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Factors related to digital reading achievement: A multi-level analysis using international large scale data

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ABSTRACT

This study aimed to examine which relevant variables were associated with adolescents' digital reading achievement using the Programme for International Student Assessment (PISA) 2009 dataset. A three-level hierarchical linear model was employed to identify significant factors predicting digital reading, controlling for print reading ability, and to examine if the extent of the association remained the same across schools and countries. The results confirmed the importance of navigation, metacognitive summary strategies, attitudes toward ICT, and social online reading activities. Female students, on average, underperformed male students when controlling for other variables. However, the associations between these factors and digital reading varied across schools and countries. Navigation appeared universally predictive in digital reading according to the results of the multilevel models.

1. Introduction

Much attention has been given to the concept of digital reading literacy in the age of information and communication technology (ICT). Knowledge of and skills in relation to Internet use are essential in today's academic, social, and career contexts (Naumann, 2015). In 2012, approximately 96% of 15-year-old students in OECD countries had a computer at home (OECD, 2015), Internet accessibility in schools has been widely expanded and websites containing a variety of information are seen as increasingly important reading resources (Rasmusson, 2016; Rouet & Le Bigot, 2007). In contemporary society, technological changes often require reading and writing through digital devices, rather than through traditional oral communication (e.g. in making appointments, asking for information, etc.) (OECD, 2016a). Therefore, students need to develop new skills to access the many activities using electronic books, textbooks, and reading materials on the web. Adolescents are often considered to be competent in reading media-text and electronic text-messages (Alvermann, 2001; Smith & Wilhelm, 2004). Pitcher et al. (2007) once interviewed students from grades 6 to 12 and found that most reported using computers at home and regularly sending e-mails and instant text messages to their friends and family members. Thus, almost all students perceived digital literacy as a necessity for communication and information gathering for both personal and academic purposes.

Digital reading literacy is not only related to print reading skills but is more often related to reading online materials, which involves understanding ICT and employing various ICT skills (Costa & Araújo, 2016). Having a positive attitude and confidence in using ICT devices, for example, helps students to attain digital reading proficiency (Lee & Wu, 2012; Naumann & Sälzer, 2017).

Thus, the present study focused on characteristics relating to adolescents' digital reading in PISA (Programme for International

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Student Assessment) 2009. Prior studies in digital reading using an international dataset were limited in some senses, because they usually analyzed samples from a single country (e.g., Cheung, Mak, & Sit, 2013; Gil-Flores, Torres-Gordillo, & Perera-Rodríguez, 2012; Hahnel, Goldhammer, Naumann, & Kröhne, 2016; Rasmusson, 2016), although a few researchers dealt with multiple countries (e.g. Lee & Wu, 2012; Naumann, 2015). The present study can complement prior research by identifying key factors that are uniquely relevant to digital reading such as navigation and attitudes to ICT, and examine whether such associations between these factors and digital reading remain the same across schools and countries under the multilevel framework, after print reading was taken into account.

2. Theoretical framework

2.1. Print and digital reading performance

Nowadays, the concept of reading literacy includes both print and digital reading (OECD, 2011). Digital reading literacy is relatively new but more important because demands and opportunities for reading electronic or online texts have increased over the years (Coiro, 2003; Rasmusson, 2016; Reinking, 1994; Rouet, 2006). Digital and/or online reading, typically reading on the web, has become more important as it allows students to access and retrieve relevant information for learning (Mangen & van der Weel, 2016). Students might also read for the purpose of social communication as they are involved in reading and writing e-mails, text messaging, blogs and social media (OECD, 2010). Traditionally, reading literacy has been defined as "understanding, using, reflecting on and engaging with written texts, in order to achieve one's goals, to develop one's knowledge and potential" (OECD, 2010, p. 23). The OECD (2010) particularly focuses on the role of written texts, and they proposed that reading literacy consists of "… all [the] coherent texts in which language is used in its graphic form: hand-written, printed and electronic" (p. 24). However, as Rasmusson (2016) saw digital reading as "… *unique* abilities represented by the nested digital reading factor when *overall reading is accounted for* …" (p. 21), we intentionally focused on specific reading competencies that require accessing, comprehending, assessing, and integrating digital texts in a variety of contexts in the present study.

Print reading and digital reading share many commonalities in cognitive operations such as decoding, interpreting nuances of language, and sentence integration. Leu, Kinzer, Coiro, and Cammack (2004) summarized the skills of digital reading into identifying important questions, locating, evaluating, synthesizing and communicating information. As many of these are the same cognitive processes involved in print reading (Costa & Araújo, 2016), a significant amount of the variation in digital reading performance can be predicted by print reading ability (OECD, 2015).

However, one of the important features in reading digital texts is that one needs to deal with their nonlinearity (Coiro, Castek, & Guzniczak, 2011), which often includes hypertext structures (e.g. embedded links to other texts, oft). Nonlinear, hypertext reading usually demands more cognitive load (DeStefano & LeFevre, 2007) because readers are required to create their own structures that fit their reading purposes and reconfigure the organization of the texts. Digital texts also often contain multi-modal forms combining text, static images, animations and so forth. Walsh, Asha, and Sprainger (2007) explained that in printed texts, readers get information linearly and sequentially while in digital texts they select and omit specific information based on the content they need. Therefore, critical thinking to evaluate the source of information is undoubtedly more important in digital reading than print reading. There are fewer cues (e.g. what the textbooks look like and where cues are found) and human filters/mediators (e.g. librarians, booksellers or critics) in digital reading, and readers need to rely on their own reasoning to reflect on and evaluate the credibility of the text (Britt & Gabrys, 2001). In other words, it is important for digital readers to assess the credibility of sources and predict the suitability of content from a series of screens and displays based on hints (e.g. the name of a link, surrounding text, URL) (OECD, 2015). This view is supported by Strømsø, Bråten, and Samuelstuen (2008) who also maintain that reading on the web with multiple sources requires skills such as being able to judge sources and make mental representations of the structure and content of a website.

2.2. Characteristics associated with digital reading

2.2.1. Gender and SES

Girls are known to be more proficient and engaged readers than boys and evidence of them outperforming boys has been reported in many studies (Chiu & McBride-Chang, 2006; Lynn & Mikk, 2009; Mullis, Martin, Gonzalez, & Kennedy, 2003; Mullis, Martin, Kennedy, & Foy, 2007; Ogle et al., 2003). The OECD (2011) reported that the gender gap favoring girls was narrower in digital reading assessment than print reading across all participating countries and economies, however. Some regional studies have attempted to explain factors related to gender difference in digital reading (e.g., Cheung et al., 2013; Liu & Huang, 2008) revealing that gender difference was moderated by several factors such as medium preference, engagement in online reading activities, and ICT use at home. Researchers often connect this gender disparity in print reading with the socialization process around gender identity. That is, male students tend to reject reading in school as they often perceive the activity as inappropriate and contrary to their masculinity (Warrington, Younger, & Williams, 2000). Such avoidance of reading, however, may be resolved when boys participate in specific types of reading such as reading via the Internet accompanied with social activities (Smith & Wilhelm, 2004). In the same vein, Tveit and Mangen (2014) interviewed Swedish adolescents in their study and noted that boys showed strong preference for reading on an e-book device compared to reading a paper book. Rasmusson and Åberg-Bengtsson (2015) also analyzed digital reading achievement in a Swedish sample and found that boys even outperformed girls when overall reading ability was accounted for.

SES is another important factor that affects students' literacy development. Students from lower-SES families consistently demonstrate poorer reading abilities than students from higher-SES counterparts (Fernald, Marchman, & Weisleder, 2013; Mullis et al.,

2003; Rowe, 2008). Researchers (e.g. Yang & Gustafsson, 2004; Yang, Hansen, & Munck, 2012) have concentrated on a multi-dimensional nature of SES background, not merely considering measures such as income and parental occupation. For example, Yang (2003) contends that not only economic but cultural capital factors which are related to social well-being have impacted students' achievement across countries. Rasmusson (2016) also identifies economic capital and cultural capital to predict reading scores. Her results showed that economic capital significantly explained the overall reading score (but not digital reading score) for Swedish students.

2.2.2. ICT-related variables

First, attitudes toward ICT and various online-based activities also have significantly impacted digital literacy (Kim, 2012; Lee & Wu, 2012). Attitude usually describes how individuals feel about an activity and how they approach or avoid it. Therefore, the more positive attitude toward digital reading students have, the more likely they are to engage in activities related to it. Lee and Wu (2012) found that the internal state regarding ICT (e.g. attitude toward computers and confidence in high-level ICT tasks) a student had significantly predicted digital reading interest, mediated by online reading activities. In studying the relationship between reading ability and ICT use, Collins, Onwuebuzie, and Jiao's (2008) study also confirmed this result by demonstrating that low-achieving students were less likely to access resources in computer-based activities and had negative attitudes toward computers compared to their high-achieving peers. Later, Luu and Freeman (2011) reported that Canadian and Australian students who had more ICT experiences and had done more activities were more likely to have confidence in using computers and the internet, which in turn, improved their scientific literacy scores. Naumann and Sälzer (2017) further demonstrated that students who had more negative attitudes (e.g. 'perceiving ICT as an uncontrollable and unreliable entity') scored lower in digital reading proficiency than those who had less negative attitudes.

Second, in a digital environment, reading activities are behaviors related to searching for information and social interaction (McKenna, Conradi, Lawrence, Jang, & Meyer, 2012; Naumann, 2015). Activities such as reading online news, using online encyclopedias and/or dictionaries, and using the Internet in order to search for a particular topic or practical information ("information-searching activities", hereafter) are usually associated with academic work, which directly and indirectly leads to higher literacy scores both for overall and digital assessment (Lee & Wu, 2012; OECD, 2011). On the contrary, activities such as participating in social networks, using e-mail and/or messenger services, and playing collaborative games ("social interaction activities", hereafter) have been reported to negatively predict academic achievement or reading performance (e.g. Jacobsen & Forste, 2011). Naumann (2015) finds that social interaction activities are often performed in a playful way, which in turn sacrifices studying or working time for academic purposes. It seems reasonable to say that different kinds of digital reading activities play distinctive roles in reading skill. However, Gil-Flores et al. (2012) found that online reading experience for 'both' academic and social purposes positively predicted digital reading ability for Spanish students, although academic experience was shown to be more relevant than social experience.

2.2.3. Metacognition and navigation

Strategic reading needs self-regulatory processes which entails cognitive skills (e.g. elaboration, control, organization), and metacognitive skills of how and when to use such strategies for reading texts (Schmar-Dobler, 2003). Metacognition in reading involves regulation of one's own reading (Veenman, van Hout-Wolters, & Afflerbach, 2006) such as planning, regulating, monitoring and evaluating reading processes. Research into print and digital reading assessment has focused on the differences in reading strategies depending on the modality of reading (Leu et al., 2007). Coiro et al. (2011) noted that students' strategies in searching, selecting, approaching, and responding to digital texts were quite different from those of written texts. Reading of hypertext or multiple-texts, for example, requires linking and relating information located in a diverse reading environment (Afflerbach & Cho, 2008). Schmar-Dobler (2003) also emphasized the importance of digital reading strategies such as skimming, scanning, figuring out features of the Internet (e.g. pop-up ads, downloading). Cho (2014) further identifies several strategies from Internet readers such as text location, meaning-making, self-monitoring, and information evaluating.

Navigating with the intention to access and evaluate online sources can be considered a strategy in digital reading (Salmerón & García, 2011; Salmerón, Kintsch, & Kintsch, 2010). Navigation is usually defined as a reader's mental movement in the correct direction over the screens of the hypertext page (Lawless & Schrader, 2008). Different from print reading, students' navigation behavior in digital text can be measured by tracking and scrolling behavior, often with visiting several pages or sites (OECD, 2015). This reflects how readers locate parts of digital texts and organize them to gain appropriate information in order to construct their own text by selecting and sequencing pages (Hahnel et al., 2016; Salmerón, Cañas, Kintsch, & Fajardo, 2005; Salmeron et al., 2010). Several researchers draw considerable attention to navigation in reading hypertexts (e.g. Rasmusson & Eklund, 2013; Rouet & Le Bigot, 2007). For instance, Naumann, Richter, Christmann, and Groeben (2008) pointed out that reading digital texts was clearly dependent upon visual-spatial abilities, in addition to text processing abilities. They focused on the specific skill that allows readers to open, layout, and close multiple displays depending on the credibility and usefulness of the information.

Navigation is also based on the ability to integrate and evaluate texts, partly explained by higher comprehension skill. However, due to easy access to cross-referenced texts, digital readers can integrate different pieces of texts in order to compile different sources on any given topic. Aggregating necessary information from multiple passages (and webpages), therefore, becomes more usual in reading digital texts. Hahnel et al. (2016) demonstrated that navigation mediated significantly between ICT knowledge and skills and digital reading performance among German students. In addition, the effect of navigation on digital reading can be moderated by print reading comprehension. For example, the OECD (2011, 2015) showed that students' higher print reading scores were highly correlated with more efficient and effective navigation strategies, which in turn improved digital reading scores. Naumann and

Salmerón (2016) also demonstrated that this kind of moderation effect was significant only for students with higher reading comprehension ability.

2.2.4. School climate and extra-curricular activities

School climates that are conducive to learning are related to a low frequency of problematic behavior (e.g. absenteeism, disruption of classes, and lack of respect for teachers) and high academic performance. Cho et al. (2011) analyzed the effect of a student-induced disciplinary climate and found that this variable in Asian countries (Korea, Shanghai, Singapore, and Japan) collectively predicted reading achievement. Lim and Jung (2014) also found a significant impact of school disciplinary climate measured by students' problematic behavior on digital reading scores. Their results clearly demonstrated a positive connection between low levels of negative school climate and students' digital reading performance.

Since student academic development can be influenced by a variety of extracurricular activities (Eccles & Gootman, 2002; Schreiber & Chambers, 2002), involvement in them serves as a valuable learning opportunity to facilitate digital reading as well. Feldman and Matjasko (2005) reviewed the studies of school-based extracurricular activities and concluded that participation in most of these activities had positive outcomes for adolescents. Provision of reading-related activities (e.g. creative writing, school newspapers, drama and plays) can help increase student motivation to read, which in turn may enhance their achievement.

3. Research questions

This study aims to identify key factors that are associated with digital reading across schools and countries with international large scale data. Based on three-level hierarchical linear models, our intention was to explore if and to what extent student background, ICT-related variables, metacognition and navigation predicted digital reading performance, and whether the associations varied across schools and countries. Because we wanted to focus on the unique variance of digital reading ability, we first examined the overall relationship between digital and print reading achievement. Then we investigated factors predicting digital reading, controlling for print reading ability (measured by paper-and-pencil reading achievement in PISA 2009) for the entire analyses, as done in previous studies (Rasmusson, 2016; Rasmusson & Åberg-Bengtsson, 2015). Specifically, the following research questions were addressed in this study:

1. Do gender and SES differences exist after controlling for other variables in digital reading and, if so, to what extent?
2. Are students' ICT attitudes (e.g. positive attitudes toward computers and ICT confidence) and online engagement (e.g. information-seeking and social interaction) significantly predictive of digital reading?
3. Is student metacognition in reading and navigation positively associated with digital reading when controlling for other variables?
4. Are variables related to school climate and school activities associated with students' digital reading performance after controlling for student-level variables?

4. Methods

4.1. Data and variables

This study used the PISA 2009 data for analysis. The PISA is a triennial survey and assesses key competences of 15-year-old students in reading, mathematics, and science across OECD countries and partner countries (OECD, 2011). With a 9 year cycle, reading was the major domain in 2009, which measured reading ability in digital texts for the first time, along with responses from students' reading engagement and metacognitive strategies (OECD, 2011). Although digital reading assessment (DRA) was conducted in recent cycles, this study focused on PISA 2009, because reading was a minor domain in PISA 2012 and 2015. The framework in those years had not been changed from PISA 2009, and information regarding reading engagement and metacognition was not collected in the 2012 and 2015 cycles (OECD, 2013, p. 60; OECD, 2016b, p. 164).

DRA consisted of nine units with a total of 29 items, and required about 60 min to complete the exam. Each unit had up to 4 items based on a stimulus comprising digital texts such as websites, e-mails, or blogs (OECD, 2011; 2012). With respect to test design, three item clusters were constructed to create test booklets, and by rotating two pairs of clusters, one of six test forms was randomly assigned to sampled students.

A subset of sampled students for the print reading assessment (PRA) was designed for participation in DRA, and the required sample size per sampled school was 14 students in PISA 2009. The actual number of students participating in the DRA varied across countries, ranging between 960 and 3429 (see OECD (2011), p. 245 for further details). Given that individual students were assigned to different test booklets and only a subset of students in PRA took the DRA, five plausible values (PVs) were used as outcome measures, which were generated from the posterior distributions of scaled scores based on students' responses to test items. These unique sampling and test design methods in the PISA assessment framework enable inferences to be drawn about abilities in digital reading and print reading for all sampled students in print reading (see OECD (2012), p. 354 and p. 186 for detailed sample sizes for print and digital assessment, respectively). Usage of PVs in data analysis can address the error variance of parameter estimation due to the usage of a subsample and different assessment booklets (OECD, 2012, p. 194). The DRA score was standardized with a mean of 499 and a standard deviation (SD) of 90 so that the print reading results were comparable to the digital reading results (OECD, 2011, p. 51).

This study focused on 15 countries which participated in both DRA and ICT questionnaires (Australia, Austria, Belgium, Chile,

Table 1
Key student- and school-level variables of interest.

	Variable	Description
Student-level	PRA scores	Print reading assessment scores
	Gender	Female = 1; male = 0
	ESCS	PISA index of economic, social and cultural status
	ATTCOMP	Attitudes toward computers
	HIGHCONF	Self-confidence in high-level ICT tasks
	ONLNREAD1	Online reading activities: online searching- information activities
	ONLNREAD2	Online reading activities: online social activities (e.g. chatting or reading emails or news)
	METASUM	Metacognition strategies: summarizing
	UNDREM	Metacognition strategies: understanding and remembering
	Navigation	Number of relevant pages visited
School-level	EXCURACT	Extra-curricular activities offered by the school (e.g. book club, debating club, etc.)
	STUDBEHA	Student-related aspects of school disciplinary climate (e.g. absenteeism, disruption of classes, etc.)

Denmark, Iceland, Ireland, Hungary, Japan, Korea, New Zealand, Norway, Poland, Spain, and Sweden). Building upon the literature review and preliminary analysis, Table 1 provides a brief description of the student- and school-variables of interest that were examined in the study (see the descriptive statistics by country in the online supplementary file). In terms of scales of independent variables, all variables except print reading, gender and navigation were z-standardized with a mean of 0 and an SD of 1.

In particular, students' navigation behaviors in PISA 2009 were operationalized by counting the pages students actually visited to complete certain tasks in DRA (OECD, 2011). PISA 2009 provided three indicators related to students' navigation behaviors in a separate data file - number of page visits, number of visits to relevant pages, and number of relevant pages visited. The number of visits to relevant pages and the number of relevant pages visited captured slightly different navigation behaviors of students. The former measures the frequency of which students accessed pages having task-relevant information (regardless of revisits) and it captured the intensity of students' task-related navigation activities. The latter counted the number of all task-relevant pages visited as a whole, so that if a student revisited the same page, it was not counted. Because the number of relevant pages visited was the most relevant factor in relation to digital reading among the three indices (the correlation ranged from 0.68 to 0.86 across countries in the OECD (2011, p. 261)), we used the variable named UN I_REL _PAGES_SO_C for the following analyses. Due to PISA's rotation system where students respond to parts of the PISA units and items, PISA 2009 provided centered navigation indices at the student-level to account for the test design effects. These were centered on the respective index mean for each test administered, and the respective index mean for each country (see OECD (2011) for the details, p. 228).

4.2. Analysis methods

Prior to the outcome analysis, we imputed missing values in each variable of interest based on a multiple imputation method to keep the original sample and assure the representativeness of the target population of 15 years for students in each country (the missing rates ranged between 1.0% and 5.6% for the student variables, and between 0% and 13.7% for the school variables in Table 1). Five sets of imputed data were generated via SAS MI procedures based on an EM algorithm for each country (SAS Institute Inc, 2015). Once completed data sets were constructed, standard data analyses were employed within each data set, and analysis results were combined based on the formula provided by Little and Rubin (2002). Statistical significance was determined based on a standard normal z distribution with an alpha level of 0.05 using the arithmetic average of the imputation specific estimates (Enders, 2017).

We employed three-level hierarchical models for data analyses (Raudenbush & Bryk, 2002). For data analysis, the HLM 6.1 program was used. Multilevel modeling can easily incorporate the PISA sampling design in analyses which, in turn, yields valid standard errors addressing the dependence among the samples within the same school and same country. Because this study is not for cross-cultural comparison, issues related to measurement invariance appeared less problematic, although one study informed a moderate measurement in-equivalence in academic scores in PISA 2009 across countries (Kankaraš & Moors, 2014).

Model 1 presents a three-level basic model without predictors:

$$Y_{ijk} = \gamma_{000} + u_{00k} + r_{0jk} + e_{ijk}, \quad (1)$$

where Y_{ijk} denotes the achievement score of student i in school j and country k; e_{ijk} is a random student effect, assuming the normal distribution with a mean of 0 and variance σ^2; r_{0jk} *is* a random school effect, assuming the normal distribution with a mean of 0 and variance τ_s; and u_{00k} is a random country effect (the deviation of country k's mean from the grand mean, γ_{000}), assuming the normal distribution with a mean of 0 and variance τ_c. Using Model 1 with no predictors, intraclass correlations were computed to find the proportion of variance with the multilevel data structure (Hedges, Hedberg, & Kuyper, 2012). That is, we can partition the variance of digital reading Y_{ijk} into three components: student-, school- and country-levels.

Model 2 included print reading as a predictor at the student level. The level-1 model was:

$$Y_{ijk} = \pi_{0jk} + \pi_{1jk} PRA_{ijk} + e_{ijk} \quad (2\text{–}1)$$

where π_{0jk} is the intercept for school j in country k; π_{1jk} is the coefficient of print reading that presents the strength of relation between

Table 2
Prediction of key variables on digital reading at three-level hierarchical models.

Fixed effect	Model 1	Model 2	Model 3	Model 4
	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)
Intercept	***483.08*** (11.97)	***482.41*** (12.40)	***482.28*** (12.43)	***499.49*** (6.19)
EXCURACT				−0.93 (0.81)
STUDBEHA				1.01 (1.25)
Print reading		***0.81*** (0.02)	***0.78*** (0.02)	***0.78*** (0.02)
Female			***−5.53*** (1.71)	***−5.46*** (1.70)
ESCS			0.96 (0.71)	*1.16(0.72)*
ATTCOMP			***3.23*** (0.44)	***3.19*** (0.44)
HIGHCONF			***3.38*** (0.59)	***3.40*** (0.59)
ONREAD1			*1.44* (0.76)	*1.44(0.74)*
ONREAD2			***6.33*** (0.60)	***6.35*** (0.62)
METASUM			***3.77*** (0.86)	***3.82*** (0.92)
UNDREM			***1.51*** (0.54)	***1.57*** (0.55)
Random effect	*Variance component (SD)*			
Level-1 Error	***5324.38*** (72.97)	***1595.13*** (39.94)	***1332.92*** (36.51)	***1335.26*** (36.54)
Level-2				
Intercept	***3437.30*** (58.63)	***3744.48*** (61.19)	***3770.15*** (61.40)	***753.57*** (27.45)
Print reading		***0.01*** (0.08)	***0.01*** (0.10)	***0.01*** (0.10)
Female			***80.04*** (8.95)	***81.66*** (9.04)
ESCS			***33.15*** (5.76)	***31.59*** (5.62)
ATTCOMP			***15.50*** (3.94)	***15.19*** (3.90)
HIGHCONF			***23.99*** (4.90)	***23.45*** (4.84)
ONREAD1			***38.47*** (6.20)	***38.21*** (6.18)
ONREAD2			***66.76*** (8.17)	***65.97*** (8.12)
METASUM			***25.26*** (5.03)	***25.18*** (5.02)
UNDREM			***19.85*** (4.46)	***20.30*** (4.51)
Level-3				
Intercept	***2148.73*** (46.35)	***2286.87*** (47.82)	***2296.42*** (47.92)	***567.05*** (23.81)
EXCURACT				4.61 (2.15)
STUDBEHA				***15.70*** (3.96)
Print reading		***0.01*** (0.08)	***0.01*** (0.10)	***0.01*** (0.10)
Female			***39.60*** (6.29)	***38.91*** (6.24)
ESCS			***6.22*** (2.49)	***6.27*** (2.50)
ATTCOMP			***2.06*** (1.44)	***2.17*** (1.47)
HIGHCONF			***3.57*** (1.89)	***3.55*** (1.88)
ONREAD1			***6.59*** (2.57)	***6.15*** (2.48)
ONREAD2			***2.56*** (1.60)	***2.85*** (1.69)
METASUM			***10.71*** (3.27)	***10.59*** (3.25)
UNDREM			***3.50*** (1.89)	***3.78*** (1.94)

Bold italic cases: $p < .05$.
Note. The level-1 variables in Models 1 to 3 were group-mean centered and the variables in Model 4 were grand-mean centered at both level-1 and level-2.

PRA and DRA in school *jk*.

The level-2 model with no school-level predictors, then, can be expressed as follows:

$$\pi_{0jk} = \beta_{00k} + r_{0jk}, \tag{2–2}$$

$$\pi_{1jk} = \beta_{10k} + r_{1jk}, \tag{2–3}$$

where β_{00k} and β_{10k} are the intercept and the slope for country k, respectively; and r_{0jk} and r_{1jk} are level-2 random effects.

The level-3 model with no predictors is further expressed as:

$$\beta_{00k} = \gamma_{000} + u_{00k}, \tag{2–4}$$

$$\beta_{10k} = \gamma_{100} + u_{10k}, \tag{2–5}$$

where γ_{000} and γ_{100} are the grand means of the intercept and the slope parameters, respectively; and u_{00k} and u_{10k} are random effects at the country-level.

Group-mean centering (centering on a level-2 mean) was used in Model 2, so that the parameter at level-1 captures the associations between student characteristics and digital reading within each school (i.e., the pooled-within-school relationship) (Raudenbush & Bryk, 2002; Enders & Tofighi, 2007). Model 3 expanded Model 2 by including the other student-level variables in Table 2 in addition to the print reading variable. In Model 4, we added school-level variables of interest. To investigate the

associations between school-level variables and digital reading after controlling for level-1 covariates, we used grand-mean centering, with the result that π_{0jk} represents an adjusted mean of school j in country k (Enders & Tofighi, 2007).

Additionally, based on the estimates of random effects (τ_s), we can compute a possible range of plausible values for the slopes of student variables among schools within a country. For example, in terms of the print reading slope in Equation (2-1), a plausible value range can be produced with the following interval formula (Raudenbush & Bryk, 2002, p. 78) which has a 95% confidence level:

$$\hat{\beta}_{10k} \pm 1.96(\hat{\tau}_{11k})^{1/2}, \quad (3)$$

This is one useful way to inform variability of the association between a student-variable of interest and an outcome measure at the school-level.

Lastly, note that the sample sizes used for analyses in Models 1–4, covering the full sampled data, are the same as the ones used in the OECD report provided (OECD, 2012, p. 354). The analysis in Model 5 however, which focuses on the association between the navigation variable and DRA, used different data with only a subset of students who actually participated in DRA and thus provides information about navigation behaviors.

5. Results

Based on Model 1 with no predictors, the variance of digital reading was partitioned into student-, school-, and country-levels. Using the variance components in Table 1, the proportion of variance among schools within a country out of the total variance was about 31.5%, and the proportion of variance among countries was 19.7%. In other words, about 50% of the variance in digital reading, on average, occurs at the student-level within schools.

The regression coefficient of print reading on digital reading in Model 2 was 0.81, showing a significant positive association such that with a 1 point increase in print reading, digital reading is expected to increase about 0.81 of a point. By comparing the level-1 random effects between Model 1 and Model 2, the amount of variance explained by print reading at the student-level was substantially large with about 70 percent. The random effects of print reading at level-2 and level-3 in Model 2 were both about 0.01. With relatively small variance at both school and country levels, we can infer print reading is universally strongly associated with digital reading.

Next, we investigated how the variables of interest were predictive for digital reading when controlled for print reading. When the student-level variables were included in Model 3 as a whole, about 16.4% of variance was further explained in comparison to the results of Model 2 with a predictor of print reading only. In the following, fixed and random effects are reported for the added student variables (results of Model 3 in Table 2).

Gender & SES. According to the results of Model 3, female students tend to score about 5.5 points lower, on average, than male students after conditioning for other student variables. This implies that among those with the same score for print reading and the same level for other factors included in Model 3, female students underperformed in digital reading compared to male students. With respect to the random effects at level 2, under the normal distribution assumption, the parameter estimate of gender variable was distributed with a mean of −5.53 and an SD of 8.95 across schools within the same country. It also varied across countries with an SD of 6.29 at the country level, indicating that the 95% coverage interval for the gender variable lies between −17.86 and 6.79. The coefficient of the ESCS variable was not statistically significant at the student-level, after controlling for other variables in Model 3. Based on the random effects of the ESCS variable, the SDs of the ESCS coefficients at the school and country levels were 5.76 and 2.49 respectively. As such, there were certain schools or countries with relatively stronger associations between female and DRA, or ESCS and DRA, than others.

ICT-related variables. Conditional on other covariates, there was a tendency for attitudes toward computers (ATTCOMP) and an index of students' self-confidence in high-level ICT tasks (HIGHCONF) to have a positive association with digital reading, with both variables being statistically significant (the coefficients were 3.23 and 3.38, respectively). The average magnitude of the coefficient of online social activities (ONLNREAD2) was statistically positive with digital reading, with this coefficient being much higher than online searching activities (ONLNREAD1) (i.e., 6.33 vs. 1.44). ONLNREAD1 was not statistically significant. In accordance with other student-level variables, it was found that there was also certain heterogeneity in the coefficients of ICT attitudes and online reading activities, with a slightly larger variance at the school level.

Metacognition. The measures of meta-cognition variables were consistently and statistically positive in digital reading, even after controlling for other variables in Model 3. In particular, summarizing strategies (METASUM) appeared to be a relatively stronger predictor than learning strategies for understanding and remembering (UNDREM) (the coefficients were 3.77 and 1.51, respectively). In particular, the 95% coverage intervals at the school and country level for METASUM lie between −6.09 and 13.63, and between −2.64 and 10.18, respectively.

Navigation. Using a subset of student data with navigation behaviors, we examined the association between navigation and digital reading, after controlling for some important student-level variables. Due to the model convergence issue, print reading was treated as fixed in Model 5 in Table 3. The regression coefficient of navigation was positive and statistically significant with a value 0f 2.05, implying that if a student visited one more relevant page, on average, their digital reading score was expected to improve by 2.05 points. Based on the normal distribution assumption, the 95% coverage interval for school effect of the navigation variable after controlling for other variables in the model lies approximately between 0.50 and 3.60, and the corresponding interval for the country effect lies between 1.54 and 2.56. This indicates that navigation is positively associated with digital reading across all schools and countries. In Table 3, ICT attitudes, ONLNREAD2 (online social activities), and METASUM still showed a positive prediction, with

Table 3
Prediction of navigation variable on digital reading.

Model 5			
Fixed effect	Est.(SE)		
Intercept	***486.34*** (12.72)		
PRA	***0.66*** (0.02)		
ESCS	0.77 (0.79)		
FEMALE	***−3.93*** (1.45)		
METASUM	***2.36*** (0.73)		
UNDREM	0.94 (0.65)		
ATTPCOMP	***2.47*** (0.55)		
HIGHCONF	***2.55*** (0.71)		
ONREAD1	0.78 (0.78)		
ONREAD2	***4.72*** (0.81)		
Navigation	***2.05*** (0.10)		
Random effect	*Variance component (SD)* Level 1	Level 2	Level-3
Error	***864.24*** (29.40)		
Intercept		***3948.62*** (62.84)	***2348.95*** (48.47)
ESCS		***64.87(***8.05)	***5.73*** (2.39)
FEMALE		***133.92*** (11.57)	***21.07*** (4.59)
METASUM		***43.91*** (6.63)	***3.74*** (1.93)
UNDREM		***44.70*** (6.69)	***4.04*** (2.01)
ATTPCOMP		***41.38*** (6.43)	***2.59*** (1.61)
HIGHCONF		***45.68*** (6.76)	***4.39*** (2.10)
ONREAD1		***93.97*** (9.69)	***4.28*** (2.07)
ONREAD2		***136.09(***11.67)	***4.53*** (2.13)
Navigation		***0.62(***0.79)	***0.07(***0.26)

Bold italic cases: $p < .05$.

female students tending to score about 4 points lower than male students after controlling for other student variables including print reading as well as navigation in Model 5. Random effects of student-level variables appeared statistically significant at both student- and school-levels.

School-level variables related to digital reading. Going back to Table 2, when differences at the student-level were adjusted with grand-mean centering in Model 4, the school variables, i.e., EXCURACT and STUDBEHA, were not statistically significant in predicting the variance of the adjusted school means within countries. The random effect of EXCURACT (extra-curricular activities offered by school) was also negligible as seen in Table 2, whereas the random effect of a variable capturing school climate (i.e., STUBEHA) appeared to vary across countries.

6. Discussion and conclusions

This study aimed to identify and examine factors that were associated with digital reading across countries based on three-level hierarchical models. Our results generally confirmed the findings from OECD (2012, 2015) but added to the previous evidence by demonstrating the importance of metacognition and navigation, along with ICT attitudes and online activities even after the association between print reading and digital reading was controlled for. Also, this study described the heterogeneity of the associations between these factors and digital reading across schools and countries based on the estimated random effects. More importantly, navigation showed a relatively small variation in terms of the estimated coefficients at the school- and country-levels, implying a universally important factor in digital reading ability. The following includes further discussions focusing on the primary findings.

6.1. Gender and SES in digital reading

The present study tested gender difference in digital reading performance to see if this pattern repeats itself in a new and legitimate literacy. The results showed that holding other variables constant along with relevant factors (e.g., print reading), female students tended to underperform compared to male students. However, a substantial amount of variation of the regression coefficient of gender between schools and between countries signaled that gender difference could be confounded with various other unexplained factors. These results are in agreement with Rasmusson and Åberg-Bengtsson (2015)'s findings which showed a lessening gender gap when it comes to digital reading for Swedish adolescents. A possible explanation for this might be that male students generally tend to spend more time playing computer games and have more experience with and interest in visiting game sites on the Internet (Rasmusson & Åberg-Bengtsson, 2015). Tveit and Mangen (2014) also pointed out that boys are more likely to use a digital device when they read. Such familiarity with technology for boys may be explained by the different socialization process involved in reading.

Although previous research indicated the positive impact of student SES in academic outcomes in various domains (Mullis et al., 2003; Rowe, 2008), the present study provided results showing that, at the student-level, the effect of SES was not significant when students' gender, cognition and ICT-related variables were controlled. Individual differences in cognition, ICT attitudes and behaviors seem more likely to be important in explaining digital reading. However, the results also demonstrated that there were significant variabilities of SES effect at the school and country-level. In-depth analysis of differential influences of SES needs to be explored in different schools and educational systems, considering the inequity in learning opportunities around the world.

6.2. ICT attitudes and online activities

The present study points to a potential role of affective domains related to ICT (i.e. attitudes toward computers and self-confidence in ICT tasks) in improving digital reading ability. Even after some key variables such as print reading and navigation were accounted for in the model, ICT attitudes and confidence in using computers still showed significant predictability in the remaining variance of digital reading. Such a positive relationship between ICT attitudes and performance was consistent in studies even in different domains; for example, Luu and Freeman (2011) found that students with prior ICT experiences, frequent Internet browsing activity, and confidence in basic ICT tasks attained higher scientific literacy scores.

In terms of online activities, our results partially confirmed prior research (Gil-Flores et al., 2012; Lee & Wu, 2012) which maintains a more relevant connection between online academic activities and reading outcomes than online social activities. In contrast to other studies reporting negative effects of online participation for social/recreational purposes (e.g. Lee & Wu, 2012), our results showed the salience of these social activities (e.g. reading emails, chatting online, publishing and maintaining personal websites, etc.) in digital reading proficiency. We speculate that this positive association between online social activities and digital reading might be due to the role of ICT attitude and confidence as described above. Given the same level of print reading ability, students who have more social/informal online experiences may feel more comfortable even in the environment of digital tests. Our finding also resonates with Naumann's (2015) result which used data similar to that of the present study. He explained that social engagement (i.e. online social interaction activity) was not necessarily detrimental to digital reading performance. The author also reasons that there may be a possibility that the overuse of online social activities (e.g. social media) negatively impacts "traditional" academic achievement, but this does not mean that those activities are harmful to students' new literacy skill.

6.3. The importance of metacognition and navigation

We found metacognitive reading strategies were highly associated with digital reading across countries. Overall, the extent to which students utilize their reading metacognition usually strongly predicts their printed reading performance (Artelt, Schiefele, & Schneider, 2001; O'Reilly & McNamara, 2007), and our results confirmed this even in digital reading. In hypertext structures, readers' metacognitive skills are important for locating information from what they have been previously read (Balcytiene, 1999). Our results suggest that the summarizing strategy (not understanding/remembering) appears especially influential in digital reading as it showed significance after controlling for the effect of navigation and print reading ability. Summarizing involves the extent to which students apply deep mental effort to identify the main ideas of a text. Although metacognition in this study was not directly measured, from students' evaluation of the effectiveness of this strategy in a 'digital' form of reading, we can conjecture summarizing helps students by means of facilitating learning (OECD, 2010).

Another important result emerged from our study regarding navigation (measured by the number of relevant pages visited) in digital reading assessment. Navigation was found to be a unique and powerful predictor in digital reading assessment in addition to print reading across schools and countries. Navigation is believed to be effective for hypertext comprehension and researchers argued that hypertext readers use different reading strategies tailored to nonlinear networks of linked text chunks (Salmerón & García, 2011; Salmerón et al., 2010). Proficient readers are able to identify task-relevant statements, resulting in selecting and visiting pages with more useful information. On the contrary, less proficient readers experienced difficulty in finding main ideas and making connections with relevant webpages, resulting in random selection of webpages (Hahnel et al., 2016; Naumann, 2015). Salmerón et al. (2005, p. 174) emphasized the importance of navigation in selecting appropriate pages which should be connected to a purpose that guides readers (e.g. interest or coherence) in digital reading.

In sum, navigation, metacognitive summary strategies, ICT attitudes and online activities were associated with digital reading even after controlling for print reading ability. Based on these study findings, future studies could examine how these variables were mediated and/or moderated, which in turn may have an influence on digital reading, as can be shown using a structural equation modeling framework. This effort could provide more concrete empirical evidence for the discussions above (e.g., gender x ICT attitudes or functions of online social activities mediated by ICT attitudes and confidence).

6.4. School climate and activities

The school-level variables were not significantly associated with student-level digital reading. School climate and activities provided by schools did not predict the outcome in this study, which is different from the findings of previous research (e.g. Feldman & Matjasko, 2005; Lim & Jung, 2014). We found that the association between school disciplinary climate and digital reading varied across countries, however. School climate was the learning-oriented environment represented by the frequency of students' problematic behavior. Since the school rules that students are bound by depend on cultural contexts, the impact of disciplinary climate was not the same across countries. Also, since only a limited number of school-level variables were used, it would be helpful to

include school structures and cultures related to teachers and school/social communities. In addition, educational programs for ICT need to be analyzed (e.g. teacher training for technology use, technology intensive learning environments, teaching and learning practices in regard to technology) to understand digital reading achievement.

6.5. Limitations and directions for future research

The present study had several limitations with implications for future studies in this area. Above all, this study provided a comprehensive picture of adolescents' digital reading and relevant factors, primarily focusing on student-level characteristics, across a wide variety of nations. In-depth analysis for individual educational systems, including school- or culture-related variables should be employed for future research. For example, there may be important differences in predictions of background variables in digital reading between Asian and Western students. This may partly be the reason why this study found significant random effects at the country level. Thus, substantive investigation is required to identify cultural and contextual factors that have an impact on various achievement measures in digital forms. Building upon such knowledge for individual countries, we may be able to explore factors that explain the variance of digital reading using country-level variables for future study.

Second, since navigation is considered to be essential in digital reading, research in this area still needs elaboration and refinement in conceptualization and operationalization of this concept. It should be noted that measurement of navigation in the present study (i.e. number of relevant pages visited) needs to be interpreted cautiously. Sometimes a higher number of page visits might be an indication of a students' distraction or confusion in judging the degree of significance (Hahnel et al., 2016). Therefore a consideration of additional indicators of navigation that count the degree of coherence or types of backtracks (e.g. Naumann et al., 2008) is recommended. However, these indicators can also reveal different strategies or intentions, identifying variables such as whether or not readers were lost.

Also, reading hypertext requires more knowledge in evaluating sources of information (Brand-Gruwel, Wopereis, & Walraven, 2009; Hahnel et al., 2016). Judging online information is related to one's own decisions vis-a-vis web information in terms of relevance, credibility, and utility of sources (Leu et al., 2004). Another potential limitation of using navigation in PISA is that, in contrast to other variables, navigation variables were not included as conditional variables in the background model for deriving the plausible values (OECD, 2011, p. 92; p. 140). This might affect the posterior distribution that PVs are drawn from and result in underestimating the regression coefficients in analytical models. Also, by using a subsample for the analysis of navigation, we created a new standardized weight using the original student weight PISA provided, suggesting the representativeness of the population might be diminished, although it is a matter of data not of analysis.

Lastly, our results regarding predictability of student- and school-level factors in digital reading should not be interpreted as causal effects, and so require a causal inference study. The cross-sectional design of PISA restricts the temporal order and independence of measures of interest. It may be a worthwhile investigation for reading researchers to examine the long-term prediction of navigation (and other ICT skills) and how this knowledge would influence digital reading proficiency directly and indirectly.

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Appendix A. Supplementary data

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