Perceived Quality of Educational Technology Matters: A Secondary Analysis of Students' ICT Use, ICT-Related Attitudes and PISA 2012 Test Scores

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Abstract: In large scale international assessments such as PISA, TIMSS or PIRLS, research has struggled to find positive associations between the frequency of educational technology use in schools and student achievement. While computer use at home showed a tendency for positive correlations with test scores, computer use in schools did not. Following a different approach, the study reanalyzes PISA 2012 data by combining frequency of use and positive perceptions with regard to educational technology as predictors for student test scores. When controlling for influential sociodemographic factors, results indicate that positive attitudes towards educational technology are associated with higher test scores in the large majority of countries. As positive attitudes are likely to be a result of positive experiences, it seems reasonable to conclude that it might be quality instead of quantity of educational technology use that matters.

Keywords: Educational technology; ICT; educational effectiveness; large scale assessments

1 Introduction: Results from Large-Scale International Assessments

Educational research has long been struggling to show the impact of educational technology on K12 student academic achievement in representative samples of schools (Balanskat, Blamire, & Kefala, 2006; Eng, 2005; M. Russell, 2010; Scheerens, Luyten, Steen, & Luyten-de Thouars, 2007). Many schools and teachers are still reluctant to use educational technology and the implementation of educational technology has not necessarily led to the anticipated increases in educational quality. Given the high costs of investing in educational technology in schools, these issues have been a matter of critical debate (Cuban, 2001; Lim, Zhao, Tondeur, Chai, & Tsai, 2013; Luschei, 2014).

Many of the pioneering experimental studies, comparing learning with a new educational technology to more traditional learning materials, resulted in the "no significant difference phenomenon" (T. L. Russell, 1999). Although some of the early projects were able to show positive evidence (Harrison, Lunzer, Tymms, Fitz-Gibbon, & Restorick, 2004; Rockman, 1997; Schaumburg, Prasse, Tschackert, & Blömeke, 2007; Wenglinsky, 1998), others have reported no or even negative effects (Angrist & Lavy, 2002; Ravitz, Mergendoller, & Rush, 2002). Since then, educational technology and research methods have changed considerably. Today, meta-analyses of experimental studies show small but positive effects for educational technology applications with regard to student performance in different core subjects (Cheung & Slavin, 2012, 2013; Reimann & Aditomo, 2013) as well as for different types of educational technologies (Hattie, 2008; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). In international large-scale studies, however, the impact of educational technology on student performance has remained elusive, despite intensive research efforts, as detailed below.

For primary schools, PIRLS (Progress in International Reading Study) has repeatedly demonstrated that there is no clear correlation between the frequency of educational technology use in school and student reading scores. In PIRLS 2001, a positive relation was found for use of computers at home and a negative correlation for computer use in schools (House, 2007). This finding has also been replicated with PIRLS 2011 data in Germany (Lorenz & Gerick, 2014).

In the TIMSS (Trends in International Mathematics and Science Study) 1995 study, secondary students who used ICT (Information and Communication Technologies) frequently for mathematics learning tended to have lower achievements scores than students who seldom or never used ICT (Pelgrum & Plomp, 2002). A similar negative relationship between the frequency of school ICT use and student achievement has been found in TIMSS 1999 (Papanastasiou, Zembylas, & Vrasidas, 2003) and TIMSS 2004 (Papanastasiou & Paparistodemou, 2007). In TIMSS 2011, a study from the Netherlands reported no significant difference between students using

ICT more or less often with respect to their mathematical achievement (De Witte & Rogge, 2014).

Very similar results have been found in the PISA (Programme for International Student Assessment) studies, where ICT use has been a major option in student questionnaires. In PISA 2000, no significant correlation between computer use at home or at school and student academic achievement was found (Bielefeldt, 2005). In PISA 2003, there was no linear relationship between frequency of ICT use in school and mathematics, reading and science test scores (Shewbridge, Ikeda, & Schleicher, 2005). Instead, results indicated that students with an average frequency of ICT use for learning fared better than students with an either lower or higher frequency of ICT use. When controlling for numerous variables with a known impact on achievement, at least home computer use shows some impact on math achievement, but not computer use in school (Woessmann & Fuchs, 2007). Similar results have been shown for the PISA 2006 science score (Spiezia, 2010). The findings that there are positive effects of computer use at home and no or even detrimental effects of computer use at school, have been replicated numerous times with different PISA waves, for different countries and with different control variables (e.g. for Canada: Bussière & Gluszynski,2004; Eastern Europe: Sofianopoulou & Bountziouka, 2011; Turkey: Güzeller & Akın, 2014; Switzerland: Ramseier & Holzer, 2005; Italy: Ponzo, 2011). With data from PISA 2009, only one study, Biagi & Loi (2012; 2013), seems to succeed in finding surprisingly large positive correlations between the diversity of ICT use and PISA 2009 test scores when controlling for the intensity of educational technology use and other variables. However, these findings seem to be an artifact of the method of analysis, as diversity and intensity scores are highly intercorrelated as both scores are constructed from the same set of variables. In effect, the regression model is most likely flawed due to variance inflation. In addition, this study did not differentiate between home and school use of educational technology, so – as in previous studies – positive findings may be due to the aspect of home use rather than school use.

PISA 2012 seems to confirm previous disappointing findings. For Australia, the Netherlands, Norway, Singapore and Germany, Gerick & Eickelmann (2015) found positive effects with regard to mathematical performance in PISA 2012 test scores for ICT-related school level variables such as educational leadership or school strategies but no or even negative effects for the actual frequency of educational technology use. Skryabin, Zhang, Liu, & Zhang (2015) analyze data from PIRLS 2011, TIMSS 2011 and PISA 2012 to determine the multilevel effects of both the national development level of ICT integration as well as the individual frequency of student ICT use in schools and at home on reading, mathematics and science test scores. Results show that the national development level as well as ICT activities at home are positively related to student test scores while computer use at schools again seem to be negatively correlated with student academic achievement. In their recent comprehensive report, the Organization for Economic Cooperation and Development (OECD, 2015) comes to the conclusion that there is no evidence for improved student achievement in schools that have invested in educational technology, nor does this investment bridge the gap between more advantaged and disadvantaged students. While moderate use of educational technology can be associated with higher achievement, both low and intensive use of educational technology seems to have a detrimental effect. Thus, the study concludes that the manifold potential of educational technology is still not being harnessed in schools. According to this interpretation, poor results might be due to poor quality of educational software as well as ineffective pedagogy when teaching with educational technology.

To sum up, according to the large majority of large-scale studies using different variables and different methodology, there seems to be a strong tendency towards the evidence that higher frequency of computer use in school is not positively correlated with academic achievement. This finding stands in stark contrast to the high number of small experimental lab studies showing the positive effects of educational technology. Although many findings try to incorporate mediating and moderating variables, there has still not been any empirical explanation why there are no positive effects for educational technology use (Ainley, Enger, & Searle, 2008). On the theoretical and methodological sides, there are a number of possible explanations for the lack of positive effects for educational technology in large-scale studies.

1.1 Possible Explanations with Regard to Educational Technology Usage Measures

"Educational technology" serves as an umbrella term for a wide range of devices (e.g. digital whiteboards, desktop and laptop computers, smartphones), applications (e.g. text and multimedia editors, internet search engines, learning management systems, social media platforms) and approaches (e.g. computer-supported inquiry learning, multimedia learning, computer-supported collaborative learning, digital game-based learning). In addition, specific use-scenarios exist for each school subject. Given this huge diversity of approaches, the search for effects across the board can be regarded as very difficult – or even pointless. Almost all the studies presented above tried to find correlations between the combined frequency of all technologies used by students and their test scores, which can be seen as combining apples and oranges. Meta-analyses are trying to solve this problem to a certain point by calculating separate effect sizes for different educational technology applications (Hattie, 2008; Tamim et al., 2011) or for different subjects (Cheung & Slavin, 2012, 2013; Reimann & Aditomo, 2013). However, the high standard deviations for these effect sizes indicate that there is substantial variability within the effectiveness of each type of educational technology. Therefore, it can be assumed that educational technology can be more or less successful depending on how it is used. Furthermore, possible effects of educational technology use are confounded with general factors of instructional quality. Questionnaires in large-scale assessments typically focus on the quantity instead of the instructional quality of ICT use for teaching and learning (Lei, 2010; Petko, 2012). The rating scales measuring the frequency of educational technology use typically range from "never" to "almost every day". These rating scales might be appropriate when the use of educational technology happens on a regular basis. However, they fail to measure infrequent phases of intensive educational technology use. In PISA 2012, this is at least partially mitigated by using item response theory to take the relative difficulty of each educational technology use item into account when calculating overall scores. Still, these measures should be treated with caution and not be taken as a measure for quality of ICT use in teaching and learning.

1.2 Possible Explanations with Regard to Achievement Measures

Another important reason for the lack of positive findings might be found in the way achievement has been defined (Sjøberg, 2012). Some authors have assumed that the main benefit of educational technology is not mere achievement, but a shift to student-centered pedagogy and 21st Century styles of learning (Mujs et al., 2014; Voogt, 2008). These changes in teaching and learning practices might lead to a decline in traditional performance orientation (Pelgrum & Plomp, 2002), but at the same time an increase in new skills that might not be adequately measured by the tests used in current large-scale assessments (Voogt, Erstad, Dede, & Mishra, 2013). These new skills include information literacy and self-regulated learning skills. In the first PISA studies, these ICT-related literacies were not specifically tested. Large-scale studies focusing on educational technology, such as the SITES-M2 study (Law, Pelgrum, & Plomp, 2008) or ICILS (Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2013) did not include assessments in traditional school subject performance. This has changed in recent PISA studies, however. In PISA 2009 and 2012, countries had the option of testing reading and mathematics not only with pen-and-paper methodology but also with computer-based assessments, where specific test items with regard to digital reading and mathematics were used (OECD, 2015). Nevertheless, the frequency of classroom computer use was still negatively associated with achievement scores, both in computer-based mathematics and digital reading. The relationship between computer use, computer literacy, subject-specific and unspecific skills is still unclear.

1.3 Possible Explanations with Regard to Research Design Issues

Finally, there might also be more general reasons for the lack of positive correlations between educational technology use and student academic achievement. It seems to be more difficult to show impacts on educational achievement in correlational studies than in experimental studies (Seidel & Shavelson, 2007). All major international large-scale assessments are cross-sectional instead of longitudinal with respect to individual students. Thus, it is only possible to model correlational patterns that are not necessarily causal. It might even be a viable assumption that educational technology might be employed more often with low-performing students. In this case, educational technology would not be the cause but the remedy for low test performancy, although this is pure speculation.

In general, explaining influences on achievement is a highly complex endeavor with numerous interactions between factors, and the influence of technology use compared to other factors in meta analyses of teaching effectiveness has been negligible (Mujs et al., 2014; Scheerens et al., 2007). At best, educational technology needs to be regarded as just a piece in the puzzle of interrelated factors influencing quality of instruction, effectiveness of learning and test performance (Mujs et al., 2014; Scheerens et al., 2007; Seidel & Shavelson, 2007) and the use of digital technology in classrooms needs to be carefully "orchestrated" (Prieto, Dlab, Gutiérrez, Abdulwahed, & Balid, 2011). As most large-scale assessments tend to have a focus on comparisons of educational systems, examining these complex multilevel patterns down to classroom and student level is very challenging. With regard to student level, OECD (2010) concludes:

> "… computer use can make the difference in educational performance if the student has the appropriate set of competences, skills and attitudes. Without these, no matter how intense the student's use of a computer, the expected benefits will not be realized." (p.172)

All of these methodological problems are most likely interrelated. To start addressing these problems, studies need to adjust the ways in which the amount of computer and internet use is conceptualized and measured, assessing not only the frequency but also the quality of educational technology use. In addition, educational technology use needs to be seen as interrelated with other known factors of educational effectiveness. As there have been so few positive findings in large-scale studies, there is an apparent lack of theoretical models explaining achievement by means of educational technology use among other variables.

2 Hypothesis

As there is overwhelming evidence that the frequency of educational technology use in classrooms is negatively associated with achievement, this studies tries to look in a different direction. Instead of frequency, perceived quality of educational technology use might be among the positive predictors of student achievement. To date, only few studies exist that have analyzed the impact of student ratings with regard to the perceived quality educational technology on achievement. Papanastasiou, Zembylas, & Vrasidas (2004) found student perceptions to be negatively correlated with achievement scores in TIMSS 1995. On the other hand, Lee & Wu (2012) found a positive association of ICT-related attitudes with students' reading literacy in PISA 2009.

Thus, we will test the following hypothesis:

Student attitudes regarding the perceived benefits of educational technology for learning are a significant and positive predictor for student test scores in mathematics, science and reading in the majority of countries when controlling for frequency of educational technology use and influencial sociodemgraphic variables.

3 Method

The Programme for International Student Assessment (PISA) study is one of the most prominent international large-scale assessments of 15-year-old students' academic performance in core school subjects as well as several other optional topics such as problem-solving or financial literacy. Next to tests in reading, math and science, additional student and school questionnaires are administered. It has been mandated by the OECD and carried out by the International Association for the Evaluation of Educational Achievement (IEA) since 2000 in a 3-year cycle. Data is publicly available (http://pisa2012.acer.edu.au/) and documented (OECD, 2014). It has to be noted, however, that test items for mathematics, reading and science are only in part publicly available and scaling procedures are not completely transparent (Sjøberg, 2012). Thus, the transparency of these measures is somewhat limited.

3.1 Sample

Around 510,000 students in 65 countries/economies took part in the PISA 2012 assessment of reading, mathematics and science, representing about 28 million 15-

year-olds globally. Pupils from 40 of those countries answered the ICT-related questionnaire. 26 of those 40 countries are OECD countries. Due to high standard errors of the regression coefficients, we excluded Liechtenstein from our analysis, resulting in a total of 39 countries. Table 1 summarizes the number of students and schools in each country and lists the percentage of the total number of students and schools respectively.

Table 1: Dataset structure: students and schools distribution by country in alphabetical order

	Students number	%	Schools number	%
Australia* (AUS)	14481	4.91	775	6.74
Austria* (AUT)	4755	1.61	191	1.66
Belgium* (BEL)	8597	2.91	287	2.5
Switzerland* (CHE)	11229	3.81	411	3.58
Chile* (CHL)	6856	2.32	221	1.92
Costa Rica (CRI)	4602	1.56	193	1.68
Czech Republic* (CZE)	5327	1.81	297	2.58
Germany* (DEU)	5001	1.7	230	2
Denmark* (DNK)	7481	2.54	341	2.97
Spain* (ESP)	25313	8.58	902	7.85
Estonia* (EST)	4779	1.62	206	1.79
Finland* (FIN)	8829	2.99	311	2.71
Greece* (GRC)	5125	1.74	188	1.64
Hong Kong-China (HKG)	4670	1.58	148	1.29
Croatia (HRV)	5008	1.7	163	1.42
Hungary* (HUN)	4810	1.63	204	1.78
Ireland* (IRL)	5016	1.7	183	1.59
Iceland* (ISL)	3508	1.19	134	1.17
Italy* (ITA)	31073	10.5	1194	10.4
Jordan (JOR)	7038	2.39	233	2.03
Korea* (KOR)	5033	1.71	156	1.36
Latvia (LVA)	4306	1.46	211	1.84
Macao-China (MAC)	5335	1.81	45	0.39
Mexico* (MEX)	33806	11.5	1471	12.8
Netherlands* (NLD)	4460	1.51	179	1.56
New Zealand* (NZL)	4291	1.45	177	1.54
Poland* (POL)	4607	1.56	184	1.6
Portugal* (PRT)	5722	1.94	195	1.7
Shanghai-China (QCN)	5177	1.75	155	1.35

Perm(Russian Federation) (QRS)	1761	0.60	63	0.55
Russian Federation (RUS)	5231	1.77	227	1.98
Singapore (SGP)	5546	1.88	172	1.5
Serbia (SRB)	4684	1.59	153	1.33
Slovak Republic* (SVK)	4678	1.59	231	2.01
Slovenia* (SVN)	5911	2	338	2.94
Sweden* (SWE)	4736	1.61	209	1.82
Chinese Taipei (TAP)	6046	2.05	163	1.42
Turkey* (TUR)	4848	1.64	170	1.48
Uruguay (URY)	5315	1.8	180	1.57
Pooled sample	294991	100	11491	100
OECD countries	230272	78.1	9385	81.7

Note: *Countries that are members of the OECD are marked with an asterisk.

3.2 Measures

The PISA 2012 ICT familiarity questionnaire was optional for countries participating in the study. Nevertheless, most countries took part. All questionnaire items and composite variables used in this paper are documented in the PISA technical report (OECD, 2014). As dependent variables we employed the plausible values of the PISA mathematics, reading and science scores. As predictor variables, we focused on the composite variables ENTUSE (frequency of computer use at home for entertainment purposes), HOMSCH (frequency of computer use for school-related purposes at home), USESCH (frequency of computer use at school) and ICTATTPOS (positive attitude towards ICT as a learning tool). These items were treated as numerical for our analysis. The variable ICTATTNEG (negative attitudes towards ICT) was not included as these items were not as specific with regard to ICT as a learning tool.

Next to the ICT-specific items, we took into account a number of covariates, as proposed by Biagi & Loi (2012; 2013) and listed in Table 2.

Table 2: Items treated as covariates

ESCS	Index of economic, social and cultural status
ST04Q01	Gender: [**1 Female**, 2 Male]
GRADE	Grade compared to modal grade in country: [-3, -2, -1, **0**, 1, 2, 3]
REPEAT	Grade Repetition: [**Did not repeat a ⟨grade⟩**, Repeated a ⟨grade⟩]
IMMIG	Immigration status: [**Native**, Second-Generation, First-Generation]
FAMSTRUC	Family Structure: [**Single parent (natural or otherwise)**, Two parents (natural or otherwise), Other]
ST28Q01	How many books at home: [**1**, 2, 3, 4, 5, 6]

Note: All covariantes but ESCS are treated as categorial variables with levels indicated in square brackets. Reference levels are typed in **bold face**.

3.3 Procedure

Statistical analyses were conducted with the publicly available PISA 2012 dataset (retrieved from http://pisa2012.acer.edu.au/). All analyses were carried out using the statistical programming language R version 3.2.0. Based on recommendations for analyzing PISA data (OECD, 2009; Rutkowski, Gonzalez, Joncas, & Davier, 2010), we built and computed our model.

We adapted the procedures described in the most recent PISA data analysis manual in chapter 8, “Analyses with Plausible Values” (OECD, 2009, p. 129), and implemented the algorithm described in Figure 1. Our weighted linear regression model was finally built by the predictor variables in chapter 3.2 and the covariates as described in Table 2. The computations according to the algorithm Figure 1 were done for each PISA domain and for each country. We used the lm() function from R core package „stats“ to compute the weighted linear regression models. All regressions were checked for normal distribution of residuals, multicollinearity and homoscedasticity and we found no questionable pattern of deviation from these assumptions across countries.

Figure 1: Algorithm to obtain reliable standard errors for regression coefficients

1. For each of the five plausible values compute a weighted linear regression model incorporating the final and the 80 replicate Fay's BRR weights consecutively.
2. Compute final regression coefficient estimates by averaging all coefficients from the five models built with the final weights.
3. Compute final sampling variance estimates by averaging the sampling variances. The sampling variances are computed as variances of the estimated coefficients over all 80 models incorporating final replicate weights and for each plausible value.
4. Compute imputation variance (measurement error variance) by dividing the squared sum of the differences of the (averaged) final regression coefficients and each regression coefficient for each plausible value by 5−1.
5. Compute final error variance by summing up the final sampling variance and the imputation variance multiplied by (1+1/5).
6. Compute final standard error by drawing the square root of the final error variance.
7. Compute t statistics und p-values for all regression coefficients. The degrees of freedom are equal to one of the computed models in step 1.

For standardization of the regression coefficients we used the R package "betas" (Cantieni, 2015). This package offers a convenient way to compute standardized coefficients for (weighted) linear models that incorporate not only numerical variables, but also factorial variables. Although students are nested in schools, it is not possible to conduct multilevel modeling with the public PISA 2012 dataset as only student weights and no school weights are provided. The full R syntax is available upon request (please contact the corresponding author).

4 Results

Tables 3, 4 and 5 list the results for all standardized regression coefficients for the ICT-related variables in the model for each country and for each PISA domain. Country abbreviations were taken from the official PISA codebook (OECD, 2014). The order of countries in the tables is ranked according to the mean test performance for each country in mathematics, reading and science respectively.

We will start with summarizing the results for the PISA domain Mathematics (Table 3). Frequency of entertainment use at home (ENTUSE) is a significant and negative predictor for mathematical performance in almost all but the least successful countries with regard to student performance. In countries with weaker test performance this turns out to be a positive predictor. The frequency of school-related technology use at home shows the opposite pattern, where this is a positive predictor in the majority of successfully performing countries and a negative predictor in some of the countries with weaker overall test performance. School use (USESCH) is negatively associated in 37 of the 39 countries in the analysis. The positive attitude towards ICT as a learning tool shows mixed results with a tendency towards positive associations. In 20 countries this is a significant positive predictor of mathematics test performance, in two countries a negative predictor and in 15 countries there is no significant association. There is no discernible pattern of this associations with regard to the ranking of countries and effect sizes. Explained variance for the model ranges from R^2=.150 to R^2=.456.

Table 3: Standardized regression coefficients (β) and explained variance (R^2) for each country predicting the achievement scores for the PISA domain Mathematics

	ENTUSE	HOMSCH	USESCH	ICTATTPOS	R^2
QCN	-0.670***	0.395***	-0.475***	0.092**	0.277
SGP	-0.103**	0.608***	-0.750***	-0.169***	0.262
HKG	-0.132**	0.899***	-0.558***	-0.014	0.235
TAP	-1.189***	0.870***	-0.292**	0.133*	0.266
KOR	-1.244***	1.865***	-1.005***	1.022***	0.215
MAC	-0.009	0.093***	-0.041***	0.022**	0.348
CHE	-0.191***	0.060	-0.372***	0.268***	0.356
NLD	-0.298***	1.481***	-1.179***	-0.028	0.351
EST	-0.102***	0.009	-0.116***	0.010	0.233
FIN	-0.382***	0.095*	-0.292***	0.100***	0.235
POL	-0.171	-0.324**	-1.035***	-0.154	0.290
BEL	-0.280***	0.204***	-0.262***	0.116***	0.446
DEU	-1.268***	-0.281	-0.852***	0.642***	0.376
AUT	-0.389***	0.490***	-0.428***	0.208***	0.335
AUS	-0.560***	0.503***	0.006	0.156***	0.241
IRL	-0.093**	-0.140**	-0.397***	0.223***	0.270
SVN	-0.042*	0.018	-0.229***	-0.038	0.265
DNK	-0.183***	0.264***	-0.642***	0.268***	0.271
NZL	-0.308***	0.265***	-0.418***	0.159***	0.294
CZE	-0.112	0.346***	-0.712***	0.062	0.347
ISL	-0.086***	-0.039*	-0.025	0.054***	0.150
LVA	0.039	-0.123***	-0.339***	0.033	0.305
PRT	-0.129*	-0.044	-0.406***	0.008	0.456
ITA	-0.054	0.066	-0.600***	-0.029	0.255
ESP	0.262***	-0.438***	-0.405***	0.131***	0.434
QRS	0.212*	0.072	-0.718***	0.042	0.217
RUS	0.683***	-0.578*	-2.410***	0.093	0.205
SVK	0.109**	-0.028	-0.322***	0.126***	0.373
SWE	-0.281***	0.032	-0.459***	0.334***	0.229
HUN	-0.117*	-0.006	-0.546***	-0.020	0.402
HRV	0.198***	0.083*	-0.405***	-0.016	0.209
GRC	0.207***	-0.412***	-0.914***	0.185***	0.293
SRB	0.108*	0.102	-0.498***	-0.060	0.217
TUR	0.677***	-0.326*	-1.587***	-0.490**	0.305
CHL	0.160*	-0.313***	-0.430***	-0.018	0.392
MEX	0.418***	0.306***	-0.983***	0.357***	0.193
URY	0.259***	-0.317***	-0.202***	-0.037	0.428
CRI	0.258***	-0.150**	-0.197***	0.120**	0.370
JOR	0.872***	-0.159	-0.628***	0.061	0.185

More consistent results can be shown for the PISA domain Reading (table 4). While the pattern of the ENTUSE, HOMSCH and USESCH variables is very similar, the positive attitude towards ICT as a learning tool shows significant and positive effects in 29 countries, while in the 10 remaining countries this seems to have no effect in this model. The models explain between 19.5% and 42.6% of the variance in the test scores.

Table 4: Standardized regression coefficients (β) and explained variance (R^2) for each country predicting the achievement scores for the PISA domain Reading

	ENTUSE	HOMSCH	USESCH	ICTATTPOS	R^2
QCN	-0.686***	0.408***	-0.612***	0.177***	0.296
HKG	-0.112*	0.868***	-0.487***	-0.033	0.240
SGP	-0.026	0.529***	-0.670***	-0.041	0.285
KOR	-0.918***	1.599***	-1.292***	1.388***	0.195
FIN	-0.223***	-0.022	-0.289***	0.238***	0.276
IRL	-0.009	-0.201***	-0.495***	0.190***	0.304
TAP	-1.030***	0.828***	-0.342***	0.487***	0.258
POL	0.475***	-1.158***	-1.153***	-0.180	0.316
EST	-0.105***	-0.014	-0.180***	0.037	0.258
NZL	-0.295***	0.137**	-0.387***	0.233***	0.291
AUS	-0.441***	0.326***	0.002	0.299***	0.244
NLD	-0.020	1.510***	-1.400***	0.064	0.328
CHE	-0.095**	-0.002	-0.383***	0.365***	0.378
MAC	0.019	0.030*	-0.060***	0.068***	0.327
BEL	-0.085*	0.008	-0.359***	0.137***	0.396
DEU	-1.112***	-0.370*	-0.751***	0.938***	0.377
DNK	-0.206***	0.170*	-0.637***	0.484***	0.269
CZE	0.021	0.257***	-0.841***	0.060	0.346
ITA	0.038	0.062	-0.866***	-0.014	0.290
AUT	-0.397***	0.410***	-0.565***	0.451***	0.348
LVA	0.174***	-0.165***	-0.433***	0.084**	0.401
HUN	0.131*	-0.286***	-0.781***	0.194***	0.426
ESP	0.438***	-0.499***	-0.460***	0.227***	0.387
PRT	0.040	-0.236***	-0.479***	0.150***	0.413
HRV	0.246***	0.028	-0.476***	0.126***	0.278
SWE	-0.214**	0.208**	-0.482***	0.371***	0.252
ISL	-0.099***	-0.007	-0.006	0.079***	0.198
QRS	0.349***	0.094	-0.827***	0.110	0.290

SVN	-0.014	-0.025	-0.283***	0.063***	0.314
GRC	0.497***	-0.715***	-0.879***	0.434***	0.338
TUR	1.037***	-0.398*	-2.019***	0.356*	0.375
RUS	1.499***	-0.207	-3.394***	0.667***	0.277
SVK	0.218***	0.020	-0.488***	0.163***	0.406
SRB	0.201***	0.095	-0.554***	-0.022	0.254
CHL	0.278**	-0.216**	-0.628***	0.280***	0.379
CRI	0.388***	-0.209***	-0.225***	0.163***	0.321
MEX	0.622***	0.443***	-1.159***	0.636***	0.217
URY	0.258***	-0.233***	-0.297***	0.055	0.392
JOR	0.774***	-0.118	-0.618***	0.291***	0.290

For the PISA domain Science, results show a very similar tendency with slight differences (Table 5). While entertainment use (ENTUSE) and school use of technology (USESCHOOL) are predominantly negative predictors of test performance, the use of technology for school-related matters at home (HOMSCH) also turns out to be negative for more countries. Only in the best performing countries is this association still positive. Positive attitudes (ICTATTPOS) are a significant and positive predictor in 30 countries, although with a large variation in standardized regression coefficients. Only one country shows a negative association. Explained variance of this model starts from $R^2 = .167$ up to $R^2 = .413$.

Table 5: Standardized regression coefficients (β) and explained variance (R^2) for each country predicting the achievement scores for the PISA domain Science

	ENTUSE	HOMSCH	USESCH	ICTATTPOS	R^2
QCN	-0.591***	0.361***	-0.468***	0.088*	0.266
HKG	-0.138*	0.814***	-0.547***	-0.003	0.221
SGP	-0.073**	0.505***	-0.667***	-0.062*	0.271
FIN	-0.289***	0.003	-0.294***	0.151***	0.203
EST	-0.048*	-0.051*	-0.149***	0.029	0.199
KOR	-0.806***	1.815***	-1.011***	1.417***	0.175
POL	0.031	-0.729***	-1.056***	0.042	0.270
DEU	-1.015***	-0.324	-0.954***	0.820***	0.352

TAP	-1.109***	0.712***	-0.253*	0.309***	0.243
NLD	-0.083	1.461***	-1.259***	0.152	0.334
IRL	-0.072	-0.150***	-0.392***	0.281***	0.254
AUS	-0.486***	0.278***	0.021	0.254***	0.223
MAC	0.016*	0.039***	-0.030***	0.039***	0.282
NZL	-0.256***	0.108*	-0.365***	0.222***	0.291
CHE	-0.199***	-0.038	-0.446***	0.350***	0.382
SVN	-0.041*	-0.007	-0.268***	0.053*	0.249
CZE	-0.044	0.243***	-0.862***	0.218***	0.333
AUT	-0.348***	0.373***	-0.386***	0.360***	0.341
BEL	-0.204***	0.003	-0.257***	0.214***	0.413
LVA	0.053	-0.122***	-0.361***	0.142***	0.283
DNK	-0.117*	0.279***	-0.728***	0.446***	0.275
ESP	0.491***	-0.526***	-0.514***	0.266***	0.362
HUN	0.141*	-0.163**	-0.639***	0.189***	0.382
ITA	0.033	-0.075*	-0.678***	0.101**	0.244
HRV	0.258***	0.014	-0.468***	0.130***	0.185
PRT	-0.037	-0.143**	-0.364***	0.093*	0.399
RUS	0.922***	-0.559*	-2.874***	1.306***	0.236
SWE	-0.053	-0.018	-0.473***	0.398***	0.228
QRS	0.453***	0.056	-0.837***	0.072	0.254
ISL	-0.086***	-0.037*	-0.028	0.036*	0.167
SVK	0.136**	-0.054	-0.358***	0.234***	0.394
GRC	0.362***	-0.583***	-0.852***	0.365***	0.275
TUR	1.138***	-0.551**	-1.634***	0.004	0.260
CHL	0.216*	-0.330***	-0.596***	0.149**	0.320
SRB	0.025	0.078	-0.540***	0.039	0.187
CRI	0.346***	-0.145*	-0.154***	0.236***	0.310
URY	0.268***	-0.258***	-0.221***	0.069	0.362
MEX	0.614***	0.201*	-1.037***	0.649***	0.176
JOR	0.742***	-0.151	-0.689***	0.175**	0.195

5 Discussion and Conclusion

As in previous studies, the frequency of technology use in schools correlates negatively with math, reading and science achievement in the large majority of countries. The use of digital technologies at home for school-related purpose predominantly shows a positive correlation with test scores in the three main subject areas in PISA 2012. Digital entertainment use at home is negatively correlated, at least in high achieving countries. These patterns are well-known from previous studies (e.g.

OECD, 2015; Shewbridge, Ikeda, & Schleicher, 2005; Woessmann & Fuchs, 2007). In this study, these observations have been expanded with an additional aspect. Students' ratings on how efficient they believe digital technologies are as a learning tool also have a substantial and significant positive effect for all three subject areas in most countries.

If we assume that these student ratings are based on positive experiences, this result might lead to the deduction that the quality of educational technology experiences is a positive predictor for academic achievement, while the mere quantity of technology use in schools and at home for entertainment purposes is not. This finding is rather new, as only a few studies have examined this relationship. While in TIMSS 1995 negative associations between student attitudes towards educational technology have been shown (Papanastasiou, Zembylas, & Vrasidas, 2004), results from PISA 2009 indicate that there might be positive associations (Lee & Wu, 2012). However, in previous PISA studies the questions with regard to student attitudes were less specific with regard to learning. Instead, they measured general interest in digital technology. It is a novelty of PISA 2012 that the items measuring student positive attitudes with regard to ICT are worded specifically with regard to digital learning potentials. Thus, in line with general research on educational technology, the interpretation that the quality of educational technology use is more decisive that the quantity seems plausible (Hattie, 2008; Lei, 2012).

Several limitations of these findings have to be pointed out. First and foremost, positive attitudes towards use of educational technology do not necessarily equal quality of ICT use in teaching. Most importantly, positive attitudes can derive from school use as well as from home use. In addition, positive attitudes might be influenced by other factors that are not part of the model (Meelissen, 2008). Especially psychological factors such as technology-related interests need to be accounted for in future studies. As PISA measures are partially changed every three years, future studies might be able to incorporate new covariates. As PISA questionnaire items are rather general and based on student self-report ratings, possible interpretations of the findings have to be treated with caution. Second, the positive associations cannot be interpreted in a causal way. As data is not longitudinal, it is not possible to discern whether student academic achievement is better because of positive experiences with digital learning or whether computers are used with increased quality when students show higher academic abilities. Furthermore, high achieving students might be more capable and willing to see the potential benefits of digital learning than lower performing students. Third, the covariates in our model are limited to students' background variables. They do not take factors which are specific to the school and classroom into account, especially those related to teaching. Thus, results do not say whether the effect of the perceived quality of computer use remains constant across different pedagogical contexts. Fourth, when looking at the coefficients for different countries, it is unclear why coefficients are higher in some countries than in others.

There does not seem to be a consistent pattern in terms of economic development or other variables. Finally, one needs to be aware of the fact that the expectation regarding overarching effects of educational technology might be questionable in itself. As pointed out in chapter 1.1, there are many particular kinds of educational technology which can be used in various ways and for many different purposes. Thus, quality of learning might have various meanings, and this calls for more specific measurements. When students make overall judgements on the perceived quality of learning with educational technology – as done in PISA 2012 –, it remains unclear, what kinds of technologies and usage experiences they refer to. Furthermore, these judgements might not only be influenced by educational technology experiences but also by other factors such as technology-related interests and affinities.

Keeping these aspects in mind, the findings might lead the way to considering quality of educational technology use as a promising factor that needs closer inspection in large-scale studies. If these findings can be replicated and more thoroughly explained, they might have a potentially large impact on technology use in schools and related teacher education. Research needs to better understand how positive experiences with digital learning are related to student achievement and how multi-faceted computer activities can enrich classrooms, not only in the quantity of educational technology use but also in the quality.

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