to the 1980s when the limitations of the original focus on inputs (such as research expenditures) and outputs (such as patents) became evident over time in that it neglected the multitude of interactions among the actors involved in the process of innovation (OECD 1997). National innovation systems have been defined as the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies (Freeman 1987). After first analyses (e.g. Freeman 1987; Lundvall 1992; Nelson 1993; Edquist 1997), the concept of national innovation systems was further elaborated up to now (e.g. Mytelka & Smith 2002; Peters 2005; Schmoch et al. 2006) in order to improve its applicability, particularly to refine technology and innovation policy.

The study of national innovation systems directed attention to the linkages or web of interactions within the complex set of relationships among actors in the system, which includes enterprises, universities and government research institutions. It was hoped that a better understanding of the interplay of these elements in their environment from a systems perspective can help identify leverage for enhancing innovative performance and overall competitiveness. Policies, which seek to improve networking among the actors and institutions in the system and which aim at enhancing the innovative capacity, are also increasingly valuable in the context of ICT-based innovations in education.

Framing ICT use in schools by an educational innovation system may help to understand the complex interdependencies between actors, institutions, and regulatory systems. By doing that, it may link the diverse findings on the dynamics of innovations in education, make them comparable across countries, and ultimately such a systematics may also support necessary research to complement previously unexplored influencing factors or links among them. Following innovation research in US schools (Fullan 2001; Kozma 2003; Owston 2007), the interplay of different influencing factors can be explained across three levels (see also figure 2):

The *individual level* addresses the teachers and students, their teaching and learning practice, the profession-specific beliefs and values and their media adoption processes. Additionally, parents shape the way the classroom organization takes place and influence the media adoption processes of their children. Furthermore, all of these actors do not only shape the adoption process but may also contribute to the generation of innovations at the first place. Of course, also other individuals may play a role with respect to the generation and the diffusion of innovations in education. However, as their impact is rather indirect, we regard them as being part of 'the environment' of the system.

The school is at the centre of the *institutional level*. The respective school culture, the school development process and the technology plan of the individual schools play an important role in media integration and are closely connected with the teaching practice. On this level there are also other institutions (e.g. suppliers of ICT in terms of hardware or software and support centres as part of the environment) influencing the diffusion of innovation (including again the generation of innovations here).

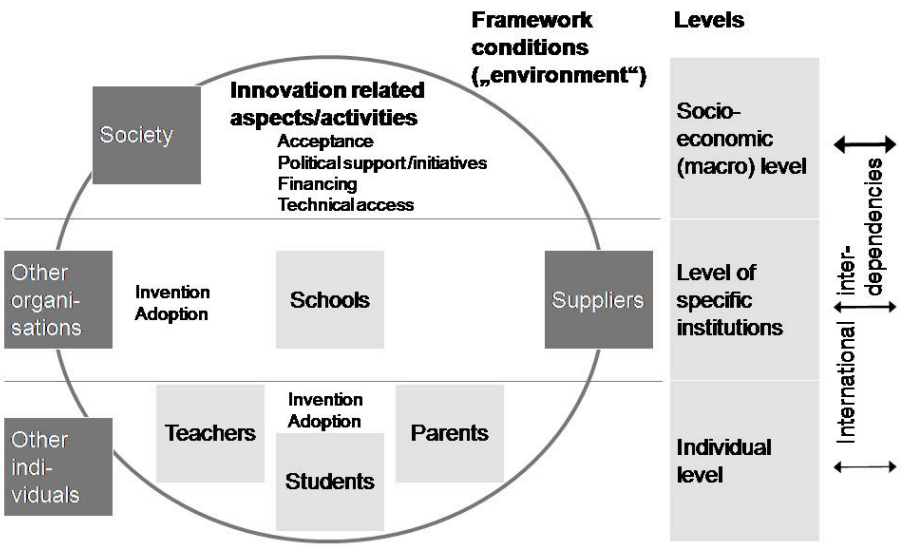

Figure 2: Levels of influences on the dynamics of ICT-based innovations in education

The *macro level* encompasses in particular the school region, the local school authority and its technology plan. These are the main pillars of the support system and have great influence on media integration in the classroom. The macro level foremost addresses the aims and activities of education policies concerning school quality improvement. Besides achievement standards, curricula or directives, this includes the integration of digital media in teacher training. The framework conditions, which are set by the society at-large, are also part of the macro level. General acceptance of new technologies is formed and either supported or impeded for example by not providing an accessible and affordable infrastructure for the private and institutional use of ICT.

Furthermore, educational policy is no longer the product of the nation state alone. International regulatory agencies are working today in joint projects and are translating, mediating and constructing educational policies within international networks (Martens et al. 2007). Of course, international interdependencies also have their influence on the individual and the institutional level - however, as we assume here, to a much lesser extent.

The delineated three-tier model first of all defines the system to be regarded as (national) educational innovation system. From such a system perspective, it comprises the teachers, the students and the parents as well as the school as an institution as elements in an environment, given by the above mentioned aspects as boundary or framework conditions (see also figure 3 for a summary of this system approach). The model thereby structures the problem space that may also be regarded as educational governance, as its dynamic is driven by the interplay of decisions among its actors (Arnott & Raab 2000; Martens et al. 2007). Educational governance thereby refers to authority within the education system. It includes the organizational structure of the

education system and the allocation of power, the formal roles and responsibilities, as well as the relationship between central, intermediate and local authorities.

In order to be useful in practice, such a model has to be seen in a dynamic perspective. As we know from innovation research, the future development is not only dependent on current socio-economical and cultural factors, but also on historical precedents along specific trajectories, also termed 'path dependence' (e.g. David 1985).

The concept of path dependency was originally developed by evolutionary economists (like Dosi et al 1992; Nelson & Winter 1982) to explain technology adoption processes and evolution of economic development. The theory was empirically substantiated by David's studies of the sustainability of a well-established technical standard: the QWERTY keyboard (see David 1985 for a summary). The key aspect emphasized in theory and evaluated in empirical studies is the missing determinant for economic processes. Progress cannot be identified as moving continuously toward some pre-determined equilibrium, but is pushed by non-linear processes (see e.g. Dosi 1982; Liebowitz & Margolis 1995). Recent research in social studies has adapted the concept of path dependence into analyses of political and social phenomena (e.g. Pierson 2000; Mahoney 2000). It was mainly used to explain the development and persistence of institutions. Path dependency highlights the constraining role of the past for current developments (also Thelen 2002). This is explicitly in contrast to other theoretical models, in which change is seen as the outcome of purposeful actions. Self-reinforcing processes decisively influence the direction of change and the historically shaped institutional configuration of organizations.

The model outlined above may therefore be not sufficient, as for the future development of a system only the current status is to be known. With a likely path dependency, the structural dimension of the system may be necessarily extended to a dynamical one describing the path that led to the current status. Path dependency of educational innovations is important, as it could explain different rates and speeds of ICT adoption in different countries. For example, the history of computing in education is significantly different in US or British school systems compared to Germany (see e.g. Cuban 1986; Breiter 2001). Hence, the concept of path dependency can help us understanding the adoption and diffusion of educational innovations.

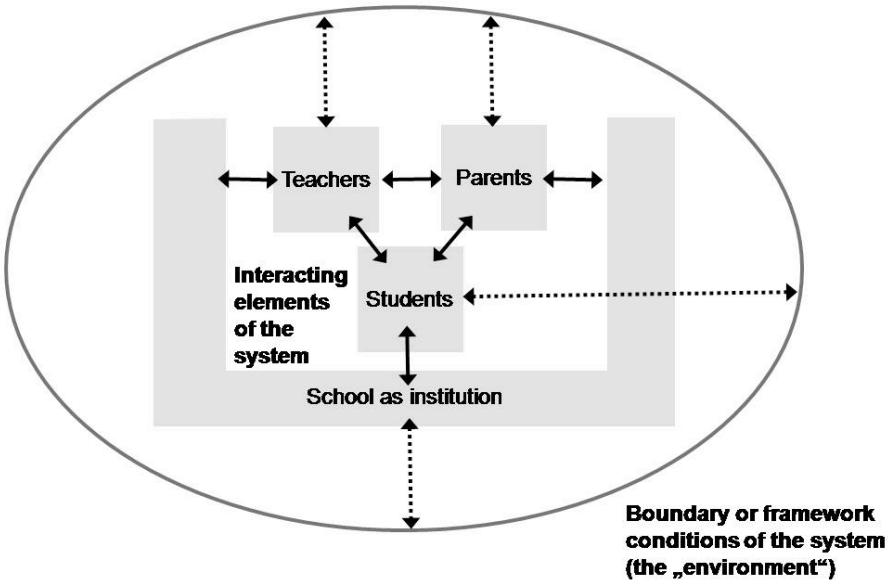

Figure 3: System approach to ICT-based innovations in education

Adoption of innovations by individuals: Teachers, students and their parents

Research on the diffusion of innovations began with the investigation of individual decision makers and was extended only later to organizational contexts or systems at large like education. In order to structure the pick-up of ICT as an innovation in education, the innovation process has to be regarded on all of these levels. This is due to the fact that the diffusion of ICT infrastructure and the role of ICT in private households are linked to the role of ICT infrastructure and PC usage in general in schools. Both roles as well as their interrelation strongly depend on the public perception of the positive and negative effects of ICT in educational settings. For the perspective on the innovation process from private households and the individual we will draw on Rogers' model of the diffusion of innovations and the respective adopter categories as well as the factors shaping the process (see Rogers 2003 and further elaborations of his model in von Pape 2009).

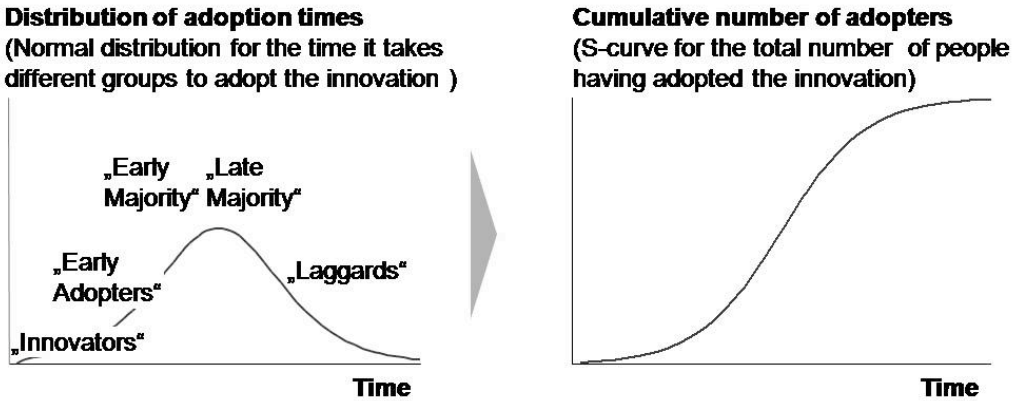

Figure 4: From the normal distribution of adoption times to the S-shaped diffusion curve

Much research has been undertaken into the dynamics of the diffusion of innovations, and a concurrent scheme is the S-shaped curve in the number of adopters versus time (see figure 4). This particular shape arises when a small number of early adopters is followed by the majority of adopters. These are followed again by a small number of 'laggards' (Rogers 2003). This behaviour across time arises from differences in the adoption process. The adoption process may thereby be assumed as consisting of five phases: *Knowledge*, *persuasion*, *decision*, *implementation* and *confirmation* (see figure 5). In the knowledge phase, an individual is exposed to an innovation for the first time. Persuasion occurs when an individual forms a favourable or unfavourable attitude towards the innovation. Decision takes place when an individual engages in activities that lead to a choice to adopt or reject the innovation. Implementation occurs when the innovation is put to use, and confirmation when the decision is reinforced after the innovation has been assessed positively, in the light of possibly conflicting information concerning its usefulness.

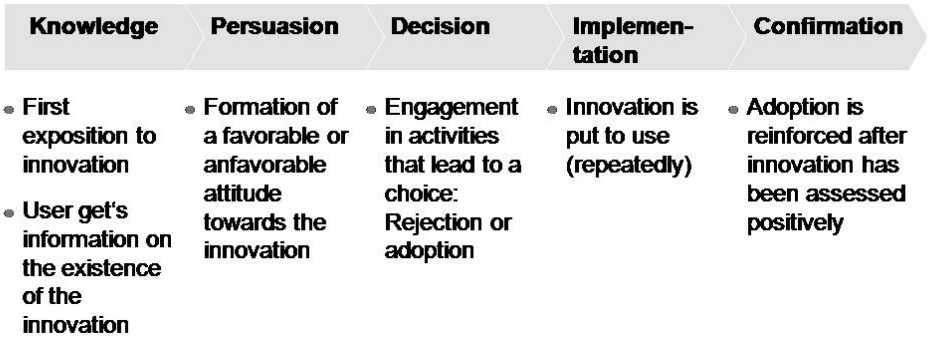

Figure 5: Phases of individual adoption (after Rogers 2003).

When, in at least one of the steps, a normal distribution of the respective behavioural trait is present, we will observe an S-shaped curve in the number of adopters versus time. This may already be the case in the knowledge phase when only few users appear to notice the existence of the innovation from the very beginning, e.g., the existence of a gaming application, followed by the majority, and finally by those people with less frequent access to information on market developments in this sphere. For most diffusion processes, this is indeed the shape that is observed (Henrich 2001).

In our case, the knowledge phase and the persuasion phase, which precede the actual decision, deserve some further elaboration, as by the factors determining these phases the individual innovation decision is linked to society at-large as well as to the organizational context under consideration here: the education system. Hence, we will come back to Rogers' model for the individual adoption, i.e. the adoption by teachers, students and parents when we discuss the interrelation to the organizational adoption by the school as an institution (next section) within the overall context of framework conditions of the educational system of innovation.

Adoption of innovations by institutions: The school

The adoption of the ICT innovation in schools can also be described as the integration of digital media in the everyday school life of teachers and pupils. Ertmer (2005), among others, considers the pedagogic approach of the teachers as the ultimate challenge ('final frontier') of media integration, while Selwyn (1999) points out the importance of subject cultures. Referring to several studies, Schulz-Zander et al. (2008) identify a lack of computer knowledge and computer-related skills as well as lacking pedagogic concepts and insufficient preparation time as main obstacles. Based on a secondary analysis of about 50 empirical studies on media integration, Hew and Brush (2007) regard knowledge and skills as a vital problem dimension of media integration. Furthermore, they identify resources, institutions, attitudes and convictions, evaluation and the professional culture as additional dimensions.

However, many of these studies are rationalistically determined and suggest that changes can be brought about by means of a simple input-output relation (Robertson 2002). Moreover, the factors identified are often standing side by side rather incoherently and are not or not sufficiently related to each other. Hennessy, Ruthven and Brindley (2005) also point out that researchers find it difficult to comprehend the complexity of media integration in a suitable way. They furthermore maintain that a large part of existing empirical research is based on large surveys that make available information on the extent of computer use and the type of applications used, but give no information on forms of classroom practices. In their opinion there are only few studies investigating media integration in average schools with everyday classroom

examples. Up to now, the empirical analyses were focused on the pupils, while the practices of the teachers have rarely been investigated.

In an organization understood as a stable system of individuals who work together to achieve common goals through a hierarchy of ranks and division of labour, innovations are usually bound to both collective negotiations and hierarchical decisions. In such cases, individuals cannot adopt a new idea unless the organization has previously adopted it. Compared to the innovation decision process by individuals, the innovation process in organizations is much more complex (see also Rogers 2003 for differences between organizational and individual adoption processes). This is particularly the case in the implementation phase, which typically involves a number of individuals – both opponents and promoters of the new idea. Further, implementation amounts to mutual adaptation, in which both the innovation and the organization change in important ways.

For the organizational perspective, one of the most influential models in this context is Nolan's (1973, 1979), separating 'six stages of growth.' Nolan claimed that the innovation diffusion process follows a similar pattern in different organizations and can also be described as an S-shaped curve. Nolan tried to use empirical evidence from innovation processes in large corporate institutions to explain these patterns. Repeating his research in the 1990s, he showed that these stages are repeated in the next innovation phase (era), leading to organizational learning (Nolan, 1993). The experiences made in the era of central data processing could only be partly used in the era of microcomputers, as this was accompanied by an organizational change from centralization to decentralization (see also Applegate et al. 2003). The following era of networks led to a re-centralization and new forms of controlling and it can be expected that we will encounter a new era of social software and web-based technologies. Nolan's model is used here in a modified way to highlight the organizational embedding of technological innovations in educational institutions (see also figure 6). In the first phase (*initialization*), technologies are introduced into the organization for performing simple administrative functions. Subsequently (*contagion* phase): Computers are adopted only in some areas. The learning curve moves up sharply and the use is more widespread. Top management encourages the adoption. In the third phase (*control*), the organization reacts to uncontrolled expenditure on computers. The deliveries of projects are late and there are unsatisfied needs. The IT support is weak and users get frustrated. The fourth phase (*integration*) can eventually be a turning point. Users start to accept the technological systems and realize and articulate their needs. There is a necessity for better control to provide more effective systems and technical support. In the final phase (*maturity*), the organization begins to trust the technological systems.

A translation of Nolan's model into the context of ICT in education can be found in Breiter (2001). In the phase of initiation, only a few members of the educational community are working with ICT as didactical tools. The organizational support is limited and they are regarded as outsiders (or, more positively, as "early adopters"). Others regard these activities with mistrust and they have no interest in joining the group. The core question of innovation research in an organizational context is: When do organizations change to widely adopting the introduced technology? In the case of ICT, the phase of contagion is crucial, as the interest of other teachers might increase if positive outcomes of their use can be identified. As we are currently still in between these phases, the next steps are hard to predict from an organizational perspective.

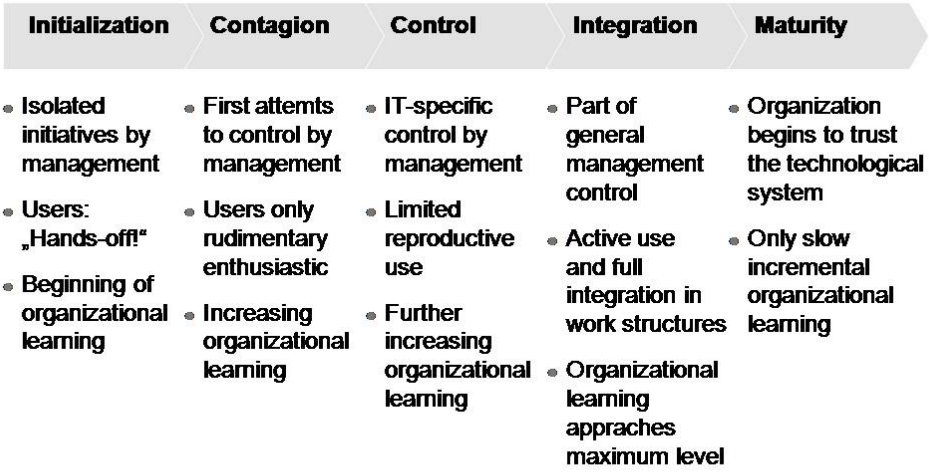

Figure 6: Phases of institutional adoption of innovations (adopted from Nolan 1993).

Individual and organizational adoption in their environment: Theory of planned behaviour

Both perspectives, the individual and the organizational, have to be integrated in a general analytical framework. How then are the individual and the institutional innovation decision processes linked to the environment, in particular to society at-large?

Several approaches aim to a better understanding of the innovation decision and its influencing factors (see for example von Pape 2009 for an overview). One of them is Ajzen's 'theory of planned behavior' (Ajzen 1985) based on an earlier approach formulated in the "theory of reasoned action" (Fishbein & Ajzen 1975). Ajzen's approach was repeatedly and convincingly applied to explain individual adoption decisions - also in the realm of ICT and learning.

According to the theory of planned behaviour, a person's behaviour is determined by his or her intention to perform the behaviour. This intention in turn is determined by three factors: their attitude toward the specific behaviour, their subjective norms and their perceived behavioural control. While the latter refers to people's perception of their ability to perform a given behaviour and is therefore a rather individual trait, the two former factors are strongly shaped by the social context of the individual (see figure 7 for a schematic representation of Ajzen's theory).

The theory of planned behaviour holds that only specific attitudes toward the behaviour in question can be expected to predict that behaviour. In addition to measuring attitudes toward the behaviour, one also needs to measure people's subjective norms – their beliefs about how people they care about will view the behaviour in question. To predict someone's intentions, knowing these beliefs can be as important as

knowing the person's attitudes. As a general rule, the more favourable the attitude and the subjective norm and the greater the perceived control, the stronger should be the person's intention to perform the behaviour in question (Ajzen 1985).

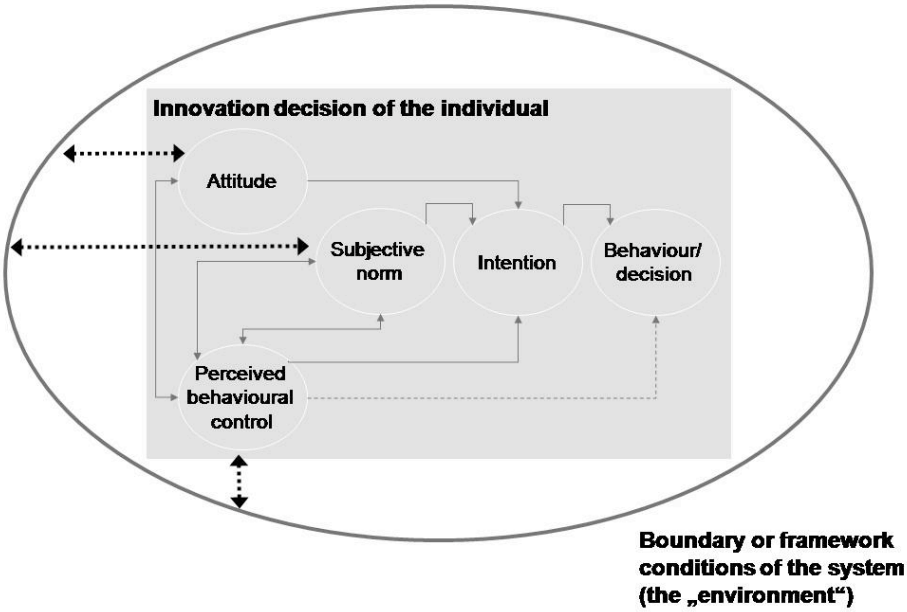

Figure7: The adoption process of the individual (after Ajzen 1985) and its interdependence on aspects of the 'environment' (e.g. the acceptance of ICT in the society at-large).

The coupling of the organizational innovation decision process to the macro level and in this respect to the socio-economic context is more complex, as the diffusion of ICT based innovations has to be linked also to the diffusion of more general organizational innovations in education, an issue, which has been treated more systematically only in the more recent innovation literature (see for example Fullan 2001; Kozma 2003). The extensive and expensive initiatives on federal, state and district level to deliver computers, local area networks and high-speed Internet connections to schools and the increasing number of instructional software and online resources for students and teachers have significant organizational impacts on the school system. The technology is partially shaping how and where teaching and learning is taking place, questioning the traditional roles of teachers and learners (Brunner & Tally 1999; DiSessa 2000; Kozma 2003).

The major impact of educational policies (which in turn are partly shaped by public opinion on these issues) on schools as social organizations is through educational reform. But as we know from educational research, change processes in schools are slow and the system is effective in absorbing innovations without any change (Cuban 1986; Fullan 2001; Tyack & Cuban 1995). Technology-oriented reform efforts, which were naively driven by the idea that information and communication technologies might change the way teaching and learning happens in institutions, such as schools, are becoming less dominant. The focus is now changing from specific technology plans to whole-school reform and comprehensive education plans including technology, following the suggestion of RAND consultants already in 1996: "Technology without reform is likely to have little value; widespread reform without technology is probably impossible" (Glennan & Melmed 1996, p. xix-xx).

The new approaches include new forms of collaborative teaching and student-centred learning in authentic and virtual environments ('blended learning'), digital

content production and quality control, embedded in a stronger framework of accountability (e.g. Behn 2003; OECD 2001). Additionally, if we account for path dependency as a major phenomenon in the adoption of innovations, the socio-economic and cultural factors play also an important role.

Mapping, analysing and comparing educational innovation systems – first examples

A model is only as good as its explanatory value. Hence, in order to be able to validate the proposed first sketches of a framework for an educational innovation system, it is necessary to link the system elements to measurable variables and to relate the linkages among the systems elements to functional dependencies. Future research should then focus on completing and improving the indicators used to map interactions in such educational systems as well as the linkages to the resulting performance on the level of educational institutions or of countries.

A next step in further refining the proposed model would be to develop robust indicators and metrics that allow the comparability of studies across countries. As adoption processes on the individual and on the institutional level are fairly sophisticated already, we think that most importantly the linkages should be tackled: Between the elements, but also between the elements and the environment. Going back to figure 1, for example, gives a first idea how sensible indicators may explain differences in the pick-up of ICT-based innovations in education. In Hungary and South Korea, we find the opposite situation as in Germany. In both countries, PC distribution in private households is preceded by political initiatives to install PCs at schools in order to promote the latter. A closer look to the exceptions, Germany on the one hand and Hungary and South Korea on the other hand, when comparing ICT infrastructure in schools with the PC penetration in private households, gives some hints where this partial decoupling comes from.

German students mainly have access to computers at home and are using PC and Internet on a non-regular basis in school. This discrepancy is one of the highest in all OECD countries. In countries with high results in high-stakes tests, access to computers in schools exceeds access at home. In Germany, it is the other way round. This leads to an increasing 'digital divide' (for more details see e.g. Warschauer 2003) and leads the PISA consortium to the conclusion that the social gradient between access, use and literacy is one of the highest in Germany (OECD 2006). Taking this into consideration, it becomes obvious that ICT integration in secondary schools in Germany is still in its infancy. This is no surprise, as Germany is a very special case with a strong tradition in its educational institutions against any (technology-induced) reforms. Taking Nolan's model, schools in Germany are not even at the stage of contagion, as many German teachers as well as the institutional level regard educational technologies as additional, but not necessary integrative tools. Software applications such as simulation systems, game-oriented learning tools or complex interactive learning environments are used only by a limited number of educators. The results show that the innovation dynamics on the individual level of students and on the institutional level of organizations differ significantly, which supports our assumptions.

On the other two cases differing from the average regression in figure 1 (Hungary and South Korea) we would have to speculate here. However, our framework could guide further research to possibly important interdependencies being at work and subsequently also to conduct qualitative cross-country case studies in order to understand the missing link.

Different dependencies among the systems elements and of the elements towards the environment will also lead to different dynamics. The adoption of technology as an innovation fits into the path dependency and, therewith, cultural 'inheritance.' While the German education system is regarded as 'conservative' in the sense of perpetuating established routines, norms and organizational development, other education systems (such as in Scandinavian countries, the Netherlands or the UK) are the centre of innovation. Therefore, the systematics outlined above hints to observable variables that need to be collected in order to understand the dynamics of ICT-based innovations in education for the sake of better (in the sense of efficiency and effectiveness) education policies.

Conclusions and next steps

The framework conditions for educational innovations are set by states and to a lesser extent by transnational political bodies. In order to change those framework conditions, education policies set reforms in order to integrate a new technology. This is done in curricula, with state programs and large-scale teacher training schemes. Nevertheless, the sustainable integration and ubiquitous access to technological innovations is mainly led by expectations (i.e. norms perceived by the individual) and attitudes developed by social interaction in the society at-large. This has a strong impact on the individual choice as well as on the educational policies.

With the help of our analytical framework, we tried to identify three interdependent layers that influence the diffusion of ICT in education. While the adoption is very much impacted by individual choice, the embedding in an institutional formal learning process is highly dependent on the organizational learning process and the implementation of adequate supportive structures.

In this paper we have primarily focused on the diffusion process, its interdependence on individual choice, organization learning, policies as well as social and cultural development. More research is needed to understand the interdependencies between the different levels. We tried to define an analytical framework, which needs to be filled with empirical evidence. The strength of this model is the use of existing systems theory to explain diffusion of innovation on different levels as well as to adopt the concept of national innovation systems to education systems. As the three levels are rather independent, the existing research can be easily embedded into the new framework model.

In a next step, a systematics for relevant variables describing the system elements (teachers, students and their parents, the school as an institution) and their environment should be compiled as well as their relations described. Subsequently, by comparing the situation of different countries may be analysed and understood as a consequence of the system dynamics. Remaining discrepancies may then be attributed to path dependency and studies as such.

Such a systematic approach will also address the differences in the rate of innovation diffusion across levels, which also have to be taken into account when designing policies. Obviously, top-down approaches are nearly impossible. Change can only be induced indirectly via the individual media competence of teachers and students.

References

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl, & J. Beckman (Eds.), *Action-control: From cognition to behavior* (pp. 11-39). Heidelberg: Springer.

Applegate, L. M., Austin, R. D., & McFarlan, F.W. (2003). *Corporate information strategy and management: The challenges of managing in a network economy*, 6th Edition. Reading, MA: McGraw-Hill.

Arnott, M. A., & Raab, C. D. (Eds.). (2000). *The Governance of schooling. Comparative studies of devolved management*. London, New York: MacMillan.

Behn, R.D. (2003). Rethinking Accountability in Education. How Should Who Hold Whom Accountable for What? *International Public Management Journal*, *6*(1*),* 43-73.

Blurton, C. (1999). New directions of ICT-use in education. Paris: UNESCO Online: retrieved from http://www.unesco.org/education/educprog/lwf/dl/edict.pdf

Breiter, A. (2001). Digitale Medien im Schulsystem: Organisatorische Einbettung in Deutschland, den USA und Großbritannien. *Zeitschrift für Erziehungswissenschaft, 4*(4), 625-639.

Breiter, A., & Kolo, C. (2008). Dynamics of innovations in education - The case of electronic gaming in Germany. In R. Ferdig (Ed.), *Handbook of Research on Effective Electronic Gaming in Education* (pp. 163-177). Hershey PA: IGI Global.

Brunner, C., & Tally, W. (1999). *The new media literacy handbook. An educator's guide to bringing new media into the classroom*. New York: Anchor Books.

Cuban, L. (1986). *Teachers and machines. The classroom use of technology since 1920*. New York: Teachers College Press.

DiSessa, A. (2000). *Changing minds: Computers, learning and literacy*. Cambridge, MA: MIT Press.

David, P. A. (1985). Clio and the Economics of QWERTY. *The American Economic Review*, *75*(2), 332-337.

Dosi, G. (1982). Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants of Technological Change. *Research Policy*, *11*, 147-162.

Dosi, G., Freeman, C., Nelson, R. R., Silverberg, G., & Soete, L. (1988). *Technical change and economic theory*. London: Pinter.

Edquist, C. (1997). *Systems of innovation: Technologies, institutions, and organizations*. London:, Pinter, London.

Ertmer, P. A. (2005). Teacher Pedagogical Beliefs: The Final Frontier in our Quest for Technology Integration?. *Educational Technology Research and Development, 53*(4), 25-39.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*. Reading, MA: Addison-Wesley.

Freeman, C. (1987). *Technology and economic performance: Lessons from Japan*. London: Pinter.

Fullan, M.G. (2001). *The new meaning of educational change*. 3rd Edition. New York, NY: Teachers College Press.

Glennan, T.K., & Melmed, A.A. (1996). *Fostering the use of educational technology: Elements of a national strategy,* Santa Monica, CA.: RAND Co

Hennessy, S., Ruthven, K., & Brindley, S. (2005). Teacher Perspectives on Integrating ICT into Subject Teaching: Commitment, Constraints, Caution, and Change. *Journal of Curriculum Studies in Educational Evaluation, 37*(2), 155-192.

Henrich, J. (2001). Cultural Transmission and the Diffusion of Innovations, *American Anthropologist*, *103*(4), 992-1013.

Hew, K. F., & Brush, T. (2007). Integrating Technology into K-12 Teaching and Learning: Current Knowledge Gaps and Recommendations for Future Research. *Educational Technology Research and Development, 55* (3), 223-252.

Jenkins, H. (2007). *Confronting the challenges of participatory culture: Media education for the 21st century*. Chicago, IL: The MacArthur Foundation.

Kozma, R.H. (Ed.) (2003). *Technology, innovation, and educational change. A global perspective*. Washington, DC: ISTE.

Liebowitz, S. J., & Margolis, S. E. (1995). Path Dependence, Lock-in, and History. *Journal of Law, Economics and Organization*, *11*(1), 205-226.

Lundvall, B-Å. (Ed.) (1992). *National innovation systems: Towards a theory of innovation and interactive learning*. London: Pinter.

Mahoney, J. (2000). Path Dependence in Historical Sociology. *Theory and Society, 29*(4), 507-548.

Martens, K., Rusconi, A., & Leuze, K. (Eds.). (2007). *New arenas of education governance – The impact of international organizations and markets on educational policymaking*. Houndmills, Basingstoke: Palgrave Macmillan.

Mytelka, L. K., & Smith, K. H. (2002). Policy learning and innovation theory: an interactive and co-evolving process. *Research Policy, 31*(8), 1467-1479.

Nelson, R. (Ed.) (1993). *National innovation systems. A comparative analysis*. New York/Oxford: Oxford University Press.

Nelson, R. R., & Winter, S. G. (1982). *An evolutionary theory of economic change*. Cambridge, MA: Harvard University Press.

Nolan, R.L. (1973). Managing the Computer Resource: A Stage Hypothesis. *Communications of the ACM*, *16*(7), 399-405.

Nolan, R.L. (1979). Managing the Crisis in data processing. *Harvard Business Review*, *57*(2), 115-126.

Nolan, R.L. (1993). *The stages theory: A framework for IT adoption and organizational learning. Cambridge,* MA: Harvard Business School Press.

OECD (1996). *The knowledge-based economy*. Paris: OECD Publications.

OECD (1997). *National innovation systems*. Paris: OECD Publications.

OECD (2001). *What works in innovation in education: New school management approaches*. Paris: OECD Publications.

OECD (2006). *Are students ready for a technology-rich world? What PISA studies tell us*. Paris: OECD Publications.

Owston, R. (2007). Contextual Factors that sustain Innovative Pedagogical Practice using Technology: An International Study. *Journal of Educational Change, 8*, 61-77.

Palfrey, J., & Gasser, U. (2008). *Born digital: Understanding the first generation of digital natives*. New York: Basic Books,

Peters, S. (2005). *National systems of innovation: Creating high technology industries*. New York: Palgrave Macmillan.

Pierson, P. (2000). Increasing Returns, Path Dependence, and the Study of Politics. *American Political Science Review, 94*(2), 251-267.

Prensky, M. (2001a). Digital Natives, Digital Immigrants. *On the Horizon 9*(5), 1-6.

Prensky, M. (2001b). Digital Natives, Digital Immigrants, part II. Do they really think differently? *On the Horizon*, *9*(6), 1-6.

Robertson, J. (2002). The Ambiguous Embrace: Twenty Years of IT (ICT) in UK Primary Schools. *British Journal of Educational Technology, 33*(4), 403-409.

Rogers, E.M. (2003)[1962]. *Diffusion of innovations*, 5th Edition, New York: The Free Press.

Schmoch, U., Legler, H., & Rammer, C. (2006). *National systems of innovation in comparison: Structure and performance indicators for knowledge societies*. Dordrecht: Springer.

Schulz-Zander, R., Pfeifer, M., & Voss, A. (2008). Observation measures for determining attitudes and competencies toward technology. In J. Voogt & G.

Knezek (Eds.), *International handbook of information technology in primary and secondary education* (pp. 367-380). New York: Springer.

Selwyn, N. (1999). Differences in Educational Computer Use: The Influences of Subject Cultures. *The Curriculum Journal, 10*(1), 29-48.

Selwyn, N. (2009). The Digital Native – Myth and Reality. *Aslib Proceedings, 61*(4), 364-379.

Thelen, K. (2002). The Explanatory Power of Historical Institutionalism. In R. Mayntz (Ed.), *Akteure-Mechanismen-Modelle: Zur Theoriefähigkeit makro-sozialer Analysen* (91-107). Frankfurt/Main: Campus.

TNS Infratest (2006). Monitoring Informationswirtschaft. 9. Faktenbericht 2006. Retrieved from: http://www.tns-infratest.com/06_bi/bmwa/infrasearchreg/ reg9.asp?dfile=TB6_Chartversion_de.pdf.

Tyack, D., & Cuban, L. (1995). *Tinkering toward Utopia. A century of public school reform.* Cambridge, MA: Harvard University Press.

UNECSO (1998). World Education Report 1998: Teachers and teaching in a changing world. Paris: UNESCO. retrieved from http://www.unesco.org/education/educprog/wer/wer.htm

von Pape, T. (2009). Media adoption and diffusion. In Hartmann, T. (eds.), *Evolving Perspectives on Media Choice: A Theoretical and Empirical Overview*. London: Taylor & Francis.

Warschauer, M. (2003). *Technology and social inclusion: Rethinking the digital divide.* Cambridge, MA: MIT Press.

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