ICT-USE IN PRIMARY SCHOOLS AND CHILDREN'S MATHEMATICS ACHIEVEMENT

- A MULTI LEVEL APPROACH TO COMPARE EDUCATIONAL SYSTEMS THROUGH AN INTERNATIONAL LENS WITH TIMSS DATA

Birgit Eickelmann[1], Kerstin Drossel[2], Heike Wendt[2] & Wilfried Bos[2]

University of Paderborn[1], TU Dortmund University[2], Germany

Abstract

ICT-use in schools and its potential to support learning schools has been a topic of special interest in educational research in the last two decades (Eickelmann, 2011). Besides learning how to use ICT, it is important to understand how ICT-use can affect learning and achievement (Voogt, 2008); as yet, it is not clear how. This contribution will use TIMSS 2007 (Trends in International Mathematics and Science Study) data to conduct an analysis, addressing the question if the use of ICT in mathematics education in primary schools is a predictor for mathematics achievement. It uses a multi-level approach to examine this question for three different education systems on three continents.

Introduction

ICT-use has been of interest in educational practice in nearly all educational systems around the globe for more than 40 years now (Cox, 2008). In this context, there is plenty of literature discussing about and researching on the educational shift and challenges for schools. Summarizing and systemizing these shifts, different waves of technology integration could be observed. The three main aspects of integrating new technologies in teaching and learning can be summarized as follows (Eickelmann & Drossel, 2012):

1. Teach how to use ICT in terms of creating presentations, word processing, and using spreadsheet applications.
2. Use ICT to enhance learning in terms of applying new potentials to open learning and to personalize learning and to support a new learning culture (Eickelmann, 2011).
3. Focus on challenges in the 21st century and on ICT-literacy as a forth key competence besides numeracy und literacy (Fraillon & Ainley, 2009).

The paper presented focuses on the second aspect: Using ICT to enhance learning and especially on researching the impact of ICT on subject specific learning and achievement. Discussing the potentials of ICT to enhance learning, four strands could be identified:

1. *Change learning itself*, for example to support learner-centered environments, self-directed learning, personalized learning, and the increase of learning motivation by applying new methods.
2. *Change learning environment* and the roles of teachers and students, e. g. emphasizing teachers' roles as a moderator of learning process and develop constructivist approaches towards learning.

3. *Support acquisition of 21st century skills* and understand the use of new technologies as helpful to support collaboration and communication skills.
4. *Support subject specific learning* by using subject specific potentials of new technologies, e.g. visualizations, simulations, discharges of step-by-step calculations, facilitations of both problem-solving and cognitive modeling.

Especially in first decade of this millennium, there has been a growing number of studies on computer use and subject-specific achievement and results show ambivalent findings on whether computer use does enhance subject-specific learning in practice or not (Eickelmann & Schulz-Zander, 2008). A number of studies struggled with their methodological approaches such as looking only at a small group of students with quantitative instruments (without a control group) or not using achievement tests but stating impact on subject specific learning outcomes.

Summing up the state of the art in only one sentence, one might say that some evidence has been provided to conclude that computer use supports subject specific learning.

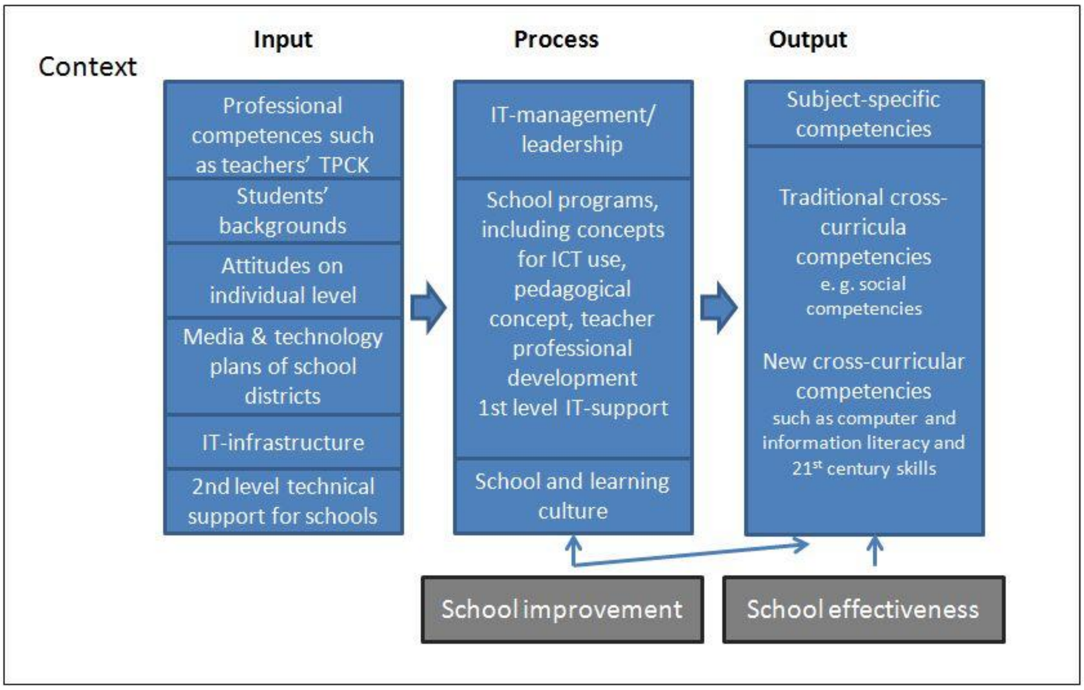
State of the Art towards ICT and students' achievement

Especially in first decade of our millennium, there has been a growing number of studies on computer use and subject-specific achievement. Results show ambivalent findings on whether computer use does enhance subject-specific learning in practice or not (Eickelmann & Schulz-Zander, 2008). A number of studies struggled with their methodological approaches such as looking only at a small group of students with quantitative instruments (without a control group) or not using achievement tests but stating impact on subject specific learning outcomes. Summing up the state of the art, one might/ can summarize that evidence has been given that computer use supports subject specific learning.

Especially mobile devices and student-owned technologies tend to improve learning and support students' achievement. Moreover, there seems to be consensus that computer use enhances learning motivation if it is implemented into student-centered, open, and innovative learning activities. However, some studies showed that computer use appeared to be more beneficial for high achieving students used in open learning scenarios with self-regulated environments (ibid.).

Transferring the perspective of school effectiveness research (cf. Scheerens, 2000) and school improvement to the research presented in this paper, the model in figure 1 describes the relevance of subject-specific student achievement as a variable on the output level in the context of ICT-use in schools. School effectiveness research asks: "What is the output of learning?", while school improvement considers how schools work with their input by using their radius of operation on the process level to optimize student learning. Here, one important aspect to point out is that students' backgrounds are a strong variable to explain students' achievements also in computer-based learning scenarios.

Figure 1: Model of school improvement and effectiveness and ICT-use



Research questions

The questions still remain are: Does ICT-use support students' subject specific achievement? And if so, does the relationship between ICT-use and students' achievement vary between different countries/school systems?
The research questions of this presentation reduce these more general questions and focus on ICT-use in primary schools and mathematics achievement as dependent variable. Therefore, research questions to be answered here are:

1. Does ICT-use in primary schools support students' subject specific achievement in mathematics?
2. Does the relationship between ICT-use and mathematics achievement vary between different countries/school systems?

Sample and methods

The presented research makes use of secondary analyses of TIMSS 2007 data (IEA-TIMSS; Trends in International Mathematics and Science Study, Grade 4, cf. Mullis et al., 2008; Bos et al., 2008).
It provides:

- Student data on mathematic achievement in primary schools;
- data about students' ICT-use in mathematics;
- students' backgrounds data as control variables;
- data from different countries;
- information on ICT-use in primary schools in these countries.

Sample and instruments

From 59 countries participating in TIMSS 2007, the sample of the presented research refers to the data of three countries on three different continents: Australia, Germany, and Singapore. This means that the research covers data from more than 14,000 students (Australia: 4,108 students, Germany, 5,200 students, and Singapore, 5,041 students).
By this choice of educational systems, the research refers to three educational systems with different traditions in implementing digital media into learning in primary education. Furthermore, educational policies in these countries are organized differently: on state level in Australia and Germany and on country level in Singapore. All countries show comparable high levels of mathematics achievement (Mullis et al., 2008). Compared internationally, the sample consists of three rich countries with a gross national income per capita between 28,000 and 36,000 USD (ibid.).

The instruments applied here are:

(1) Student mathematics test: achievement scores in TIMSS test which has a multi-matrix design;
(2) student background questionnaire TIMSS 2007;
(3) mathematics curriculum questionnaire TIMSS 2007.

Methods

What is applied besides descriptive analyses are regression analyses and estimation of complete achievement scores by using plausible values. The data of TIMSS 2007 has been analyzed with the statistic software IDB analyzer which is made available by the IEA and which is applied to analyze huge data sets (Rutkowski et al., 2010), e. g. those of IEA international studies.

Analysis and results

Possession of a computer and access to the Internet

In 2007, in all three countries (Australia, Germany and Singapore) 90% or more of 4th grade students reported having a computer at home. In addition, more than 80% reported that their families have internet access at home as well. On average across countries, students from homes with a computer had higher mathematic achievements than those from homes without. The difference between those two groups of students amounts to 39 achievement points. As to the selected countries, the difference adds up even higher (Australia: 75 points, Germany: 43 points, Singapore: 63 points). This observation could also be revealed for internet access in students' homes. Aiming to interpret these differences in mathematical achievement, it should be considered that these differences are partly a reflection of students' socioeconomic differences: Students from families with higher socioeconomic backgrounds are more likely to have computers at home. Therefore, it is important to reconsider the background of students for further analysis.

Computer use and mathematics achievement – descriptive statistics

In all three countries high percentages of children in grade 4 report to use computers. Here, the term "using a computer" does not include using PlayStation®, GameCube®, XBox®, or other TV/video game computers. In Australia and Singapore it becomes obvious that students who report to use computers show higher achievements in mathematics than their classmates (Australia: 517 vs. 444 achievement points; Singapore: 560 vs. 498). Interestingly this pattern was not found for Germany. Here the achievement scores for non-users were even a little higher (17 points) than those of students who use computers. Of course, by providing these descriptive statistics, the findings could not be interpreted as a causal relationship.

As to computer use at home, in all three countries more than 90% of the students report using a computer at home. Those children perform remarkably higher in mathematics compared to those who do not use a computer at home (but use a computer elsewhere).

As to computer use at school, only a comparable low percentage of students report using a computer at school in Germany (only 36.7 % of all students who reports to use a computer).Whereas in Australia and Singapore, students use computers to a higher percentage (Australia: 86.6% and Singapore: 77.0%). Students who use computers in school in these countries perform better than other students in their countries (24 in Australia respectively 27 points higher achievement in Singapore). No difference in achievement can be observed in Germany: mathematics achievement of both students' groups seems to be rather similarly.
As to the frequency of computer use for schoolwork in mathematics (in and outside of school), only a low number (< 10%) of students uses computers on a daily basis. Those students using computers frequently have lower achievements in mathematics than the other students (in all three countries). However, in Australia and Singapore students who use computers moderately (once or twice a month) perform best. In Germany students who only use a computer a few times a year perform best.

Computer use and mathematics achievement – regression analyses

In the following, regression analyses controlling for students socioeconomic backgrounds and students' sex are presented focusing on mathematics achievement as dependent variable.

Controlling firstly for student background characteristics, general computer use in the three countries has different effects on mathematics achievement. Positive significant correlations (+47,82 points) can be observed in Australia. In Germany there is a negative relationship (-13,56) which is also significant. In Singapore general computer use does not make a difference. Moreover, the socioeconomic background has an effect on mathematical achievement which could be confirmed by the variables "possession of a computer at home" and "possession of a study desk". As to gender effects: boys perform better in Australia and Germany. In Singapore – taking the given background variables into account – girls perform better than boys, which is an overall finding of TIMSS 2007 (cf. Mullis et al., 2008).

Secondly, there is a significantly positive relationship between computer use at home and mathematics achievement in Germany (+26,84 points) and in Singapore (+35,93). However, computer use at home in Australia did not make a difference towards mathematics achievement for Australian primary school pupils in 2007.

A third regression model towards computer use at school and its relationships with mathematics achievement shows that computer use at school shows positive relationships with mathematics achievement in Australia (+24,28 points) and in Singapore (26,10 points). In Germany, computer use at school did not relate with student achievement in mathematics in 2007.

Finally, a holistic model (figure 2) shows that although students' computer use for mathematics does not correlate with their mathematics achievement in Singapore primary schools at first sight, the regression analysis reveals that the use of computers on a daily basis has negative effects on mathematics achievement. This confirms the hypothesis which came from the interpretation of the descriptive statistics presented above. Also computer use on a weekly basis is still an indicator of low mathematics achievement. Or vice versa; which means that low achieving students might use computers more often, e. g. for training purposes with mathematical software.

Figure 2: Regression analyses ICT-use and student mathematics achievement

	Australia			Germany			Singapore		
	β	β (SE)	T-Value	β	β (SE)	T-Value	β	β (SE)	T-Value
Use for math: daily	-43,74	10,84	**-4,04**	-69,04	8,81	**-7,84**			
Use for math: weekly				-16,66	5,48	**-3,04**			
Use for math: monthly	19,72	5,26	**3,75**						
Use for math: yearly	14,68	5,28	**2,78**	13,05	4,45	**2,93**			
Use for math: never									
Background Variables									
possession of a computer	62,27	8,23	**7,56**	48,77	7,69	**6,34**	53,99	5,90	**9,15**
possession of a study desk	27,41	5,56	**4,93**	48,71	12,44	**3,92**	25,31	5,01	**5,05**
sex of student	-7,88	3,21	**-2,45**	-11,23	2,37	**-4,73**			
	R^2= 8%			**R^2= 9%**			**R^2=11%**		

Discussion and outlook

The link between ICT-use and achievement varies across countries. In order to interpret these variations there seems to be a need for more detailed research on related policies in the different educational systems. In 2007, the main finding of the presented research is that frequent computer use correlates with low achievement. However, this is no causal relationship; with regression analyses only correlation could have been determined. One explanation for this finding might be that low achievers are more likely to use computers, e.g. training software. Therefore further analysis should also examine this special aspect. Moreover, teacher and school questionnaire data should be included in order to figure out whether teachers' approaches to teach mathematics or school characteristics (e. g. of school goals related to ICT-use, IT leadership, and teachers' cooperation) make a difference.

On system level, one might compare the impact of educational systems with their strategies of implementing technologies into teaching and learning more detailed.

Implications for further research might include a change in the methodological approach and the aim of gathering and analyzing longitudinal data. From a pedagogical perspective, the question remains if using longitudinal data will satisfactorily answer the research questions. There are also strong arguments for getting more in-depth insights into classroom practice and how computers are used in subject-specific learning to understand which computer use supports the acquisition of subject-specific competencies.

Moreover, next steps will be to use TIMSS 2011 data - for which the international report has been released in December 2012, only a few days after the WERA Focal Meeting 2012 where this paper has been presented (cf. Mullis et al, 2012). On the basis of this more recent data gathered in 2011, it will be expedient to find out in which way educational systems have developed successfully in using new technologies for mathematics teaching and learning.

References

Bos, W., Bonsen, M., Baumert, J., Prenzel, M., Selter, C. & Walther, G. (Eds.). (2008). TIMSS 2007 – Mathematische und naturwissenschaftliche Kompetenzen von Grundschulkindern in Deutschland im internationalen Vergleich [TIMSS 2007: National report Germany]. Münster: Waxmann.

Cox, M. (2008). Researching IT in education. In J. Voogt & G. Knezek (Eds.), International handbook of information technology in primary and secondary education (965–982). New York: Springer.

Eickelmann, B. & Drossel, K. (2012). Supporting Students with Disadvantaged Backgrounds by Using ICT for Teaching and Learning – Challenges for Upper Secondary Schools. Paper presented at the European Conference in Educational Research (ECER) 2012. Cadiz, Spain.

Eickelmann, B. & Schulz-Zander, R. (2008). Schuleffektivität, Schulentwicklung und digitale Medien. In W. Bos, H. G. Holtappels, H. Pfeiffer, H.-G. Rolff & R. Schulz-Zander (Hrsg.), Jahrbuch der Schulentwicklung. Band 15. (S. 157-194). Weinheim: Juventa.

Eickelmann, B. (2011). Supportive and hindering factors to a sustainable implementation of ICT in schools. Journal for Educational Research Online, 3(1), 75–103.

Fraillon, J. & Ainley, J. (2009). An International Study of Computer and Information Literacy (ICILS). Melbourne: Australian Council of Educational Research.

Mullis, I.V.S., Martin, M.O., & Foy, P. (2008). TIMSS 2007 International Mathematics Report. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Mullis, I.V.S., Martin, M.O., Foy, P., & Arora, A. (2012). Mullis, I.V.S., Martin, M.O., Foy, P., & Arora, A. (2012). TIMSS 2011 International Mathematics Report. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Rutkowski, L., Gonzalez, E., Joncas, M. & von Davier, M. (2010). International Large-Scale Assessment Data: Issues in Secondary Analysis and Reporting, Educational Researcher, 39 (2), 142–151.

Scheerens, J. (2000). Improving school effectiveness. Paris: UNESCO, International Institute for Educational Planning.

Voogt, J. (2008). IT and curriculum processes: Dilemmas and challenges. In J. Voogt & G. Knezek (Eds.), International handbook of information technology in primary and secondary education (pp. 117-132). New York: Springer. New York: Springer.