Digital reading proficiency in German 15-year olds: Evidence from PISA 2012

Kompetenzen 15-jähriger Schülerinnen und Schüler beim Lesen digitaler Texte in Deutschland: Befunde aus PISA 2012

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Abstract

The present study for the first time reports results on digital reading proficiency in German 15-year-old secondary students, based on the PISA 2012 computer-based assessment (N = 2,785). We report mean performance in digital reading and associations with student background, availability of ICT, use of ICT, and attitudes towards ICT. With a mean score 494 points on the PISA scale, German students performed not significantly different from the OECD average. However, their digital reading proficiency significantly lagged behind their print reading proficiency. A regression model with student background variables gender, immigrant status, and socio-economic status combined explained 13% of digital reading variance. ICT availability, use of ICT, and attitudes towards ICT combined explained 16% of variance. A regression model combining both student background and ICT availability, attitudes, and use explained 23% of variance. ICT availability and use had inversely u-shaped associations with digital reading proficiency.

Keywords: Digital reading, Hypertext, PISA 2012, ICT use, computer-related attitudes

Zusammenfassung

Die vorliegende Studie berichtet erstmals die Ergebnisse zum Lesen digitaler Texte aus dem computerbasierten Teil des PISA-Tests 2012 für Schülerinnen und Schüler in Deutschland (N = 2,785) im Hinblick auf Performanz und Zusammenhänge mit soziodemographischen Variablen sowie Zugang zu Informations- und Kommunikationstechnologien (ICT), ICT-Nutzung und ICT-bezogenen Einstellungen. Im Mittel erreichten deutsche 15-jährige im Lesen Digitaler Texte 494 Punkte auf der PISA-Skala. Die Performanz beim Lesen digitaler Texte liegt damit im Bereich des OECD-Durchschnitts und ist signifikant niedriger als die Performanz deutscher 15-jähriger beim Lesen gedruckter Texte. Ein Regressionsmodell mit den soziodemographischen Prädiktoren Geschlecht, Migrationsstatus und den ICT-bezogenen Variablen Zugang zu ICT, ICT-Nutzung und ICT-bezogenen Einstellungen erklärte 23% der Varianz im Lesen digitaler Texte. Soziodemographische Variablen allein erklärten 13% und ICT-bezogene Variablen erklärten 16% der Varianz. Der Zusammenhang der Performanz beim Lesen digitaler Texte mit Zugang zu ICT und Nutzung von ICT war dabei umgekehrt U-förmig.

Schlüsselwörter: Lesekompetenz, Hypertext, Lesen Digitaler Texte, PISA 2012, Nutzung von Informations- und Kommunikationstechnologie, computerbezogene Einstellungen

Digital reading proficiency in German 15-year olds: Evidence from PISA 2012

This article reports an analysis of OECD PISA 2012 data speaking to the proficiency of German 15-year olds in reading digital texts. While Germany participated in the Digital Reading Assessment for research purposes, the results of this assessment have not been part of the recently published OECD report (OECD, 2015). In the following, we report German students' average proficiency in digital reading, as well as associations of digital reading proficiency with print reading proficiency, student background, and ICT availability, attitudes, and use.

Digital reading proficiency

It has become something like a truism to note that the ability to access, comprehend, and critically evaluate digital texts is a key requirement to participate in 21st century societies occupationally, privately, and socially. At the same time, there is broad consensus that individual proficiency in reading digital text cannot be mapped upon individual proficiency in reading printed text (e.g. Afflerbach & Cho, 2008; Leu, Kinzer, Coiro, & Cammack, 2005). While reading both in the print and the digital medium involves cognitive operations and corresponding component skills such as decoding, syntactic parsing, semantic integration, and building text-base and situational models (e.g. Kintsch, 1998, Perfetti, 1994), a number of specific requirements come with reading digital texts.

First, digital texts are presented on devices such as computers, tablets, or mobile phones (information and communication technology, ICT). Theoretical models of problem solving in digital environments, such as Brand-Gruwel's, Wopereis', and Walravens' (2009) IPS (Information Problem Solving on the Internet) model, assume basic computer skills as one prerequisite for skills in digital information problem solving to unfold. In line with this, Goldhammer, Naumann, and Keßel (2013) found that in 15-year old German high school students from all tracks, performance in digital reading tasks was predicted by both speed and accuracy in basic ICT tasks such as clicking a hyperlink, or copying and pasting text.

Second, digital reading requires a specific process where text comprehension and operating digital environments intersect, often referred to as “navigation”. Typically, digital texts come as “hypertexts” and combine several layers or levels of text which are cross-linked. Thus, they cannot be read linearly from beginning to end, but it is left to the reader to select and put into an appropriate order different parts of a text, also referred to as “nodes” (see e.g. Lawless & Schrader, 2008; Voss, 2006, chapter 2.6). How proficiently students navigate is a strong predictor of their learning and performance when reading digital texts (e.g. Hahnel, Goldhammer, Naumann, & Kröhne, 2016; Naumann, 2015; Naumann & Salmerón, 2016; OECD, 2011a, 2015; Salmerón, Cañas, Kintsch, & Fajardo, 2005).

The specifics of reading digital texts are taught neither regularly nor extensively in German classrooms. For instance, only 36% of German teachers surveyed in the International Computer and Information Literacy Study (ICILS, see Fraillon, Ainley, Schulz, Friedman, & Gebhard, 2014) reported that they put emphasis on teaching the efficient access of online information, against an international average of 63%. Likewise, only 29% of German teachers reported that they put emphasis on teaching students to judge the credibility of online information, against an international average of 52% (Eickelmann, Schaumburg, Drossel, & Lorenz, 2014).

Against this background, it is likely that practice in digital reading gained outside school will play an important role in bringing about German students’ digital reading proficiency. Thus, individual ICT availability, individual motivations to use ICT (attitudes towards ICT), and individual use of ICT might contribute to German students’ digital reading proficiency.

In addition to the specific processes required for reading digital texts, related research has consolidated a number of student background variables that are consistently found to be relevant predictors of reading proficiency. The most prominent variable is probably the gender gap in reading proficiency, meaning that girls outperform boys in reading across

numerous studies (e. g. PISA, OECD, 2011a, 2014a; PIRLS, Mullis et al., 2012; NAEP, Robinson & Lubienski, 2011). Two further background variables, which cannot always be fully separated, are students' socio-economic status (SES) and their immigrant status. Both are repeatedly found to predict proficiency in reading (e.g. Stanat & Christensen, 2006; Stanat, Rauch, & Segeritz, 2010). Also, in countries other than Germany, gender, SES, and immigrant status have been found to predict digital reading proficiency, with girls outperforming boys (OECD, 2011a; 2014c), high SES students outperforming low SES students (OECD, 2014c), and native students outperforming immigrant students (OECD, 2014c). Some findings show that discrepancies between students in digital reading with different SES or immigration background can be traced back to primary school age. E.g. Voss (2006), in a sample of 77 fourth graders, found that students from higher SES families, with higher educational aspirations, outperformed students from lower SES families, and families with lower educational aspirations in digital reading.

At the same time, from previous research it seems that it is not a student's gender, SES, or immigrant status per se that accounts for proficiency. As, amongst others, Artelt, Naumann, and Schneider (2010) reported, effects of cultural possessions in students' homes and gender on print reading proficiency were completely mediated through reading motivation and strategies. Against this background, the question arises not only how ICT-specific variables on the one hand and student background on the other predict digital reading proficiency, but also whether student background variables' associations with digital reading skill, where they are found, can statistically be explained in terms of ICT availability, attitudes, and use.

The present research

The present research used data from the PISA 2012 computer-based assessment to three ends. First, we explored how proficient German students are in digital reading, both in comparison to digital reading proficiency in other OECD countries, and in comparison to

German students' proficiency in print reading. Second, we estimated the association of digital reading proficiency with student background variables Gender, Socio-Economic Status (SES), and immigrant status on the one hand, and ICT availability, attitudes and use on the other. Finally, we estimated associations of digital reading proficiency with both student background and ICT-related variables in a combined model. The logic to this last step was to see whether dependencies of digital reading proficiency on gender, immigrant status or SES where they emerged could be explained by differences in ICT availability, attitudes and use.

Regarding bivariate associations of ICT availability, attitudes, and use with digital reading proficiency, we expected the following:

Availability of ICT. We expected that computer access both at home and school would be positively associated with digital reading proficiency. We expected these associations to be non-linearly shaped. We hypothesized that students need access to the most common ICT tools (e.g. a desktop or laptop computer, and an internet connection) in order to develop their digital reading skills and practice, while less familiar items (e.g. a tablet computer and E-Book reader, see OECD, 2014b) should not be incremental in promoting digital reading proficiency. The prediction of a non-linear association between ICT availability is also in line with previous findings for countries other than Germany (OECD, 2015).

Attitudes towards ICT. ICT related attitudes have been reported to predict performance in ICT tasks (e.g. Keith, Richter, & Naumann, 2010; Naumann, Richter, & Groeben, 2001). Presumably, students who hold more positive, and less negative attitudes towards ICT tasks are more prone to stay focused, and adequately cope with difficulties and problems occurring through task completion (Keith et al., 2010). In PISA 2012, a conceptualization of ICT related attitudes was adopted that sees positive and negative components of attitudes as partly independent: A person might hold both positive and negative beliefs about a particular topic at the same time (e.g. Cacioppo & Berntson, 1994).

Amongst others, this is true of computers and ICT, where positive attitudes, framed as perceiving ICT as a "useful tool" can be separated from negative attitudes, framed as perceiving ICT as an "uncontrollable entity" (see Brock & Sulsky, 1996; Naumann et al., 2001; Richter, Naumann, & Groeben, 2000, 2001; Richter, Naumann & Horz, 2010). We expected that positive attitudes towards ICT would be positively associated with digital reading proficiency, while negative attitudes towards ICT would be negatively associated with digital reading proficiency. Moreover, we expected an interaction between these two attitude components. We hypothesized that positive attitudes towards ICT (e.g. when students were seeing the computer as a "very useful tool for [my] schoolwork", OECD, 2013a, p. 13) would be especially predictive when at the same time negative attitudes towards ICT were low (e.g. students were *not* thinking that "using the computer for learning is troublesome", OECD, 2011b, p. 13).

Use of ICT. We expected different associations with digital reading proficiency for different dimensions of ICT use. While use of ICT at home for school and use of ICT at school were both expected to have positive associations with digital reading proficiency, we expected a negative association for computer use directed at entertainment and social interaction on the basis of earlier research findings. For instance, Alloway and Alloway (2012) found that in a go/no-go task, heavy users of social media were prone to false positive errors, i.e. they reacted to stimuli they were opposed to ignore. In a similar vein, Naumann (2015) found that students who were high in social online reading engagement were likely to access more pages than the task actually required in digital reading tasks, thus impairing the efficiency of their hypertext navigation. Addressing digital reading proficiency directly, Lee and Wu (2013) found a negative association between social entertainment online activities and digital reading proficiency. Thus, their finding generalized earlier findings of negative associations between print literacy scores and social and entertainment directed computer use,

and Internet use outside the classroom (e.g. Junco, 2012a; Pfost, Dörfler, & Artelt, 2013, Schulz-Zander, Eickelmann, & Goy, 2010) to the "new" literacies domain.

To summarize, we analyzed the association of digital reading proficiency in German 15-year-olds with three indices of ICT use: use of ICT at home for school, use of ICT at school, and use of ICT for entertainment. While we predicted positive linear trends for the first two, we predicted a negative linear trend for the latter. In addition, we expected these linear trends to be moderated by a negative quadratic trend. For use of ICT at home for school, and use of ICT at school we expected that it would be especially detrimental if students were hardly ever using ICTs, while it would make less of a difference whether they used them moderately or intensely. For use of ICT for entertainment, we expected that a moderate kind of use would not be detrimental, but a style of heavy use would be (see e.g. Alloway & Alloway, 2012; Junco, 2012a, b). Previous analyses in countries other than Germany found such a negatively u-shaped non-linear association between proficiency and use of ICT (OECD, 2015).

If effects of student background variables (gender, immigrant status and SES) were indeed transmitted through ICT availability, attitudes and use, these variables besides having bivariate associations with digital reading proficiency also should have a substantial increment in variance explained over and above student background. Student background variables in contrast, in this case, should have no substantial increment in variance explained over and above ICT availability, attitudes, and use. Finally, in a model that combines socio-demographic and ICT related predictor variables, regression coefficients for socio-demographic variables should be substantially reduced if their effects on digital reading were transmitted through ICT attitudes, availability, and use.

Method

Subjects

Subjects were those 5,001 students who were sampled for PISA 2012 in Germany (2,539 male). Students were around the age of 15, due to PISA's sampling design (unweighted M = 15.83, SD = 0.29). Of these, 2,785 (1,415 male) participated in the computer-based assessment. Due to PISA's sampling and rotated booklet design, 50% received at least one cluster (three units) of digital reading items. Each CBA booklet contained two clusters.

Materials and instruments

Print reading proficiency. Students' proficiency in print reading was measured using the PISA 2012 print reading assessment (see OECD, 2014b, and see OECD, 2009; 2013 for the PISA reading framework). In PISA 2012, where reading was not a major domain, this assessment comprised 44 items, which were organized in 13 units. Each unit consisted of one or several texts as a stimulus, followed by one to four items. The units were organized in three clusters. Due to the multi-matrix design applied in PISA 2012, a total of 13 paper-based test booklets was administered. Each booklet contained four clusters. Among the booklets, six booklets contained one cluster measuring reading proficiency and three booklets contained two reading clusters. Following the assessment framework for reading literacy (OECD, 2009; 2013), students' reading proficiency is measured as a multidimensional skill. The framework distinguishes three major task characteristics to organize the domain of reading literacy: situation, text and aspect. Situation variables differentiate personal, public, occupational and educational texts, whereas the text variable is classified into medium (print and digital), environment (authored, message-based and mixed texts), text format (e. g. continuous versus non-continuous texts) and text type (e. g. narration, instruction). Aspects of reading are mental strategies used by the students to work and interact with a text, such as accessing and retrieving, integrating and interpreting, and reflecting and evaluating. Since reading was not a

major domain however, in PISA 2012 no reporting of subscales based on format, or aspect was done. Rather, print reading proficiency was reported as one unidimensional scale.

Digital reading proficiency. Digital reading proficiency was measured separately form print reading proficiency, and forms a separate scale (see OECD, 2013, page 78 f.). This scales' mean and standard deviation were tied to the OECD mean and standard deviation of the print reading scale in PISA 2009 (OECD, 2011a, 2015). Digital reading proficiency was measured with 19 items that required students to read texts on the computer screen, which were organized in six units. Each unit was composed of one text stimulus and between one and four items. Three units were grouped into one cluster, so that two digital reading clusters contained six units. Out of the two digital reading clusters, each student participating in the computer-based assessment received either both, or one of them, and in the latter case in combination with a cluster from the computer-based math or problem solving assessment, or none at all. The texts represented typical genres of online texts such as blogs, e-mails, or websites. The items were constructed in a way that besides generic competences required for reading (e.g. word recognition, or semantic integration at the sentence level), knowledge and skills specific for digital reading were targeted, such as knowledge of medium-specific text genres, cues for source evaluation, or navigation. The items varied as to the degree to which they required students to navigate. While in some items, the required information was available on the page with which students were prompted, in other tasks they had to navigate through several pages, and to integrate information from several pages, to answer the item. Figures 1 and 2 give two examples.

Figure 1 about here

Item CR017Q01 (Figure 1) is an item from the unit "Language Learning". To correctly answer this item, medium-specific knowledge for source evaluation is needed. Students need to identify the "Salesman's" message as spam, referring to the facts that the "Salesman" is not on the "friends-list", and/or the bad spelling, or apparently automated

translation in the message. Navigation demands in this item are low since all the information required is available on the screen the student is prompted with.

Figure 2 about here

Item CR013Q07 (Figure 2) is an item form the unit “Sports club”. In this item, students are prompted with an e-mail exchange between two girls, Liz and Anna, who talk about joining a sports club, comprising six e-mails in total. Students are asked to recommend a sports club to Liz and Anna that best fits their requirements. To accomplish this, students have to complete a navigation sequence of at least 14 steps, and to integrate information from four websites and four e-mails.

Socio-economic status. Socio-economic status was measured through the ESCS index (PISA index of economic, social and cultural status, OECD, 2002). This index combines information on students’ parents’ education, wealth, and cultural and educational resources in the home. Specifically, the ESCS index is a weighted sum of a student’s parents’ highest occupational status (HISEI), a student’s parents’ highest education in years of schooling (PARED), and a student’s home possessions (HOMEPOS, e.g. a dictionary, a dishwasher, cellular phones, etc.). Details about how the HISEI, PARED, and HOMEPOS indices are computed, and integrated into the PISA index of socio-economic status can be found in OECD (2014b, p. 351f.).

Immigrant status. The coding scheme used in PISA for immigrant status was employed. In the PISA student background questionnaire, students are asked for their own country of birth, as well as both their parents’. Students born in a country other than the country of assessment are classified as “first generation immigrant students”. Students who are born in the country of assessment, but have at least one parent born in another country are classified as “second generation immigrant students”. All other students are classified as “native students”.

Availability of ICT. Availability of ICT at home and at school were measured through the PISA ICT familiarity questionnaire, asking for a number of ICT devices such as a desktop computer, and Internet connection, a printer, or an e-book reader whether students had these available in their homes and in their schools, and if so, whether they used them. The number of items was eleven for availability of ICT at home, and seven for availability of ICT at school. See OECD (2014b, Tables 16.51 and 16.52) for item wordings and item parameters.

Attitudes towards ICT. Attitudes towards ICT were measured using two short scales with three items each, included in the PISA ICT familiarity questionnaire, and consisting of items from the Computer Literacy Inventory (Richter et al., 2010), which had been slightly revised. One of these scales addressed positive attitudes towards the use of ICT for learning (usefulness beliefs, see Brock & Sulsky, 1996; Richter et al., 2000), and one scale addressed negative attitudes towards the use of ICT for learning (uncontrollability beliefs, see Brock & Sulsky, 1996; Richter et al., 2000). See OECD (2014b), Tables 16.57 and 16.58 for item wordings and item parameters.

Use of ICT. Use of ICT at home for school, at home, and for entertainment were measured through three scales from the PISA ICT familiarity questionnaire. These comprised items asking students how often they used a computer at home for school (e.g. doing homework on the computer), at school (e.g. playing simulations at school), or for entertainment (e.g. participating in social networks). See OECD (2014b), Tables 16.53, 16.54, and 16.55 for item wordings and item parameters.

Procedure

In accordance with PISA procedures, students were tested in schools during school hours. Each test session followed the standardized protocol implemented in PISA 2012. Trained test administrators, who were not part of the school community, administered the PISA test. Each group of tested students began with the proficiency test of the paper-based assessment in the morning of the PISA testing day. This session comprised 120 minutes of

test items organized in four clusters per student. After a short break, the student questionnaire was administered (approximately 45 minutes). Those students who had been randomly selected for participation in the computer-based assessment entered a room with set-up computers after their lunch break. The computer-based assessment took 40 minutes plus 15 minutes of preliminary practice guided by the test administrators.

Data base and Statistical modelling

We relied on data provided in the international PISA 2012 database for the computer-based test components, which are available at http://www.oecd.org/pisa/pisaproducts/database-cbapisa2012.htm (06/27/2016). Students were weighted by student weights incorporating a school weight and based on the stratified, probabilistic sampling procedure (OECD, 2014b). Standard errors were corrected for PISA's complex sampling design using replicate weights. The R-environment (R Development Core Team, 2015) was used for data analysis with the package BIFIEsurvey (Robitzsch, 2015). For all statistical tests, an α-level of .05 was assumed. As a measure of effect size, we report the proportion of explained variance R^2.

Results

In the following, we firstly report German 15-year-olds' digital reading proficiency, as of 2012, both in comparison to OECD countries and print reading proficiency. Then we describe how digital reading proficiency relates both to students' background (gender, SES, immigrant status), and ICT-related variables (availability, attitudes, and use). For each variable, we describe their bivariate association with digital reading proficiency. We also report how well digital reading proficiency is predicted by student background variables combined, how well it is predicted by ICT related variables combined, and how well it is predicted by both background and ICT related variables in combination.

German 15-year olds' proficiency in digital reading and relation to print reading

The mean proficiency of German 15-year olds in digital reading was 494 points on the PISA-scale (*SE* = 3.98). German students' digital reading proficiency thus did not differ significantly from the OECD mean of 499. The standard deviation was 99 (*SE* = 3.40) and thus higher than the OECD average, which was 90 (OECD, 2011a; 2015).[1]

German students' proficiency in digital reading fell short of their proficiency in print reading, which was 508 points on the PISA-scale and thus significantly higher than the OECD mean (OECD, 2014a). The difference between German students' print and digital reading proficiency was significant, M_{Diff} = 14.12 (*SE* = 2.81). The relative weakness of German 15-year olds' digital reading proficiency as compared to their print reading proficiency was also apparent in the distribution of students across proficiency levels (see Fig. 3).

Figure 3 about here

While in print reading, less than 15% (*SE* = 1%) of students did not reach the basic level 2, this percentage for digital reading was 19% (*SE* = 2%). Correspondingly, while in print reading 25% (*SE* = 1%) of students reached level 4, and 9% (*SE* = 1%) level 5 or above, these percentages in digital reading were only 22% (*SE* = 1%) and 7% (*SE* = 1%) respectively.

The correlation between print and digital reading proficiency in Germany was .80 (*SE* = 0.01). To interpret this correlation it is informative to look at the corresponding correlations between print reading proficiency and proficiency in mathematics and science. These correlations amounted to .87 (*SE* = 0.01) and .90 (*SE* < 0.01) and were thus higher than the correlation between digital and print reading proficiency. This means that while the constructs of digital reading and print reading amongst German 15-year-olds are clearly related, their association is not higher than the association of cognitive variables that is found in PISA in

[1] PISA 2012 Digital Reading results were reported on the scale established in 2009, which was introduced in OECD (2011a). See also OECD (2015, page 85).

general. The correlation between digital and print reading in 15-year olds is also comparable to the figure found previously for primary students at the end of fourth grade, which amounted to .76 (Voss, 2006).

Associations of digital reading proficiency with gender, immigrant status and socio-economic status

Gender. As in print reading (see OECD, 2014a), girls outperformed boys in digital reading by a margin of about 40 points on the PISA scale, M_{girls} = 509 (*SE* = 4.06), M_{boys} = 479 (*SE* = 4.35). This effect is in line with what had previously been found for countries other than Germany (see OECD, 2011a; OECD, 2014c).

Immigrant status. Again similar to the results for print reading, native students performed better than second generation immigrant students, who performed better than fist-generation immigrant students, M_{native} = 506 (*SE* = 3.77), $M_{second.gen}$ = 470 (*SE* = 6.87), $M_{first.gen}$ = 432 (*SE* = 10.65). To test these differences for significance, we regressed digital reading proficiency on immigrant status (two dummy variables with second generation immigrants as the reference group). This revealed a significant difference between second generation immigrant and native students, *b* = 36.08 (*SE* = 6.56), and between first-generation immigrant and second-generation immigrant students, *b* = -37.97 (*SE* = 11.70). Immigrant status accounted for 3% (*SE* = 0.01) of the variance in digital reading proficiency.

Socio-economic status. Digital reading proficiency was dependent on students' socio-economic status (ESCS). One unit increase in ESCS was associated with a predicted increase in digital reading scores of 32.85 (*SE* = 2.51) points on the PISA scale, explaining 10% of variance in digital reading proficiency (*SE* = 0.01). The magnitude of this effect was slightly lower than the OECD average (R^2 = .12, see OECD, 2015), and also lower than what was observed for print reading proficiency for German students (R^2 = .15, *SE* = 0.01).

Combined student background model. Taken together, gender, immigrant status, and socio-economic status explained 13% (*SE* = 0.01) of the variance in digital reading

proficiency. The regression coefficients for gender, ESCS, and being a first generation immigrant student (compared to a second generation immigrant student) did not considerably change, and remained significant (see Table 1).

Table 1 about here

The contrast depicting the difference between native and second-generation immigrant students was reduced to about one third of its original size, but remained statistically significant.

Associations of digital reading proficiency with ICT availability, use, and attitudes

In a second step, we analyzed how digital reading proficiency was associated with ICT availability at home and at school, use of ICT for entertainment, use of ICT at home for school-related work, and both negative and positive attitudes towards ICTs. Again, we first looked how each of these variables individually would be associated with digital reading proficiency, and then analyzed them in a joint model.

ICT availability. Against our expectations, ICT availability both at home and at school had significant negative associations with digital reading proficiency (ICT at home: b = -7.65, SE = 1.98, for ICT at school: b = -16.61, SE = 2.82). These negative linear trends were moderated by negative quadratic trends of b = -6.86 (SE = 0.80) for ICT at home, and b = -8.11 (SE = 1.18) for ICT at school. This meant that rather than being steeply positive in the beginning, and then flattening the association of ICT availability both at school and at home was flat at the beginning and grew more and more negative with increasing availability (see Fig. 4).

Figure 4 about here

Attitudes towards ICT. As expected, digital reading proficiency was positively predicted by positive attitudes towards ICT, although this effect was small, b = 3.71 (SE = 1.54). Corresponding to our expectations as well, digital reading proficiency was negatively predicted by negative attitudes towards ICT, b = -18.57 (SE = 1.35). These two main effects

were qualified by an interaction, which was negative as expected, b = -12.03 (SE = 1.59). The proportion of variance explained by positive and negative attitudes, including their interaction, amounted to R^2 = .07 (SE = 0.01). The interaction meant that positive attitudes had a strong positive association with digital reading proficiency in students who held low negative attitudes (-1 *SD*), b = 15.74 (SE = 2.35). In students who held high negative attitudes (+ 1 *SD*), the association between positive attitudes and digital reading proficiency was even reversed to negative, b = -8.32 (SE = 2.06). Correspondingly, negative attitudes had a particularly strong negative association with digital reading proficiency in students who held high positive attitudes (+1 *SD*), b = -30.61 (SE = 1.99). In students who held low positive attitudes (-1 *SD*), the negative association between negative attitudes and proficiency was still present, but came out weaker, b = -6.54 (SE = 2.17). These results largely corroborated our assumptions about associations between attitudes toward ICT and digital reading proficiency.

Use of ICT. As can be seen from Figure 5, all three indices of ICT use, use of ICT at home for school, use of ICT at school, and use of ICT for entertainment were non-linearly associated with digital reading proficiency.

Figure 5 about here

These non-linear (quadratic) trends were negative, meaning that the maximum model-predicted digital reading proficiency was reached for moderate levels of computer use. For use of ICT at home for school, the linear trend was not significant, b = 0.94 (SE = 2.15). The negatively sloped quadratic trend in contrast was significant, b = -8.75 (SE = 0.86). The proportion of variance explained by use of ICT at home for school was R^2 = .03 (SE = 0.01). Use of ICT at school had a significant negative linear trend, b = -12.34 (SE = 2.17), as well as a significant negative quadratic trend, b = -10.16 (SE = 1.36). The proportion of variance explained by use of ICT at school was R^2 = .03 (SE = 0.01). Use of ICT for entertainment displayed also a significant negative linear trend, b = -8.03 (SE = 1.81), as well as a

significant negative quadratic trend b = -4.97 (SE = 0.66). The proportion of variance explained by use of ICT for entertainment was R^2 = .03 (SE = 0.01).

In sum, our assumptions about the association between use of ICT and digital reading proficiency were only partly confirmed. While the expected negative quadratic trend was found for all three indicators, we failed to find the expected positive linear trends for both use of ICT at home for school and use of ICT at school. Rather, these linear trends were either non-significant, or even negative. These results are in line with findings for OECD countries other than Germany (see OECD, 2015, page 153f.).

Combined ICT model. All ICT related variables combined, including non-linear effects, explained 16% of variance in digital reading proficiency. The parameters from the combined ICT model are given in Table 1 (columns 4-5). As can be seen from this table, the negative association of digital reading proficiency with ICT availability at school was retained, but the negative association with ICT availability at home was not. The effects of positive and negative attitudes, including their interaction, largely stayed the same when ICT availability and use were controlled for. For use of ICT, the most marked change in the combined model occurred for the use of ICT at home for school. While this variable had no significant bivariate linear association with digital reading proficiency, a positive linear regression component emerged in the combined ICT model.

Joint model of ICT and student background

As a last step, we entered student background and ICT related variables in one combined regression model. This model explained 23% of variance. When comparing this combined model to model 1 (student background only), and model 2 (ICT only), the following findings emerged: The effects of student background were still all significant. Effects of immigrant status and SES remained largely the same, while the effect gender was reduced to about half its original size, which was still substantial. Regarding the ICT related predictors, effects of ICT availability and effects of positive and negative attitudes, including

their interaction, stayed largely the same. Regarding variables of ICT use, however, the positive linear effect of use of ICT at home for school, that had been found in the model combining all ICT variables, was now negligible and non-significant, while the quadratic trend was retained. The same was true for the (negative) effect of use of ICT for entertainment. The linear component of this effect was no longer significant, while the quadratic component was. All in all, ICT availability, attitudes, and use explained 10% of variance in addition to gender, immigrant status, and SES. Gender, immigrant status, and SES on the other hand explained 7% of variance in addition to ICT availability, attitudes and use. This result is inconsistent with the assumption that effects of gender, immigrant status and SES are transmitted through ICT availability, attitudes, and use.

Discussion

The present research is the first to give evidence of German 15 year-old students' proficiency in the 21st century skill of reading digital text on a large-scale basis. We found that while German 15 year-old students in print reading as of 2012 were proficient above the OECD average, they were only average, as compared to the OECD mean, in digital reading. At the same time, digital reading proficiency was only in part dependent on ICT availability and use. Especially for ICT availability, in contrast to our expectations, negative associations with digital reading proficiency were found. This runs against the idea that low digital reading proficiency is due to a lack of access to ICT. Rather, ICT might be used at school in a remedial fashion. This interpretation is in line with the finding that in model 3, where each predictor's effect was adjusted for all other predictors in the model, a negative linear component of the effect of use of ICT at school remained. This, in turn, was in contrast to use of ICT at home for school, and use of ICT for entertainment. The linear trend for both these predictors was no longer significant once both other ICT and student background variables were controlled for.

The only variables amongst those relating to ICT that had their effect not substantially reduced in the final model were students' attitudes towards ICT. Especially for negative attitudes towards ICT (uncontrollability beliefs), a substantial negative association with digital reading proficiency was retained in the final model, as was the interaction between positive and negative attitude components. In other words, the proficiency of students who thought of ICT as uncontrollable and unreliable lagged behind those students who held less negative beliefs. This was true especially when they thought ICT *could* be useful, as indicated by the significant interaction between positive and negative attitudes towards ICT: If a student did not deem ICT as potentially useful in the first place, it would not matter how controllable or not they were.

Two explanations lend themselves to this finding: First, students with more negative attitudes might be less motivated to learn with digital texts. If a person thinks the Internet is too unreliable to be used for studying anyway, they might not even bother to separate reliable from unreliable sources, or to develop good routines to make sensible judgements as to which links to follow in hypertext environments. A second explanation of course is that students who are proficient digital readers are less prone to hold negative attitudes toward ICT. A person who is in command of the skills required for digital reading – from word recognition to navigation – might perceive ICT as less uncontrollable, and more useful than a person who is overtaxed due to a lack of skill. Which direction of effects is operating here cannot be disentangled by cross-sectional data sets such as the present and must be left to future research employing longitudinal designs. Building on previous research, however, it seems likely that attitudes towards ICT and digital reading proficiency have a reciprocal relation, as has been claimed for reading engagement and print reading proficiency (see Artelt et al., 2010; Stanovich, 1986; but see Gou, Sun, Breit-Smith, Morrison, & Connor, 2015, for a cautionary note).

Effects of gender, immigrant status, and SES prevailed after availability of ICT, use of ICT, and attitudes toward ICT had been controlled for. Gender, immigrant status and SES explained an additional 7% of variance over and above what was explained by ICT related predictors, while ICT related predictors explained 10% of variance over and above what was explained by gender, immigrant status and SES. This is in contrast to what had been previously found for print reading literacy: Artelt et al. (2010) reported that effects of reading motivations and strategies had a large increment in predicting print reading literacy over and above student background variables, as compared to a relatively small increment of student background variables over and above reading motivation and strategies. Thus, in their analysis there was evidence that effects of background variables on print reading performance were transmitted through reading motivations and strategies. In our analysis, in contrast, we couldn't find clear evidence that lower SES students, or immigrant students, performed worse than their higher SES or native counterparts because of less availability, or use of ICT, or because of more negative and less positive attitudes towards ICT: Especially the effects of SES and immigrant status remained largely the same between models 1 and 3.

If digital reading proficiency in German students is only to a small extent explained by their ICT availability and use, and e.g. discrepancies between immigrant and native students are explained only to a small extent by variables of ICT attitudes, availability, and use, the question stands what the present analysis has missed. One notable point certainly is that we had no measures included of students' strategies in digital reading (other than Artelt et al., 2010, who had measured reading strategies). In this vein, recent results obtained on PISA 2009 digital reading data from countries other than Germany showed that digital reading performance was strongly predicted by measures of strategic navigation behavior. At the same time, these indicators transmitted effects of immigrant status and social background almost completely (Naumann, Elson, & Rauch, 2016).

Taken altogether, the present findings thus suggest the following. While German students' print reading proficiency has advanced from being below the OECD average in 2000 to above OECD average in 2012 (OECD, 2014a), their digital reading proficiency lags behind. Most likely however, this is not due to lack of ICT availability. Also, when students use ICT in their homes or at school, it is not to the benefit of their digital reading proficiency. Rather, it might be that German students are not sufficiently in command of specific skills which are required for reading digital texts to excel in digital reading, such as knowledge of appropriate cues for source evaluation. One reason for this might be that German teachers, according to ICILS results, make only very limited use of technology to the end of teaching these specific skills (see Eickelmann et al., 2014; see also section "Digital reading proficiency" above). Future instructional research and development might thus address the question of how teaching of these skills could be integrated into German school curricula.

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Table 1

Regression of digital reading performance on student background and ICT availability, attitudes, and use

	Model 1		Model 2		Model 3	
Student background	*B*	(*SE*)	*b*	(*SE*)	*b*	(*SE*)
Intercept	469.90	(6.92)	522.69	(4.17)	499.03	(6.42)
Gender (boys = 0)	29.45	(2.74)			15.86	(3.09)
Immigration: 2nd vs. native	-39.09	(10.67)			-29.03	(9.18)
Immigration: 2nd vs. 1st	12.46	(6.69)			11.54	(6.25)
SES	31.26	(2.64)			25.08	(2.47)
ICT availability [a]						
ICT availability at home			*-3.33*	(2.04)	-7.60	(1.99)
ICT availability at home^2			-3.54	(0.94)	-2.91	(0.84)
ICT availability at school			-10.02	(2.66)	-7.83	(2.51)
ICT availability at school^2			-3.54	(1.11)	-2.59	(1.15)
ICT attitudes [a]						
Positive attitudes			3.80	(1.63)	4.43	(1.58)
Negative attitudes			-16.01	(1.34)	-13.82	(1.16)
Pos. attitudes × neg. attitudes			-6.99	(1.39)	-5.92	(1.33)
ICT use [a]						
Use of ICT at home for school			10.16	(2.41)	*3.27*	(2.38)
Use of ICT at home for school^2			-2.90	(1.17)	-3.01	(1.13)
Use of ICT at school			-8.07	(1.90)	-5.73	(1.89)
Use of ICT at school^2			-5.54	(1.41)	-4.33	(1.32)
Use of ICT for entertainment			-7.01	(1.91)	*-3.71*	(2.00)
Use of ICT for entertainment^2			-1.89	(0.66)	-2.16	(0.66)
R^2 (*SE*)	.13 (0.01)		.16 (0.02)		.23 (0.02)	

Note. Non-significant ($p > .05$) coefficients are printed in italics. See text for bivariate associations of digital reading proficiency with each predictor variable.

[a] *z*-standardized variables.

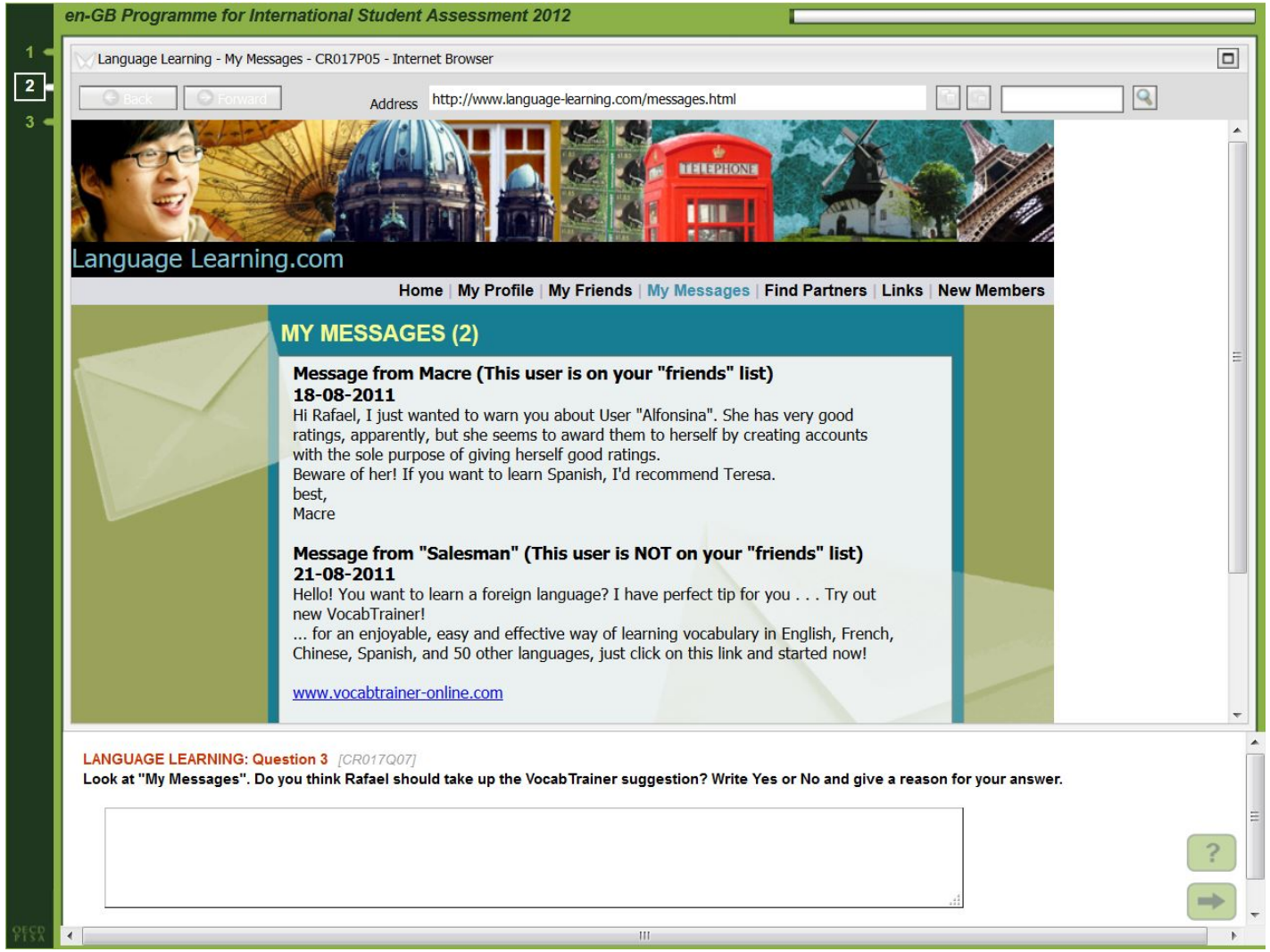

Figure 1: Sample digital reading item CR017Q01.

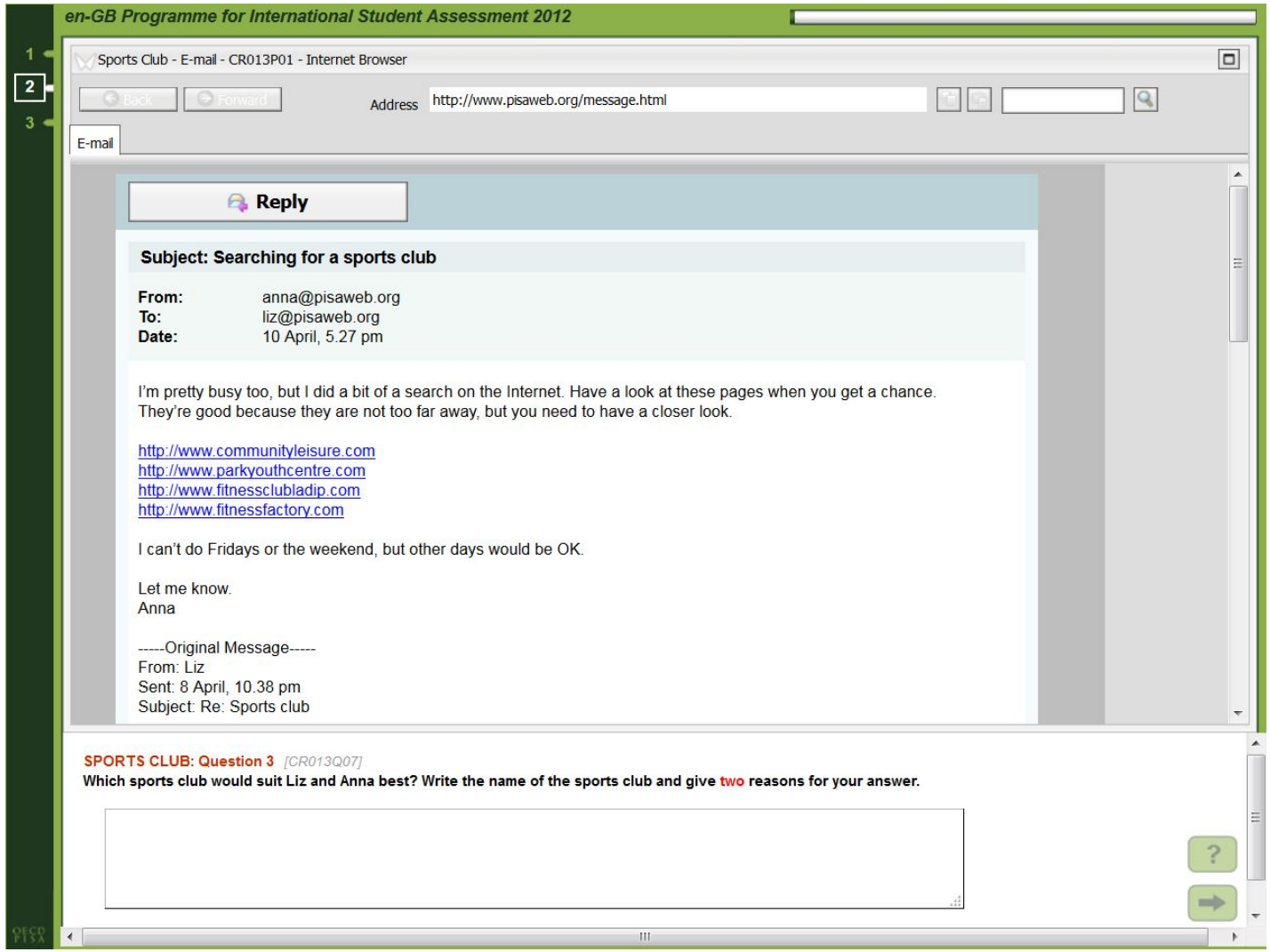

Figure 2: Sample digital reading item CR013Q07.

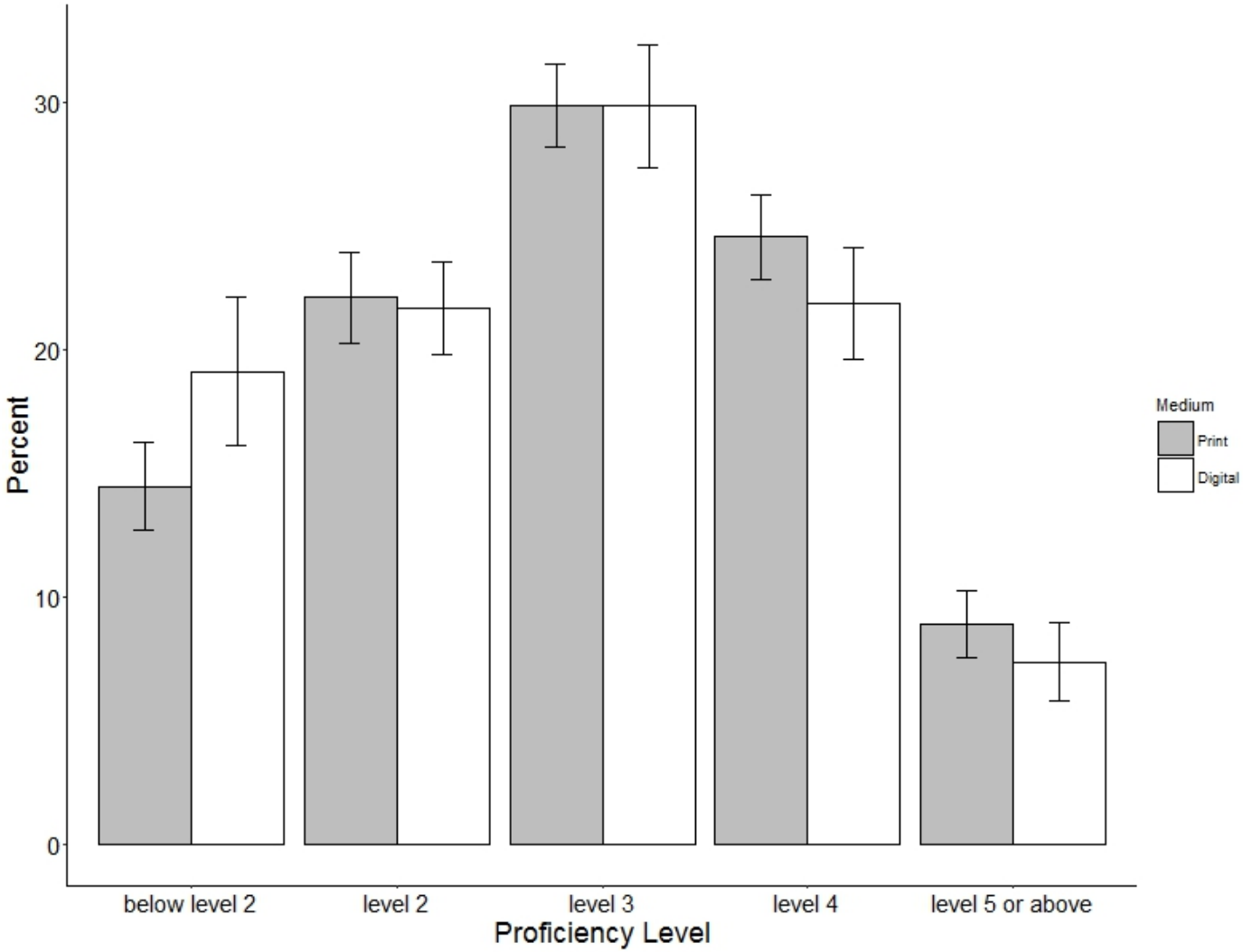

Figure 3 Distribution of students across proficiency levels in print and digital reading proficiency. Errorbars indicate 95% confidence intervals. Because of the low number of digital reading items covering the upper and lower ends of the proficiency distribution, proficiency levels below 1b, 1b, and 1a are collapsed into below level 2, and proficiency levels 5, 6, and above 6 are collapsed into level 5 or above.

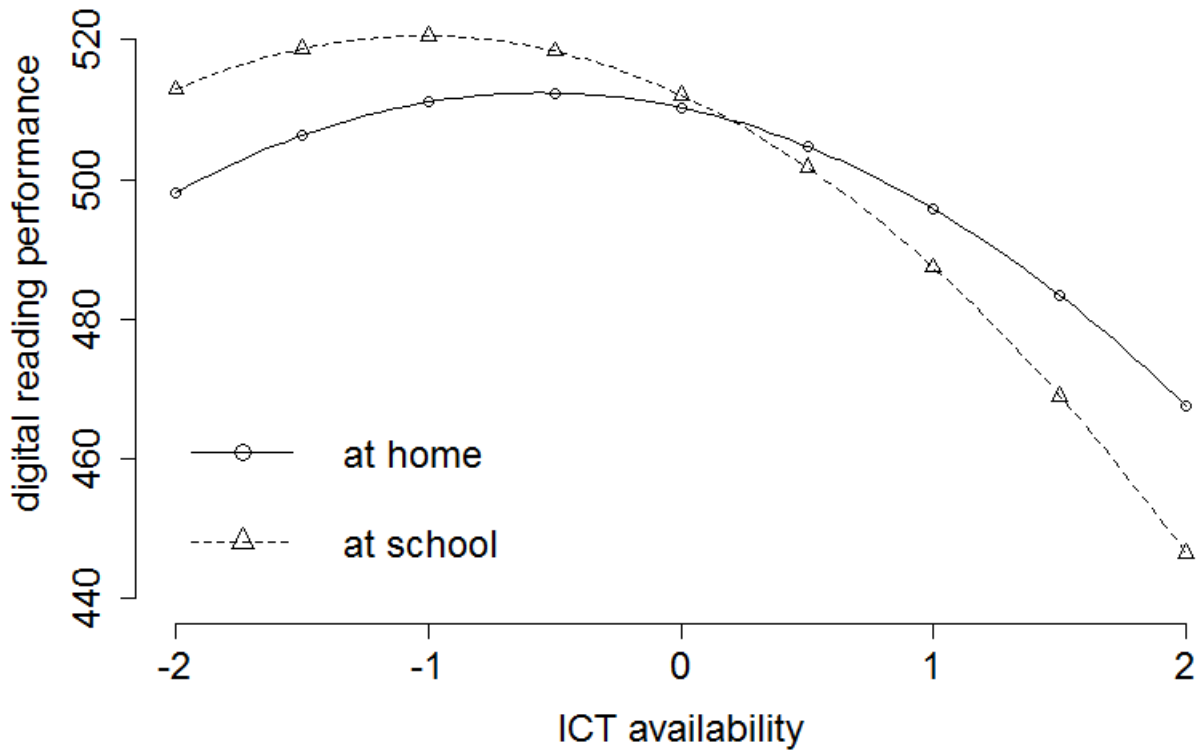

Figure 4: Bivariate association of three measures of ICT availability with digital reading proficiency. See text for regression coefficients of each the linear and the quadratic components as well as proportions of variance explained.

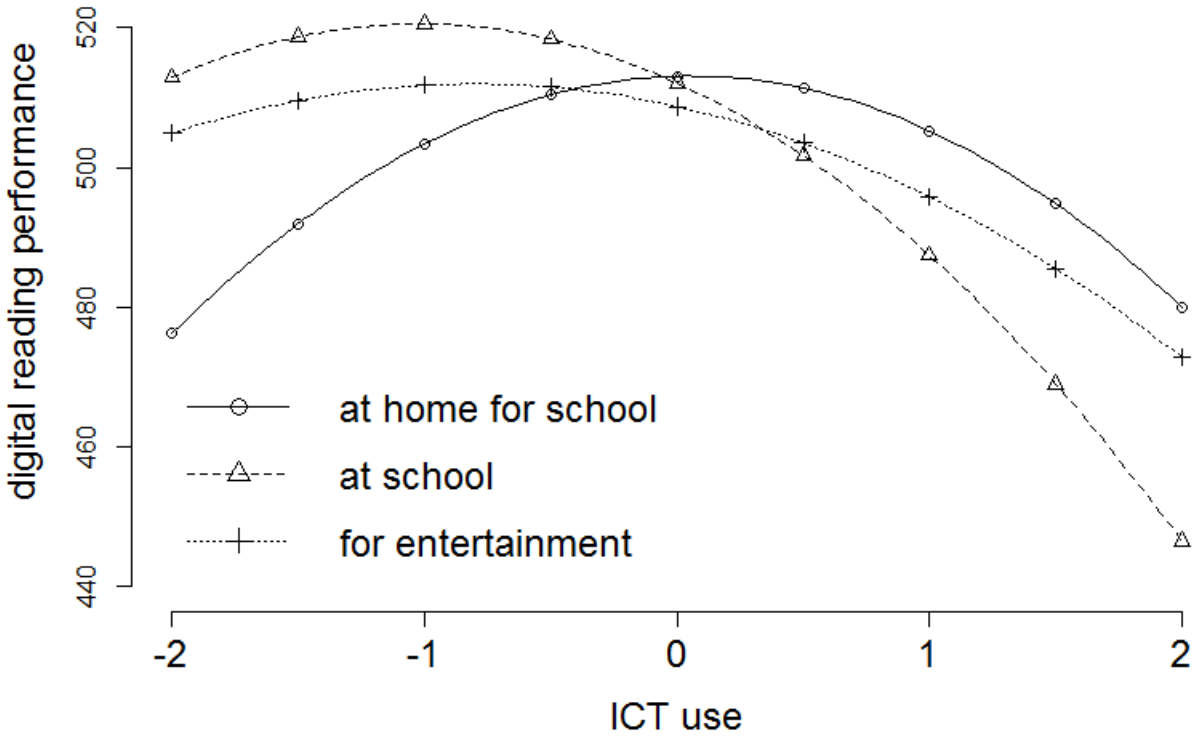

Figure 5: Bivariate association of three measures of ICT use with digital reading proficiency. See text for regression coefficients of each the linear and the quadratic components as well as proportions of variance explained.