Education and Information Technologies (2020) 25:2933–2970
https://doi.org/10.1007/s10639-019-10089-z

Does ICT familiarity always help promote educational outcomes? Empirical evidence from PISA-Thailand

Kitisak Srijamdee[1] · Piriya Pholphirul[1]

Received: 22 October 2019 / Accepted: 13 December 2019 / Published online: 4 January 2020

Abstract

Since education is a major step toward long-term human capital development, it is assumed that facility in the use of information and communication technology (ICT), which can help complement, enrich, and transform education, should be promoted among students. However, does a higher level of ICT familiarity always help promote learning skills and educational outcome? This empirical research paper investigates the impacts of ICT familiarity on educational outcomes in developing countries where access to ICT infrastructure is limited. Using Thailand as a case study of a developing country, a nationally representative survey of 8249 students from the Programme for International Student Assessment (PISA) in Thailand was analyzed. Our results show that using ICT for educational proposes can help improve Thai students' PISA scores. However, using ICT that is not tailored to educational proposes is found to have an insignificant effect on educational outcomes. This result supports government, related agencies, and families in their efforts to foster children's use of ICT to enhance their education, but suggests limiting such usage for non-educational proposes.

Keywords ICT familiarity · Education outcomes · PISA · Developing countries · Thailand

1 Introduction

As education plays a key role in human resource development of a country, countries around the world emphasize improvement in the quality of education. Traditionally, "education" has occurred in a classroom where teachers and students are required to

✉ Piriya Pholphirul
pholphir@hotmail.com

Kitisak Srijamdee
k.srijamdee@gmail.com

[1] Center for Development Economics Studies, Graduate School of Development Economics, National Institute of Development Administration, Serithai Road, Klong-Chan, Bangkapi, Bangkok 10240, Thailand

meet face to face. But due to today's technological advancements, education has evolved to the point where a classroom is no longer the only venue where learning can take place. Rather, education and learning can be carried out via the Internet through online courses or through other computer- and high-tech-assisted curricula. And since the world has so dramatically entered the digital realm, the relation between ICT and education has become more crucial in the twenty-first century (Oliver 2002).

However, despite how crucial information technology is to manpower development of a country, how much a country benefits from ICT utilization depends on ICT's accessibility and to what extent its population is "competent" or "familiar" with ICT. Ilomäki et al. (2016) explained this quality as "Digital Competence," which is one of the factors comprising core competence for economic development these days. Digital competence comprises (1) technical competence, (2) the ability to use digital technologies in a meaningful way for work, study, and in everyday life, (3) the ability to evaluate digital technologies critically, and (4) as generating motivation to participate and commit in the digital culture.

However, the ability to utilize ICT varies from country to country. In developed countries where ICT equipment is available to all students, the familiarity level is higher than it is for students in developing (or underdeveloped) countries, where access to ICT gadgets is still limited. For that reason, students in developed countries find it easier to become familiar with using information technology for the benefit of their education.

In developing countries, the prevalence of poverty means that not only may poor households lack access to ICT at home, but also that students from those countries may have limited ICT access even in the schools. In addition to many schools still lacking ICT infrastructure and other resources due to limited budgets, they also most likely lack ICT teachers. Such an environment results in students in developing countries lacking familiarity with ICT relative to their peers in developed countries. Such a lack constitutes an obstacle to learning and to keeping up with contemporary educational practices, in which ICT is crucial.

Nowadays, information and communication technology is widely used for most activities, including those related to education. The term ICT, in this case, stands for information and communication technologies and is defined, as a "diverse set of technological tools and resources used to communicate, and to create, disseminate, store, and manage information among students". This provides an increasing demand for schools to produce technologically literate students. Information and communication technologies have also changed the ways in which students access and process information and the ways in which they communicate with each other, providing educators with an impetus to modify and adapt curriculum to ensure capitalizing on the power of these technologies and the engagement of students with them.

Utilizing ICT in classroom education definitely enhances teaching proficiency. And Kingsley (2017) states that ICT will play a key role in enhancing education proficiency in developing countries. For example, Suryani (2010) discovered that when ICT (movie-making software) was utilized in a school in Indonesia, the students were encouraged to help each other in using the computers to learn how pictures related to sound and to develop creativity by producing movies around themes in which they were interested.

The objective of our research here is to study the level of ICT familiarity among Thai students and its impacts on educational outcomes in developing countries such as Thailand. Our research is divided into five sections. The second section is a literature review of ICT familiarity level and education outcomes. The third section is an introduction to the descriptive statistics on data used in the research. The fourth section will discuss econometrics estimation models used to study the impacts of ICT familiarity on education outcomes with controlled multi-dimension factors. And the final section presents the conclusion and a policy proposal.

2 ICT familiarity and education outcomes

Studies on the relationship between ICT familiarity and education outcomes have been conducted in many developed countries, and most have analyzed data from the Program for International Student Assessment (PISA). The majority of the studies discovered positive impacts between ICT utilization and education outcomes. One such study is that of Kubiatko and Vickova (2010), carried out to investigate the relation between ICT familiarity and the science scores of 5932 students in the Czech Republic, using data from PISA 2006. The authors found that ICT familiarity positively influenced science scores with statistical significance. This finding indicated that even though ICT familiarity has a positive, significant impact on science scores, students who utilized ICT related directly to their education had higher scores than students who utilized ICT for non-educational purposes.

Similarly, using data from PISA 2009, Delen and Bulut (2011) studied the relation between ICT familiarity and science and mathematics scores of 4996 students in Turkey. Results indicated that ICT utilization both at home and school significantly boosted science and mathematics scores. This coincides with a study conducted by Wittwer and Senkbeil (2008) involving home computer utilization and mathematics scores of German students (using the data from PISA 2003), indicating that students who used a computer at home had higher scores than students who did not. Another study, by Luu and Freeman (2011) on the relation between ICT utilization and the science scores of students in Canada and Australia (employing data from PISA 2006), indicated that computer experiences of students helped increase science scores.

Apart from the impacts on science and mathematics scores, there have been impacts on other academic skills. For example, Leino (2014) found that the relationship between ICT and the reading skills of students in Finland indicated that Internet browsing increased reading skill, depending on one's familiarity with Internet data searching. Individuals who were more familiar with such searching had a higher-level reading skill than those who were less familiar. All of this empirical evidence shows that young people who use technologies in the online environment would do well to familiarize themselves with such skills in order to boost their learning potential (Shields and Chugh 2018).

By using cross-country comparisons, a study by Eickelmann et al. (2017) examined the relationship between ICT use and the performance of Grade 9 students in mathematics from five countries—Australia, Germany, the Netherlands, Norway, and Singapore. Using PISA-2012 and including school-level data such as the availability of IT equipment of schools, school leadership, aspects of school goals, and educational

strategies, as well as teachers' attitudes, the authors found that the relationships among these factors affected students' mathematics achievement when they were synchronously assessed in the various countries' educational systems. The results show that characteristics at the school level do play a major role in the integration of ICT into teaching and learning and turn out to be relevant across educational systems.

From various studies, we can conclude that the impacts of ICT use on educational outcomes can vary, depending on the types of use to which ICT is put, the level of confidence and familiarity in using ICT, and attitudes towards using ICT for education and overcoming learning difficulties in school. In terms of types of usage, different uses of ICT can produce different educational outcomes. As an example, Zhang and Liu's study (2016) of the relation of ICT utilization and mathematics/science scores of students in China (employing data from PISA 2000–2012) indicates that in 2000–2009 ICT utilization for entertainment purposes had negative impacts on mathematics and science scores, but such utilization had positive impacts in 2012. Even more puzzling, Internet utilization for educational purposes in the schools in 2009 and 2012 had negative impacts on the scores of both subjects.

Furthermore, a study from Bulut and Cutumisu (2017), which aimed to explain the relationship between ICT and mathematics/science scores of students in Finland and Turkey, found that although ICT utilization for entertainment purposes had significant negative impacts on Finnish mathematics and science scores, such utilization had positive impacts for students in Turkey, where ICT utilization at home and in schools had significant positive impacts on mathematics and science scores. But Aypay (2010) discovered that ICT utilization had no significant impact on the scores of the 4942 Turkish students from 160 schools who were tested in PISA 2006. On the other hand, similar to the Finnish students, students in Canada and Australia who used ICT for entertainment purposes too often exhibited lower science scores (Luu and Freeman 2011).

Results in the above paragraph, however, contradict those of Biagi and Loi (2013), who used an econometric model to measure the relationship between students' computer use and their achievement in reading, mathematics, and science in 23 countries. Biagi and Loi (2013) found that students' PISA test scores in reading, mathematics, and science increased with intensity of computer use for gaming activities while they decreased with intensity of computer use for activities that are more related to school curricula. However, the number of activities (and hence the diversification of activities) is positively correlated with students' proficiency in all three PISA domains in the vast majority of countries, indicating that computers breadth of use, as opposed to intensity of use in a given activity, should have a positive effect on students' learning outcomes.

Another possible factor to explain why various ICT usages can have different impacts on students' educational outcomes is the extent to which students are confident using ICT for a particular purpose. For the most part, students in developed countries seem to be highly confident in using ICT. Results from Thomson and De Bortoli (2007), for example, indicate just how extensive the access to ICT is in schools, homes, and other places for students in Australia. However, this study focused on the aspects of the "digital divide," and examined access and use of ICT in Australia by state, gender, socioeconomic background, and geographic location. It indicated that Australian students *were highly confident of being* able to perform routine ICT tasks such as opening, saving, and deleting files by themselves, and that they were among the most confident in the world at performing Internet tasks. Although fewer students from low socioeconomic backgrounds

had access to a computer at home, there was little difference between students from low and high socioeconomic backgrounds in their use of computers and their confidence in using computers.

Attitudes toward educational technology are also important. A study from Petko et al. (2017) indicates that, using PISA-2012 data and combining frequency of use and positive perceptions with regard to educational technology as predictors for student test scores, positive attitudes toward using technology for education are associated with higher test scores in the large majority of countries. The authors therefore argue that ICT usage quality is more important than ICT usage quantity if the aim is to achieve a positive impact of ICT on education performance.

In both developed and, especially, developing countries, the need to address learning difficulties can be another important factor that supports the use of ICT. The term "learning difficulties" is used to refer to conditions experienced by children who need extra assistance with schooling due to any number of a vast range of cognitive and physical impairments. Therefore, any tool that could make learning easier and more interesting and that could enthuse and inspire such students would lead to better educational outcomes for them. To test this idea, Adam and Tatnall (2017) conducted research in two Special Schools in metropolitan Melbourne and investigated whether ICT could be used to support school communities involving students with learning difficulties and help them to improve their learning. They found that ICT certainly did ameliorate learning difficulties among students by equipping them with adequate skills to allow them to enter the workforce or continue with further study through various pathways.

This review of the literature indicates both positive and negative impacts of ICT familiarity in developed countries, while the studies in developing countries are still limited, and the effect of ICT on education remains uncertain. Therefore, in the next section we will use data from PISA-Thailand as a case study for developing countries. The data was conducted in the year 2015.

3 Data

This study employed secondary data obtained from a questionnaire filled out for PISA-Thailand. Conducted by the OECD and in cooperation with the Thai government, the PISA-2015 evaluated achievement in reading, mathematics, and science among 8249 randomly chosen students from 237 schools. The advantage of employing PISA data used in this study are the following:

1) PISA data comes from a national survey of students. It generates better data than do other studies in developing countries that often select particular schools or communities and thus do not provide good national data.
2) In 2015, PISA added many ICT familiarity-related questions compared to the previous surveys, enabling it to be used in more detailed ICT familiarity analysis.
3) In this 2015 PISA survey session, the science test was weighted as the main criterion for assessment vs. reading and mathematics. Hence, the 2015 survey contained many science and technology questions suitable for more detailed analysis.

Initial analysis of the ICT utilization ratio indicates (Fig. 1) that while 75.55% of Thai students surveyed had access to the Internet at home and 79.78% had access at school, only 16.05% had access to e-books at home and 28.12% at school. Laptops were the most-used devices at home (among 55.42% of students), and desktop computers were the most used at school (76.7%).

In terms of ICT experience (Table 1), data indicate that 32.96% of students had used digital devices for the first time at age 7–9, and 44.9% had used computers for the first time at that age. And 38.36% had first accessed the Internet at age 10–12. While 20.42% used the Internet outside of school on weekdays for 2–4 h per day, 34.35% used it more than six hours a day on weekends (Table 2). This shows that (in terms of usage time) Thai students use ICT during weekends 2–3 times more than on weekdays (when they go to school).

Time spent with ICT by Thai students outside school is mostly spent on social media platforms such as Facebook (50.68%), followed by Line or MSN chats (41.43%) and browsing the Internet to watch videos such as those found on YouTube (39.67%) (Table 3). It can be concluded that Thai students use ICT for many activities, such as email and social media communication and entertainment. And while they do use the Internet for educational purposes such as following up on classes, communicating with teachers, learning foreign languages and mathematics, or doing homework assignments, they also use ICT for entertainment, such as gaming, watching videos, or uploading shared user-created content.

An analysis of 2015 PISA reading, mathematics, and science scores categorized by access to ICT devices indicates that scores for students who use devices such as home desktop computers, school desktop computers, home laptops or notebooks, or home tablets, and have a home Internet connection and a school Internet connection are higher for reading, mathematics, and science than they are for students who do not use ICT (Figs. 2, 3, and 4, respectively).

Classified by the use of various ICT devices, Table 4 also indicates that Thai students who had been familiar with ICT from the age of six years or younger were likely to have higher scores for the three subjects than were students who only became acquainted with ICT at the age of 13 years or older (or who had never used ICT until the date of the survey). Also, those who used ICT for an average of 2–4 h on weekdays tended to have higher scores in the three subjects, while students who used ICT an

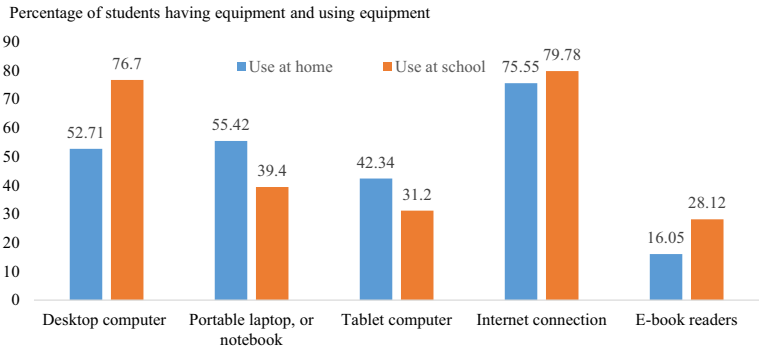

Fig. 1 Percentage of students having and using ICT equipment. Source: Calculated by the researcher from 2015 PISA student questionnaire data

Table 1 Experience with a digital device, computer, and accessing the Internet (percent)

	6 years old or younger	7–9 years old	10–12 years old	13 years old or older or never used a digital device until today
How old were you when you first used a digital device?	14.07	32.96	31.51	21.46
How old were you when you first used a computer?	16.35	44.39	28.08	11.19
How old were you when you first accessed the Internet?	8.65	35.79	38.36	17.20

Source: Calculated by the researcher from 2015 PISA student questionnaire data

average of 4–6 h on weekends tended to have higher scores. Apart from that, if students used the Internet for educational purposes 1–2 times a week, the scores were higher than for those who never or almost never used the Internet for educational purposes.

From what is indicated in Table 4, it is still not possible to determine whether non-educational uses of ICT have positive or negative impacts on educational outcomes. This is because in addition to the different scores for reading, mathematics, and science correlated with the particular ICT usage of each person, there are also multiple factors, such as household factors, school factors, and area factors that affect educational outcomes. Thus, it is necessary to eliminate those factors by econometric evaluation and controlling other factors in the dimensions, which are presented in the next section.

4 Model estimations

The focused methodology of this paper is based on descriptive statistics and econometrics estimation that aim to quantify the impacts of ICT familiarity among Thai

Table 2 ICT use per day (percent of students per time period)

	No time	1–30 min per day	31–60 min per day	Between 1 h and 2 h per day	Between 2 h and 4 h per day	Between 4 h and 6 h per day	More than 6 h per day
During a typical weekday, for how long do you use the Internet at school?	14.10	21.68	18.19	25.02	10.17	5.56	5.28
During a typical weekday, for how long do you use the Internet outside of school?	10.78	10.20	11.41	18.34	20.42	13.76	15.11
During a typical weekend day, for how long do you use the Internet outside of school?	5.76	4.99	5.85	11.83	17.31	19.90	34.35

Source: Calculated by the researcher from 2015 PISA student questionnaire data

Table 3 Frequency of ICT activities outside school (percent)

Types of ICT use	Once or twice a week	Almost everyday	Everyday
Use for playing games and for entertainment			
Playing one-player games	22.46	21.76	12.43
Playing collaborative online games	19.06	16.44	11.71
Online games/social networks, e.g., Farmville, The Sims Social	16.71	13.66	13.32
Browsing the Internet for fun videos, e.g., YouTube	16.55	30.76	39.57
Downloading music, films, games, or software from the Internet	26.84	30.00	22.43
Use for communication and finding information but not related to education			
Using email	24.06	15.92	10.64
Chatting online, e.g., MSN	14.01	25.60	41.43
Social networks, e.g., Facebook	11.17	22.88	50.68
Reading news on the Internet	25.79	25.90	21.68
Obtaining practical information from the Internet	25.31	26.00	20.04
Uploading your own created content for sharing	22.60	21.79	16.58
Downloading new apps on a mobile device	28.01	21.99	18.28
Use for education			
Browsing the Internet for schoolwork	37.21	27.11	10.88
Browsing the Internet to follow up on lessons, e.g., for finding explanations	36.90	26.53	11.00
Using email for communication with other students about schoolwork	29.40	22.12	11.18
Using email for communication with teacher	29.62	17.18	8.44
Using social networks for communication with other students about schoolwork	21.35	29.27	34.34
Using social networks for communication with teachers	25.66	21.45	22.76
Checking the school's website for announcements	29.27	17.31	9.15
Doing homework on a computer	34.48	23.95	11.12
Doing homework on a mobile device	29.46	25.31	14.25
Downloading learning apps on a mobile device	29.24	19.60	11.31
Downloading science learning apps on a mobile device	27.45	17.28	10.37

Source: Calculated by the researcher from 2015 PISA student questionnaire data

students on their education outcomes with controlled multi-dimension factors. Based on Fasih (2008), factors affecting education outcomes can be classified into two aspects:

1) Demand-Side Factors

1.1) Family Characteristics: parents' highest education, household equipment, careers of the parents, and family's financial status
1.2) Student Characteristics, which are gender, student's attitude, health and lifestyles of students, including their ICT usage

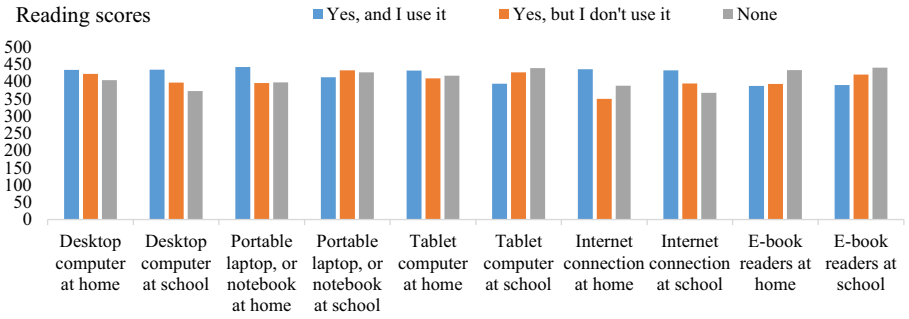

Fig. 2 Reading scores classified by the use of various ICT devices. Source: Calculated by the researcher from 2015 PISA student questionnaire data

2) Supply-Side Factors

2.1) School Characteristics: school location, number of students in a classroom, school support such as school activities, IT equipment shortage, IT equipment quality problems, teacher characteristics, availability of teachers, education level of teachers, amount of teacher training, and teacher support program

It can be noticed that factors related to ICT familiarity among students fall into both demand-side and supply-side categories. Therefore, in this case, the variables used to explain ICT familiarity factors will be classified into: 1) Access to the ICT equipment, 2) ICT use experience, 3) Internet usage duration, and 4) Types of ICT usage.

The econometrics models are estimated in the following forms:

$$Log\ (PISA\ Score_i) = \alpha + \beta\ ICT_i + \gamma\ Family_i + \delta\ Student_i + \theta\ School_i + \varepsilon_i$$

Where the dependent variables are test scores (log-form) of the students i on Reading subject (Model 1), Mathematics subject (Model 2), and Science subject (Model 3) by controlling family characteristics ($Family_i$), student characteristics ($Student_i$), and school characteristics and teacher factors ($School_i$). And ε_i is the error term.

Estimated results from Table 5 show that male students had significantly higher mathematics and science scores than did female students by 3.2% and 2.5%,

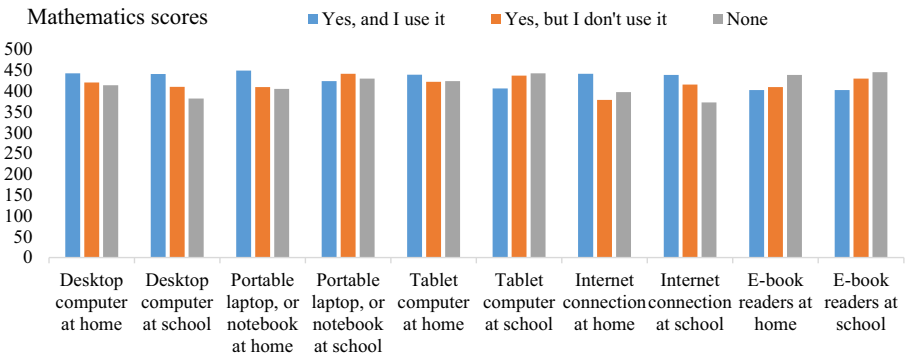

Fig. 3 Mathematics scores classified by the use various ICT devices. Source: Calculated by the researcher from 2015 PISA student questionnaire data

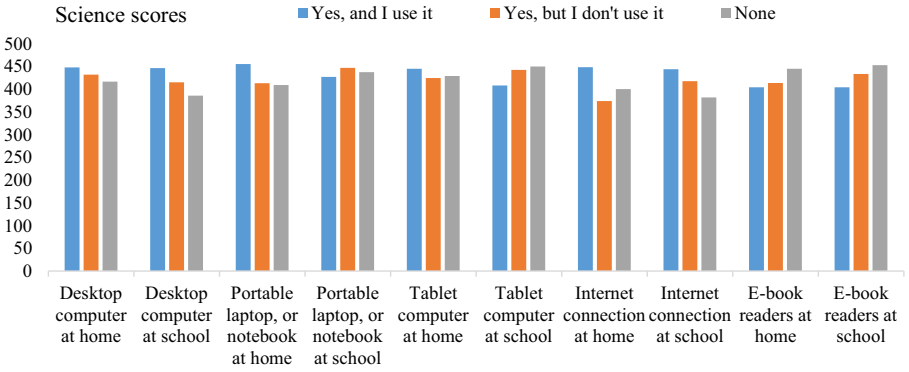

Fig. 4 Science scores by using various information communication technology. Source: Calculated by the researcher from 2015 PISA student questionnaire

respectively. But female students had higher reading scores than did male students by 1.4%. Students whose parents had "professional" occupations tended to have the highest scores than those whose parents engaged in general basic occupations.

Apart from these factors, other statistically significant factors included whether a house had a quiet area for study, whether educational software was available, and whether there was a mobile phone with Internet access, a computer, and a musical instrument. Students for whom these factors were present tended to have statistically significantly higher scores in reading, mathematics and science than did students for whom these factors were absent.

A look at students' before- and after-school activities indicates that students who read books before going to school had significantly better scores in reading, mathematics, and science than did students who did not read before going to school. In addition, students who finished their homework after coming home from school had better scores in mathematics (2.3%), science (2.5%), and reading (2.9%) than did students who did not finish their homework.

As for the school factor, students studying in classes of 15 or fewer persons got significantly better scores in reading (5.2%), mathematics (6.9%), and science (10.0%) than did students studying in classes containing more than 50 students.

Furthermore, students in schools that offered musical activities had significantly better scores in science (1.3%) and reading (1.8%) than did students in schools that did not offer musical activities. (There was no effect on mathematics scores, however.) And students in schools that had an art club had significantly better scores in reading (4.6%), science (4.7%), and mathematics (7.0%) than did students in schools without an art club.

With regard to teachers, students with science teachers who sometimes allowed an exchange of opinions among students enjoyed significantly better scores in reading (1.8%), science (2.6%), and mathematics (3.2%) than did students with science teachers who did not allow exchanges of opinions. This could be the result of knowledge sharing and debating, which can generate new learning.

Focusing on the analysis of ICT familiarity factors affecting education scores, factors are categorized in terms of: 1) Access to the ICT equipment, 2) ICT use experience, 3) Internet usage duration, 4) Types of ICT usage.

Table 4 Educational achievement classified by the use of various ICT devices

Variable	PISA Score			
	Reading	Mathematics	Science	Observation
Use experience				
How old were you when you first used a digital device?				
6 years old or younger	460.06	470.44	478.07	1119
7–9 years old	436.33	442.98	449.53	2622
10–12 years old	418.42	425.31	431.15	2506
13 years old or older or never used a digital device until today	379.89	390.20	392.19	1707
How old were you when you first used a computer?				
6 years old or younger	453.40	462.83	469.84	1271
7–9 years old	431.37	439.66	444.93	3451
10–12 years old	413.30	418.93	423.79	2183
13 years old or older or never used a digital device until today	374.73	382.38	391.06	870
How old were you when you first accessed the Internet?				
6 years old or younger	438.82	449.02	455.23	674
7–9 years old	433.96	443.10	448.51	2789
10–12 years old	424.66	432.08	437.23	2989
13 years old or older or never used a digital device until today	390.64	394.47	402.66	1340
Number of minutes/h of use per day				
During a typical weekday, for how long do you use the Internet at school?				
No time	417.35	422.81	430.69	1094
1–30 min per day	427.83	434.52	439.89	1682
31–60 min per day	424.87	433.90	442.84	1411
Between 1 h and 2 h per day	418.44	423.82	428.21	1941
Between 2 h and 4 h per day	439.92	448.97	455.31	789
Between 4 h and 6 h per day	425.67	437.08	445.30	431
More than 6 h per day	415.27	428.46	424.76	410
During a typical weekday, for how long do you use the Internet outside of school?				
No time	416.94	426.68	433.14	834
1–30 min per day	388.50	395.87	403.88	789
31–60 min per day	405.87	419.99	426.46	883
Between 1 h and 2 h per day	422.25	430.20	433.19	1419
Between 2 h and 4 h per day	445.42	456.61	460.35	1580
Between 4 h and 6 h per day	437.86	438.21	449.73	1065
More than 6 h per day	427.76	428.70	434.33	1169
During a typical weekend day, for how long do you use the Internet outside of school?				
No time	377.98	388.06	392.76	446
1–30 min per day	369.07	372.13	378.53	386
31–60 min per day	377.45	402.10	400.03	453
Between 1 h and 2 h per day	403.46	417.63	420.85	915

Table 4 (continued)

Variable	PISA Score			
	Reading	Mathematics	Science	Observation
Between 2 h and 4 h per day	435.54	444.48	450.31	1339
Between 4 h and 6 h per day	443.75	451.88	458.07	1540
More than 6 h per day	437.87	439.06	447.37	2658
Types of ICT use				
Use for playing games and for entertainment				
Playing one-player games				
Never or hardly ever	412.81	418.68	423.97	2006
Once or twice a month	427.17	433.52	441.58	1344
Once or twice a week	435.31	441.39	444.97	1735
Almost every day	426.57	434.92	44.05	1681
Every day	417.05	430.40	436.14	960
Playing collaborative online games				
Never or hardly ever	431.10	433.31	440.73	2791
Once or twice a month	429.20	434.53	443.25	1274
Once or twice a week	423.84	434.10	435.41	1468
Almost every day	414.95	424.73	433.84	1266
Every day	408.03	426.63	428.33	902
Online games/social networks, e.g., Farmville, The Sims Social				
Never or hardly ever	434.30	438.12	445.16	3104
Once or twice a month	431.71	437.47	446.81	1226
Once or twice a week	418.93	427.62	431.88	1285
Almost every day	406.40	418.21	423.54	1050
Every day	409.10	423.16	426.10	1024
Browsing the Internet for fun videos, e.g., YouTube				
Never or hardly ever	359.23	375.98	376.36	469
Once or twice a month	373.98	393.90	394.08	543
Once or twice a week	407.38	420.25	422.09	1276
Almost every day	431.79	435.64	444.66	2372
Every day	443.83	447.99	455.76	3051
Downloading music, films, games or software from the Internet				
Never or hardly ever	384.42	398.14	397.68	556
Once or twice a month	415.57	427.07	432.00	1035
Once or twice a week	429.44	438.63	446.18	2060
Almost every day	430.10	433.17	440.91	2302
Every day	427.56	433.97	439.17	1721
Use for communication and finding information but not related to education				
Using email				
Never or hardly ever	403.67	409.27	413.85	1709
Once or twice a month	441.46	445.48	454.06	2087
Once or twice a week	439.38	449.17	455.14	1850

Table 4 (continued)

Variable	PISA Score			
	Reading	Mathematics	Science	Observation
Almost every day	412.74	422.08	428.81	1224
Every day	403.05	415.31	417.48	818
Chatting online, e.g., MSN				
Never or hardly ever	386.66	402.37	404.52	765
Once or twice a month	392.17	407.00	411.32	693
Once or twice a week	414.47	425.79	430.79	1078
Almost every day	420.61	426.79	434.70	1969
Every day	445.28	448.45	455.29	3187
Social networks, e.g., Facebook				
Never or hardly ever	368.19	379.48	382.88	601
Once or twice a month	373.73	391.91	393.89	573
Once or twice a week	405.47	416.42	419.13	858
Almost every day	418.13	429.56	436.10	1758
Every day	446.71	449.54	457.15	3894
Reading news on the Internet				
Never or hardly ever	381.74	394.76	396.50	961
Once or twice a month	407.41	412.93	420.24	1088
Once or twice a week	421.64	430.76	434.42	1984
Almost every day	436.42	442.12	451.18	1993
Every day	447.38	452.77	460.28	1668
Obtaining practical information from the Internet				
Never or hardly ever	389.04	399.97	401.19	1055
Once or twice a month	409.33	419.11	423.41	1143
Once or twice a week	427.49	433.95	440.15	1942
Almost every day	433.94	441.22	449.56	1995
Every day	443.31	447.82	455.72	1538
Uploading your own created content for sharing				
Never or hardly ever	446.29	453.75	462.17	1636
Once or twice a month	433.68	443.98	451.67	1359
Once or twice a week	419.06	428.56	432.49	1734
Almost every day	410.20	414.88	420.91	1672
Every day	410.77	415.88	420.62	1272
Downloading new apps on a mobile device				
Never or hardly ever	393.09	407.56	407.26	829
Once or twice a month	444.70	447.82	461.17	1611
Once or twice a week	432.55	442.20	446.58	2154
Almost every day	416.71	423.17	428.38	1691
Every day	415.67	421.04	426.67	1406
Use for education				
Browsing the Internet for schoolwork (e.g., for preparing an essay or presentation)				

Table 4 (continued)

Variable	PISA Score			
	Reading	Mathematics	Science	Observation
Never or hardly ever	365.84	384.94	383.74	628
Once or twice a month	404.31	412.09	421.45	1280
Once or twice a week	435.49	440.15	448.51	2862
Almost every day	436.82	443.34	448.56	2085
Every day	429.39	439.68	440.21	837
Browsing the Internet to follow up lessons, e.g., for finding explanations				
Never or hardly ever	377.58	393.26	394.21	590
Once or twice a month	408.77	419.19	427.03	1368
Once or twice a week	433.77	438.24	446.63	2826
Almost every day	433.01	440.51	445.28	2032
Every day	430.02	437.70	439.16	842
Using email for communication with other students about schoolwork				
Never or hardly ever	424.42	430.64	437.25	1236
Once or twice a month	426.48	437.00	446.04	1597
Once or twice a week	425.64	433.03	438.43	2233
Almost every day	420.85	428.44	433.67	1680
Every day	424.76	429.61	432.05	849
Using email for communication with teacher				
Never or hardly ever	426.05	430.73	438.20	1542
Once or twice a month	434.68	445.46	454.13	1869
Once or twice a week	428.08	433.33	439.34	2257
Almost every day	411.00	421.17	423.48	1309
Every day	405.55	413.22	415.38	643
Using social networks for communication with other students about schoolwork				
Never or hardly ever	368.67	386.46	387.50	436
Once or twice a month	383.19	400.60	408.29	718
Once or twice a week	420.91	430.91	433.35	1638
Almost every day	431.02	438.94	447.56	2246
Every day	441.27	442.33	448.70	2635
Using social networks for communication with teachers				
Never or hardly ever	427.45	437.04	442.35	1001
Once or twice a month	427.37	438.50	448.15	1306
Once or twice a week	428.12	434.82	440.89	1965
Almost every day	417.14	428.60	433.09	1643
Every day	422.08	423.25	428.11	1743
Checking the school's website for announcements				
Never or hardly ever	425.36	432.39	437.72	1578
Once or twice a month	439.51	444.72	456.12	1808
Once or twice a week	422.80	430.90	435.67	2239
Almost every day	414.17	423.74	427.64	1324

Table 4 (continued)

Variable	PISA Score			
	Reading	Mathematics	Science	Observation
Every day	408.91	417.21	419.57	700
Doing homework on a computer				
Never or hardly ever	389.66	400.74	402.70	898
Once or twice a month	414.98	420.93	429.77	1431
Once or twice a week	433.98	441.12	447.74	2638
Almost every day	434.70	442.46	447.99	1832
Every day	425.82	432.79	438.13	851
Doing homework on a mobile device				
Never or hardly ever	402.77	412.64	415.95	1066
Once or twice a month	412.41	420.92	428.81	1301
Once or twice a week	422.58	431.77	437.81	2251
Almost every day	437.99	444.26	449.14	1934
Every day	439.73	442.60	451.09	1089
Downloading learning apps on a mobile device				
Never or hardly ever	422.86	429.78	436.33	1296
Once or twice a month	438.99	446.09	455.71	1751
Once or twice a week	423.62	433.66	438.54	2236
Almost every day	416.29	423.15	426.17	1499
Every day	413.74	417.73	423.67	865
Downloading science learning apps on a mobile device				
Never or hardly ever	433.35	435.71	444.12	1690
Once or twice a month	437.86	446.91	456.09	1739
Once or twice a week	423.98	432.81	437.43	2097
Almost every day	409.21	419.37	421.22	1320
Every day	404.19	410.75	415.44	792

Source: Calculated by the researcher from 2015 PISA student questionnaire data

For Access to ICT Equipment (availability of home/school computers): results indicate that merely having computer equipment at home (if it is rarely used) does not contribute to better education scores. In fact, students who had access to a computer at home but who did not use it got lower scores in reading (1.5%), science (1.9%), and mathematics (2.1%) than did students who did not have a computer at home at all. Moreover, students who had a notebook computer at home but who did not use it had lower scores in mathematics (1.8%), reading (2.4%), and science (2.5%) than did students who did not have a notebook at home. In contrast, students who used computers in school had better scores in mathematics (1.5%), reading (1.8%), and science (1.8%) than did students who had no access to school computers.

Table 5 Estimation results of coefficients of variables representing ICT familiarity and impacts on PISA scores

Variable	2015 PISA Score		
	Reading	Mathematics	Science
Available for you to use at home			
Desktop computer (Benchmark: None)			
Yes, and I use it	−0.015**	−0.021***	−0.019***
	(0.006)	(0.007)	(0.006)
Yes, but I don't use it	−0.002	−0.038***	−0.014*
	(0.007)	(0.008)	(0.007)
Portable laptop, or notebook (Benchmark: None)			
Yes, and I use it	−0.014**	−0.009	−0.014**
	(0.006)	(0.007)	(0.006)
Yes, but I don't use it	−0.024***	−0.018**	−0.025***
	(0.008)	(0.009)	(0.008)
Tablet computer, e.g., iPad (Benchmark: None)			
Yes, and I use it	−0.006	−0.010	−0.007
	(0.007)	(0.008)	(0.007)
Yes, but I don't use it	−0.021***	−0.016*	−0.022***
	(0.008)	(0.009)	(0.008)
Internet connection (Benchmark: None)			
Yes, and I use it	−0.011	−0.007	−0.010
	(0.007)	(0.008)	(0.008)
Yes, but I don't use it	−0.039***	−0.018	−0.033***
	(0.012)	(0.013)	(0.012)
Video games console (Benchmark: None)			
Yes, and I use it	−0.008	−0.005	−0.006
	(0.005)	(0.006)	(0.005)
Yes, but I don't use it	0.006	0.012*	0.009
	(0.007)	(0.007)	(0.007)
Cell phone without Internet access (Benchmark: None)			
Yes, and I use it	−0.000	0.003	0.001
	(0.005)	(0.006)	(0.005)
Yes, but I don't use it	0.012**	0.010	0.010*
	(0.006)	(0.006)	(0.006)
Cell phone with Internet access (Benchmark: None)			
Yes, and I use it	−0.001	−0.015	−0.013
	(0.012)	(0.013)	(0.012)
Yes, but I don't use it	−0.025*	−0.020	−0.022
	(0.015)	(0.017)	(0.015)
Portable music player (Benchmark: None)			
Yes, and I use it	−0.019***	−0.021***	−0.020***
	(0.005)	(0.005)	(0.005)

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
Yes, but I don't use it	−0.007	−0.009	−0.015**
	(0.007)	(0.008)	(0.007)
Printer (Benchmark: None)			
Yes, and I use it	0.003	0.011*	0.013**
	(0.005)	(0.006)	(0.005)
Yes, but I don't use it	−0.008	−0.005	0.008
	(0.007)	(0.008)	(0.007)
USB (memory) stick (Benchmark: None)			
Yes, and I use it	0.036***	0.036***	0.045***
	(0.006)	(0.006)	(0.006)
Yes, but I don't use it	0.003	0.009	0.006
	(0.008)	(0.009)	(0.008)
E-book readers (Benchmark: None)			
Yes, and I use it	−0.029***	−0.022***	−0.029***
	(0.007)	(0.008)	(0.008)
Yes, but I don't use it	−0.012	−0.010	−0.006
	(0.008)	(0.009)	(0.009)
Available for you to use at school			
Desktop computer (Benchmark: None)			
Yes, and I use it	0.018**	0.015*	0.018**
	(0.008)	(0.009)	(0.008)
Yes, but I don't use it	0.007	0.011	0.010
	(0.010)	(0.011)	(0.011)
Portable laptop or notebook (Benchmark: None)			
Yes, and I use it	−0.006	−0.003	−0.005
	(0.005)	(0.006)	(0.006)
Yes, but I don't use it	0.003	0.009	0.006
	(0.006)	(0.007)	(0.006)
Tablet computer (Benchmark: None)			
Yes, and I use it	−0.013**	−0.005	−0.005
	(0.006)	(0.006)	(0.006)
Yes, but I don't use it	−0.002	−0.001	0.008
	(0.006)	(0.007)	(0.006)
Internet-connected school computers (Benchmark: None)			
Yes, and I use it	0.016	0.030***	0.011
	(0.010)	(0.011)	(0.010)
Yes, but I don't use it	−0.002	0.025*	0.009
	(0.012)	(0.013)	(0.012)
Internet connection via wireless network (Benchmark: None)			
Yes, and I use it	0.024***	0.047***	0.025***

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
	(0.009)	(0.010)	(0.009)
Yes, but I don't use it	0.003	0.039***	0.018*
	(0.010)	(0.011)	(0.010)
Storage space for school-related data, e.g., a folder for own documents (Benchmark: None)			
Yes, and I use it	−0.003	0.001	−0.007
	(0.006)	(0.006)	(0.006)
Yes, but I don't use it	0.006	0.013*	0.001
	(0.007)	(0.008)	(0.007)
USB (memory) stick (Benchmark: None)			
Yes, and I use it	−0.001	−0.003	0.003
	(0.006)	(0.006)	(0.006)
Yes, but I don't use it	0.004	−0.006	−0.002
	(0.007)	(0.007)	(0.007)
E-book readers (Benchmark: None)			
Yes, and I use it	−0.033***	−0.033***	−0.033***
	(0.006)	(0.007)	(0.007)
Yes, but I don't use it	−0.021***	−0.025***	−0.025***
	(0.006)	(0.007)	(0.006)
Data projector (Benchmark: None)			
Yes, and I use it	0.042***	0.042***	0.044***
	(0.007)	(0.008)	(0.007)
Yes, but I don't use it	0.025***	0.019**	0.022***
	(0.008)	(0.009)	(0.009)
Interactive whiteboard (Benchmark: None)			
Yes, and I use it	−0.006	0.001	−0.002
	(0.005)	(0.006)	(0.006)
Yes, but I don't use it	0.013**	0.019***	0.015**
	(0.006)	(0.006)	(0.006)
Use experience			
How old were you when you first used a digital device? (Benchmark: 13 years old or older or never used a digital device until today)			
6 years old or younger	0.039***	0.040***	0.046***
	(0.009)	(0.010)	(0.009)
7–9 years old	0.026***	0.024***	0.027***
	(0.007)	(0.007)	(0.007)
10–12 years old	0.017***	0.024***	0.023***
	(0.006)	(0.007)	(0.006)
How old were you when you first used a computer? (Benchmark: 13 years old or older or never used a digital device until today)			
6 years old or younger	0.022**	0.030**	0.010
	(0.011)	(0.012)	(0.011)

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
7–9 years old	0.011	0.022**	0.001
	(0.008)	(0.009)	(0.009)
10–12 years old	0.019**	0.019**	0.008
	(0.008)	(0.009)	(0.008)
How old were you when you first accessed the Internet? (Benchmark: 13 years old or older or never used a digital device until today)			
6 years old or younger	−0.019*	−0.000	−0.011
	(0.011)	(0.012)	(0.011)
7–9 years old	−0.015**	0.007	−0.000
	(0.007)	(0.008)	(0.008)
10–12 years old	−0.011*	0.008	0.001
	(0.007)	(0.007)	(0.007)
Number of minutes/h of use per day			
During a typical weekday, for how long do you use the Internet at school? (Benchmark: No time)			
1–30 min per day	0.012*	0.021***	0.014**
	(0.007)	(0.007)	(0.007)
31–60 min per day	0.001	0.005	0.010
	(0.007)	(0.008)	(0.007)
Between 1 h and 2 h per day	0.001	0.002	−0.001
	(0.007)	(0.007)	(0.007)
Between 2 h and 4 h per day	−0.002	0.005	0.003
	(0.008)	(0.009)	(0.008)
Between 4 h and 6 h per day	−0.029***	−0.005	−0.009
	(0.010)	(0.011)	(0.010)
More than 6 h per day	−0.006	0.015	−0.009
	(0.011)	(0.012)	(0.011)
During a typical weekday, for how long do you use the Internet outside of school? (Benchmark: No time)			
1–30 min per day	−0.014	−0.020**	−0.002
	(0.009)	(0.010)	(0.009)
31–60 min per day	−0.007	0.002	0.007
	(0.008)	(0.009)	(0.009)
Between 1 h and 2 h per day	0.009	0.003	−0.003
	(0.008)	(0.009)	(0.008)
Between 2 h and 4 h per day	0.002	0.021**	0.012
	(0.008)	(0.009)	(0.008)
Between 4 h and 6 h per day	0.003	0.001	0.006
	(0.009)	(0.010)	(0.009)
More than 6 h per day	−0.002	−0.008	−0.006
	(0.009)	(0.010)	(0.009)
During a typical weekend day, for how long do you use the Internet outside of school? (Benchmark: No time)			

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
1–30 min per day	−0.016	−0.041***	−0.039***
	(0.013)	(0.014)	(0.013)
31–60 min per day	−0.012	0.017	−0.004
	(0.012)	(0.013)	(0.012)
Between 1 h and 2 h per day	−0.004	0.007	−0.002
	(0.011)	(0.012)	(0.011)
Between 2 h and 4 h per day	0.030***	0.034***	0.027**
	(0.010)	(0.012)	(0.011)
Between 4 h and 6 h per day	0.026**	0.033***	0.022**
	(0.011)	(0.012)	(0.011)
More than 6 h per day	0.030***	0.025**	0.023**
	(0.011)	(0.012)	(0.011)
Types of use ICT			
Use for playing games and for entertainment			
Playing one-player games (Benchmark: Never or hardly ever)			
Once or twice a month	0.017***	0.011	0.018***
	(0.006)	(0.007)	(0.006)
Once or twice a week	0.023***	0.011	0.015**
	(0.006)	(0.007)	(0.007)
Almost every day	0.022***	0.015**	0.026***
	(0.007)	(0.007)	(0.007)
Every day	0.013	0.008	0.026***
	(0.008)	(0.009)	(0.009)
Playing collaborative online games (Benchmark: Never or hardly ever)			
Once or twice a month	0.012*	0.002	0.010
	(0.006)	(0.007)	(0.007)
Once or twice a week	0.007	0.004	−0.003
	(0.007)	(0.007)	(0.007)
Almost every day	0.004	−0.004	0.007
	(0.007)	(0.008)	(0.008)
Every day	0.002	0.011	0.004
	(0.009)	(0.010)	(0.010)
Online games/social networks, e.g., Farmville, The Sims Social (Benchmark: Never or hardly ever)			
Once or twice a month	−0.004	−0.011	−0.002
	(0.006)	(0.007)	(0.006)
Once or twice a week	−0.002	−0.003	−0.002
	(0.007)	(0.007)	(0.007)
Almost every day	−0.016**	−0.014	−0.012
	(0.007)	(0.008)	(0.008)
Every day	−0.021***	−0.009	−0.016**

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
	(0.008)	(0.009)	(0.008)
Browsing the Internet for fun videos, e.g., YouTube (Benchmark: Never or hardly ever)			
Once or twice a month	0.004	0.023	0.010
	(0.013)	(0.015)	(0.014)
Once or twice a week	0.035***	0.025*	0.028**
	(0.012)	(0.013)	(0.012)
Almost every day	0.032***	0.015	0.023*
	(0.012)	(0.013)	(0.012)
Every day	0.023*	0.014	0.018
	(0.012)	(0.013)	(0.012)
Downloading music, films, games, or software from the Internet (Benchmark: Never or hardly ever)			
Once or twice a month	0.012	0.014	0.016
	(0.011)	(0.012)	(0.011)
Once or twice a week	0.016	0.019	0.029***
	(0.011)	(0.012)	(0.011)
Almost every day	0.017	0.006	0.014
	(0.011)	(0.012)	(0.011)
Every day	0.015	0.022*	0.020
	(0.012)	(0.013)	(0.012)
Use for communication and finding information but not related to education			
Using email (Benchmark: Never or hardly ever)			
Once or twice a month	0.013**	0.011	0.012*
	(0.006)	(0.007)	(0.006)
Once or twice a week	−0.006	0.005	0.002
	(0.006)	(0.007)	(0.007)
Almost every day	−0.011	−0.007	−0.002
	(0.007)	(0.008)	(0.008)
Every day	−0.030***	−0.022**	−0.019**
	(0.009)	(0.010)	(0.009)
Chatting online, e.g., MSN (Benchmark: Never or hardly ever)			
Once or twice a month	0.001	0.005	−0.002
	(0.010)	(0.012)	(0.011)
Once or twice a week	−0.003	0.002	0.001
	(0.009)	(0.010)	(0.010)
Almost every day	−0.007	−0.002	−0.005
	(0.009)	(0.010)	(0.009)
Every day	−0.002	0.010	0.001
	(0.009)	(0.010)	(0.009)
Social networks, e.g., Facebook (Benchmark: Never or hardly ever)			
Once or twice a month	−0.011	0.003	−0.007

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
	(0.012)	(0.014)	(0.013)
Once or twice a week	0.012	0.015	0.008
	(0.011)	(0.013)	(0.012)
Almost every day	0.003	0.020*	0.012
	(0.010)	(0.012)	(0.011)
Every day	0.011	0.016	0.013
	(0.010)	(0.012)	(0.011)
Reading news on the Internet (Benchmark: Never or hardly ever)			
Once or twice a month	0.007	−0.003	−0.003
	(0.010)	(0.011)	(0.010)
Once or twice a week	−0.008	0.002	−0.007
	(0.009)	(0.010)	(0.009)
Almost every day	0.012	0.015	0.013
	(0.009)	(0.011)	(0.010)
Every day	0.009	0.018	0.010
	(0.010)	(0.012)	(0.011)
Obtaining practical information from the Internet (Benchmark: Never or hardly ever)			
Once or twice a month	−0.023**	−0.034***	−0.029***
	(0.009)	(0.010)	(0.010)
Once or twice a week	−0.002	−0.015	−0.007
	(0.009)	(0.010)	(0.009)
Almost every day	−0.007	−0.018*	−0.003
	(0.009)	(0.010)	(0.010)
Every day	0.001	−0.022*	0.001
	(0.010)	(0.012)	(0.011)
Uploading your own created content for sharing (Benchmark: Never or hardly ever)			
Once or twice a month	−0.018***	−0.015**	−0.019***
	(0.007)	(0.007)	(0.007)
Once or twice a week	−0.024***	−0.027***	−0.027***
	(0.007)	(0.007)	(0.007)
Almost every day	−0.032***	−0.032***	−0.038***
	(0.007)	(0.008)	(0.008)
Every day	−0.025***	−0.028***	−0.032***
	(0.009)	(0.010)	(0.009)
Downloading new apps on a mobile device (Benchmark: Never or hardly ever)			
Once or twice a month	0.011	−0.005	0.007
	(0.009)	(0.010)	(0.009)
Once or twice a week	−0.012	−0.012	−0.016*
	(0.009)	(0.010)	(0.009)
Almost every day	−0.012	−0.015	−0.015

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
	(0.010)	(0.011)	(0.010)
Every day	−0.003	−0.020	−0.010
	(0.011)	(0.012)	(0.011)
Use for education			
Browsing the Internet for schoolwork (e.g., for preparing an essay or presentation) (Benchmark: Never or hardly ever)			
Once or twice a month	0.005	−0.023*	0.002
	(0.011)	(0.012)	(0.011)
Once or twice a week	0.007	−0.011	0.009
	(0.011)	(0.012)	(0.011)
Almost every day	0.016	0.001	0.012
	(0.012)	(0.013)	(0.012)
Every day	0.017	0.012	0.020
	(0.014)	(0.016)	(0.015)
Browsing the Internet to follow up lessons, e.g., for finding explanations (Benchmark: Never or hardly ever)			
Once or twice a month	0.014	0.018	0.022*
	(0.011)	(0.012)	(0.011)
Once or twice a week	0.025**	0.020	0.030**
	(0.011)	(0.012)	(0.012)
Almost every day	0.021*	0.023*	0.022*
	(0.012)	(0.013)	(0.012)
Every day	0.026*	0.035**	0.022
	(0.015)	(0.017)	(0.016)
Using email for communication with other students about schoolwork (Benchmark: Never or hardly ever)			
Once or twice a month	−0.015*	−0.020**	−0.012
	(0.008)	(0.009)	(0.008)
Once or twice a week	−0.002	−0.016*	−0.009
	(0.008)	(0.009)	(0.009)
Almost every day	−0.006	−0.019*	−0.010
	(0.009)	(0.010)	(0.009)
Every day	0.000	−0.010	−0.011
	(0.011)	(0.012)	(0.011)
Using email for communication with teacher (Benchmark: Never or hardly ever)			
Once or twice a month	−0.006	0.009	0.001
	(0.007)	(0.008)	(0.008)
Once or twice a week	0.001	0.001	−0.003
	(0.008)	(0.009)	(0.008)
Almost every day	−0.010	−0.009	−0.011
	(0.009)	(0.010)	(0.010)

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
Every day	−0.017	−0.029**	−0.027**
	(0.012)	(0.013)	(0.012)
Using social networks for communication with other students about schoolwork (Benchmark: Never or hardly ever)			
Once or twice a month	0.008	−0.003	0.022*
	(0.013)	(0.014)	(0.013)
Once or twice a week	0.014	0.014	0.011
	(0.012)	(0.013)	(0.012)
Almost every day	0.003	0.000	0.012
	(0.012)	(0.013)	(0.012)
Every day	0.008	0.006	0.010
	(0.012)	(0.014)	(0.013)
Using social networks for communication with teachers (Benchmark: Never or hardly ever)			
Once or twice a month	−0.003	−0.002	0.004
	(0.008)	(0.009)	(0.008)
Once or twice a week	−0.001	−0.008	−0.001
	(0.008)	(0.009)	(0.008)
Almost every day	−0.005	−0.004	−0.002
	(0.008)	(0.009)	(0.009)
Every day	−0.013	−0.022**	−0.019**
	(0.009)	(0.010)	(0.009)
Checking the school's website for announcements (Benchmark: Never or hardly ever)			
Once or twice a month	0.023***	0.008	0.017**
	(0.007)	(0.007)	(0.007)
Once or twice a week	0.010	0.006	0.008
	(0.007)	(0.008)	(0.007)
Almost every day	0.023***	0.016*	0.022**
	(0.009)	(0.010)	(0.009)
Every day	0.008	0.010	0.012
	(0.012)	(0.013)	(0.012)
Doing homework on a computer (Benchmark: Never or hardly ever)			
Once or twice a month	0.014	0.008	0.011
	(0.009)	(0.010)	(0.009)
Once or twice a week	0.015*	0.024**	0.018**
	(0.009)	(0.010)	(0.009)
Almost every day	0.010	0.020*	0.015
	(0.009)	(0.011)	(0.010)
Every day	0.017	0.031**	0.019
	(0.012)	(0.013)	(0.012)
Doing homework on a mobile device (Benchmark: Never or hardly ever)			

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
Once or twice a month	−0.007	−0.009	−0.001
	(0.008)	(0.009)	(0.009)
Once or twice a week	−0.004	0.005	0.009
	(0.008)	(0.009)	(0.009)
Almost every day	0.016*	0.018*	0.019**
	(0.009)	(0.010)	(0.009)
Every day	0.015	0.008	0.028**
	(0.011)	(0.012)	(0.011)
Downloading learning apps on a mobile device (Benchmark: Never or hardly ever)			
Once or twice a month	0.010	0.007	0.006
	(0.008)	(0.009)	(0.009)
Once or twice a week	−0.010	−0.013	−0.009
	(0.009)	(0.010)	(0.010)
Almost every day	0.000	−0.019	−0.013
	(0.011)	(0.012)	(0.011)
Every day	0.010	−0.012	0.003
	(0.014)	(0.015)	(0.014)
Downloading science learning apps on a mobile device (Benchmark: Never or hardly ever)			
Once or twice a month	−0.005	0.009	0.002
	(0.008)	(0.008)	(0.008)
Once or twice a week	−0.000	0.004	−0.003
	(0.009)	(0.010)	(0.009)
Almost every day	−0.012	0.002	−0.011
	(0.011)	(0.012)	(0.011)
Every day	−0.030**	−0.022	−0.026*
	(0.014)	(0.015)	(0.014)
Demand control variables (Student characteristics and Family characteristics)			
Gender (Benchmark: Female)			
Male	−0.014***	0.032***	0.025***
	(0.005)	(0.005)	(0.005)
Mother's educational attainment (Benchmark: No education)			
Primary education	−0.022**	−0.010	0.005
	(0.011)	(0.012)	(0.011)
Lower-secondary education	−0.046***	−0.011	−0.003
	(0.011)	(0.013)	(0.012)
Upper-secondary education	−0.042***	−0.023*	−0.007
	(0.011)	(0.012)	(0.011)
Bachelor's degree and higher	−0.024*	0.007	0.009
	(0.012)	(0.014)	(0.013)
Father's educational attainment (Benchmark: No education)			

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
Primary education	−0.009	0.023*	−0.006
	(0.011)	(0.012)	(0.011)
Lower-secondary education	−0.023*	0.014	−0.009
	(0.012)	(0.013)	(0.012)
Upper-secondary education	−0.013	0.017	−0.008
	(0.011)	(0.013)	(0.012)
Bachelor's degree and higher	0.002	0.034**	0.007
	(0.013)	(0.014)	(0.013)
Mother's' main occupation (Benchmark: Basic occupation)			
Civil service/manager	0.009	0.017	0.005
	(0.010)	(0.011)	(0.010)
Professional	0.022***	0.027***	0.024***
	(0.008)	(0.009)	(0.009)
Technician	0.020**	0.024**	0.020**
	(0.009)	(0.010)	(0.009)
Clerk	0.033***	0.040***	0.034***
	(0.010)	(0.012)	(0.011)
Service staff	0.012**	0.017**	0.013**
	(0.006)	(0.007)	(0.006)
Agricultural worker	0.006	0.020**	0.014*
	(0.008)	(0.008)	(0.008)
Craftsman	−0.017*	−0.004	−0.013
	(0.010)	(0.011)	(0.011)
Industrial machine controller	0.010	0.011	0.020
	(0.016)	(0.018)	(0.017)
Father's main occupation (Benchmark: Basic occupation)			
Civil service/manager	0.009	0.012	0.009
	(0.008)	(0.009)	(0.008)
Professional	0.020**	0.019*	0.023**
	(0.009)	(0.010)	(0.009)
Technician	0.010	0.008	0.007
	(0.009)	(0.010)	(0.010)
Clerk	−0.013	−0.018	−0.019
	(0.013)	(0.015)	(0.014)
Service staff	0.005	0.017**	0.011
	(0.007)	(0.008)	(0.007)
Agricultural worker	−0.004	−0.008	−0.004
	(0.007)	(0.008)	(0.008)
Craftsman	0.014*	0.000	0.013
	(0.008)	(0.009)	(0.008)

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
Industrial machine controller	0.020***	0.016**	0.016**
	(0.007)	(0.008)	(0.008)
Economic status (Benchmark: Very poor)			
Poor	0.007	−0.009	−0.002
	(0.009)	(0.010)	(0.009)
Middle	0.006	−0.013	−0.003
	(0.013)	(0.015)	(0.014)
Wealthy	0.003	−0.012	0.003
	(0.019)	(0.021)	(0.019)
Very wealthy	0.035	0.018	0.037
	(0.024)	(0.027)	(0.025)
Have a desk to study (Benchmark: none)	0.012*	−0.009	−0.001
	(0.007)	(0.007)	(0.007)
Have a room of your own (Benchmark: none)	−0.007	−0.008	−0.012**
	(0.005)	(0.005)	(0.005)
Have a quiet place to study (Benchmark: none)	0.018***	0.010*	0.011**
	(0.005)	(0.005)	(0.005)
Have a computer you can use for school work (Benchmark: none)	−0.006	−0.020**	−0.009
	(0.007)	(0.008)	(0.007)
Have educational software (Benchmark: none)	0.013***	0.018***	0.013***
	(0.004)	(0.005)	(0.004)
Have a link to the Internet (Benchmark: none)	0.014*	0.010	0.017**
	(0.007)	(0.008)	(0.007)
Have classic literature (Benchmark: none)	0.008*	0.015***	0.017***
	(0.004)	(0.005)	(0.005)
Have books of poetry (Benchmark: none)	−0.001	0.008	−0.004
	(0.004)	(0.005)	(0.005)
Have works of art (e.g. paintings (Benchmark: none)	−0.011**	−0.019***	−0.016***
	(0.004)	(0.005)	(0.005)
Have books to help with your school work (Benchmark: none)	0.013**	−0.010	0.004
	(0.007)	(0.007)	(0.007)
Have technical reference books (Benchmark: none)	0.017***	0.015***	0.016***
	(0.004)	(0.005)	(0.005)
Have a dictionary (Benchmark: none)	0.013**	−0.002	0.002
	(0.006)	(0.007)	(0.007)
Have books on art, music, or design (Benchmark: none)	0.000	0.011**	0.008
	(0.005)	(0.005)	(0.005)
Have an air conditioner (Benchmark: none)	0.006	0.005	−0.001
	(0.007)	(0.007)	(0.007)
Have a massage chair (Benchmark: none)	−0.028***	−0.017**	−0.028***
	(0.008)	(0.009)	(0.008)
Have a microwave (Benchmark: none)	−0.003	−0.009	−0.008

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
	(0.006)	(0.006)	(0.006)
Televisions (Benchmark: none)			
One	−0.054**	−0.054**	−0.061**
	(0.024)	(0.027)	(0.025)
Two	−0.056**	−0.057**	−0.062**
	(0.024)	(0.027)	(0.025)
Three or more	−0.063**	−0.067**	−0.078***
	(0.024)	(0.027)	(0.025)
Cars (Benchmark: none)			
One	0.004	0.009	0.005
	(0.006)	(0.006)	(0.006)
Two	−0.018**	−0.004	−0.006
	(0.007)	(0.008)	(0.007)
Three or more	−0.025***	−0.015	−0.008
	(0.008)	(0.009)	(0.009)
Rooms with a bath or shower (Benchmark: none)			
One	−0.004	0.007	0.001
	(0.006)	(0.006)	(0.006)
Two	−0.000	−0.000	0.001
	(0.007)	(0.008)	(0.007)
Three or more	0.022**	0.012	0.009
	(0.009)	(0.010)	(0.009)
Cell phones with Internet access (Benchmark: none)			
One	0.013	0.037***	0.015
	(0.011)	(0.013)	(0.012)
Two	0.025**	0.043***	0.023*
	(0.012)	(0.013)	(0.012)
Three or more	0.035***	0.043***	0.025**
	(0.012)	(0.013)	(0.012)
Computers (Benchmark: none)			
One	0.018**	0.024***	0.019**
	(0.008)	(0.009)	(0.009)
Two	0.031***	0.028**	0.024**
	(0.011)	(0.012)	(0.011)
Three or more	0.035***	0.050***	0.040***
	(0.012)	(0.014)	(0.013)
Tablet computers (Benchmark: none)			
One	−0.007	−0.011	−0.008
	(0.007)	(0.007)	(0.007)
Two	−0.007	−0.004	−0.009

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
	(0.009)	(0.010)	(0.009)
Three or more	0.008	−0.002	−0.003
	(0.011)	(0.012)	(0.011)
E-book readers (Benchmark: none)			
One	−0.035***	−0.024***	−0.034***
	(0.007)	(0.008)	(0.007)
Two	−0.014	0.004	−0.035**
	(0.014)	(0.015)	(0.014)
Three or more	−0.043***	−0.091***	−0.030**
	(0.015)	(0.017)	(0.015)
Musical instruments (Benchmark: none)			
One	0.017***	0.018***	0.017***
	(0.005)	(0.005)	(0.005)
Two	0.038***	0.028***	0.026***
	(0.007)	(0.007)	(0.007)
Three or more	0.021***	0.040***	0.032***
	(0.007)	(0.008)	(0.008)
I often worry that it will be difficult for me to take a test (Benchmark: Strongly disagree)			
Disagree	0.023**	0.021*	0.021*
	(0.011)	(0.012)	(0.011)
Agree	0.010	0.015	0.007
	(0.011)	(0.012)	(0.012)
Strongly agree	−0.006	−0.016	0.002
	(0.013)	(0.014)	(0.013)
I worry that I will get poor grades at school (Benchmark: Strongly disagree)			
Disagree	−0.009	−0.000	−0.008
	(0.013)	(0.014)	(0.013)
Agree	0.010	0.008	0.003
	(0.013)	(0.014)	(0.013)
Strongly agree	0.020	0.005	0.008
	(0.014)	(0.016)	(0.014)
Even if I am well-prepared for a test I feel very anxious (Benchmark: Strongly disagree)			
Disagree	−0.012	−0.004	−0.001
	(0.010)	(0.011)	(0.010)
Agree	−0.020*	−0.016	−0.016
	(0.010)	(0.011)	(0.010)
Strongly agree	−0.016	−0.006	−0.014
	(0.012)	(0.014)	(0.013)
I get very tense when I study for a test (Benchmark: Strongly disagree)			
Disagree	−0.007	−0.016*	−0.006

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
	(0.008)	(0.009)	(0.008)
Agree	−0.015*	−0.029***	−0.015*
	(0.008)	(0.009)	(0.009)
Strongly agree	−0.025**	−0.027**	−0.023**
	(0.011)	(0.012)	(0.012)
I get nervous when I don't know how to solve a task at school (Benchmark: Strongly disagree)			
Disagree	−0.003	−0.004	−0.004
	(0.008)	(0.009)	(0.008)
Agree	−0.009	−0.006	−0.009
	(0.008)	(0.009)	(0.009)
Strongly agree	−0.003	−0.017	−0.006
	(0.010)	(0.012)	(0.011)
I want top grades in most or all of my courses (Benchmark: Strongly disagree)			
Disagree	−0.023	−0.021	−0.021
	(0.027)	(0.030)	(0.028)
Agree	−0.027	−0.018	−0.015
	(0.026)	(0.029)	(0.027)
Strongly agree	−0.028	−0.016	−0.010
	(0.026)	(0.030)	(0.027)
I want to be able to select from among the best opportunities available when I graduate (Benchmark: Strongly disagree)			
Disagree	−0.008	0.021	−0.011
	(0.040)	(0.045)	(0.041)
Agree	0.029	0.046	0.001
	(0.039)	(0.043)	(0.040)
Strongly agree	0.048	0.066	0.018
	(0.039)	(0.043)	(0.040)
I want to be the best, whatever I do (Benchmark: Strongly disagree)			
Disagree	0.005	−0.070	−0.005
	(0.040)	(0.045)	(0.042)
Agree	0.028	−0.023	0.014
	(0.039)	(0.043)	(0.040)
Strongly agree	0.030	−0.018	0.020
	(0.039)	(0.043)	(0.040)
I see myself as an ambitious person (Benchmark: Strongly disagree)			
Disagree	−0.007	−0.011	−0.008
	(0.012)	(0.013)	(0.012)
Agree	−0.005	−0.011	−0.012
	(0.012)	(0.013)	(0.012)
Strongly agree	−0.016	−0.008	−0.014

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
	(0.013)	(0.014)	(0.013)
I want to be one of the best students in my class (Benchmark: Strongly disagree)			
Disagree	0.002	−0.008	0.007
	(0.012)	(0.014)	(0.013)
Agree	−0.016	−0.026*	−0.007
	(0.012)	(0.014)	(0.013)
Strongly agree	−0.012	−0.035**	−0.008
	(0.013)	(0.014)	(0.013)
Eat breakfast before going to school (Benchmark: don't)	−0.005	−0.003	−0.007
	(0.006)	(0.007)	(0.006)
Study for school or homework before going to school (Benchmark: don't)	−0.022***	−0.019***	−0.016***
	(0.005)	(0.006)	(0.005)
Watch TV, DVD, Video before going to school (Benchmark: don't)	−0.014***	−0.007	−0.011**
	(0.005)	(0.006)	(0.005)
Read a book before going to school (Benchmark: don't)	0.015***	0.015***	0.015***
	(0.005)	(0.006)	(0.005)
Internet/Chat/Social networks, e.g., Facebook before going to school (Benchmark: don't)	0.007	−0.001	−0.005
	(0.006)	(0.007)	(0.006)
Play video-games before going to school (Benchmark: don't)	−0.010*	0.001	−0.008
	(0.006)	(0.006)	(0.006)
Meet friends or talk to friends on the phone before going to school (Benchmark: don't)	0.000	−0.008	−0.006
	(0.005)	(0.006)	(0.005)
Talk to your parents before going to school (Benchmark: don't)	0.005	−0.004	0.004
	(0.008)	(0.009)	(0.008)
Work in the household before going to school (Benchmark: don't)	0.006	0.003	0.001
	(0.005)	(0.006)	(0.005)
Work for pay before going to school (Benchmark: don't)	−0.016**	−0.005	−0.013*
	(0.006)	(0.007)	(0.007)
Exercise or practice a sport before going to school (Benchmark: don't)	−0.012**	−0.014**	−0.016***
	(0.005)	(0.006)	(0.005)
Eat dinner after leaving school (Benchmark: don't)	0.009	0.001	0.023**
	(0.009)	(0.010)	(0.009)
Study for school or homework after leaving school (Benchmark: don't)	0.029***	0.023***	0.025***
	(0.007)	(0.007)	(0.007)
Watch TV, DVD, video after leaving school (Benchmark: don't)	−0.011*	−0.007	−0.005
	(0.006)	(0.007)	(0.007)
Read a book/newspaper/magazine after leaving school (Benchmark: don't)	0.007	0.008	0.007
	(0.005)	(0.006)	(0.005)
Internet/Chat/Social networks e.g., Facebook after leaving school (Benchmark: don't)	0.005	−0.012	0.001
	(0.009)	(0.010)	(0.010)
Play video-games before going to school after leaving school (Benchmark: don't)	−0.005	−0.001	−0.005
	(0.005)	(0.006)	(0.006)
Meet friends or talk to friends on the phone after leaving school (Benchmark: don't)	−0.004	−0.008	−0.015***
	(0.005)	(0.006)	(0.006)
	0.005	0.020*	0.012

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
Talk to your parents before going to school after leaving school (Benchmark: don't)	(0.010)	(0.011)	(0.010)
Work in the household after leaving school (Benchmark: don't)	−0.016***	−0.021***	−0.012*
	(0.006)	(0.007)	(0.006)
Work for pay after leaving school (Benchmark: don't)	−0.022***	−0.021***	−0.016**
	(0.006)	(0.007)	(0.006)
Exercise or practice a sport after leaving school (Benchmark: don't)	0.002	0.008	0.010**
	(0.005)	(0.005)	(0.005)
Supply Control Variables (School characteristics, Teacher characteristics, and Learning and teaching)			
School location (Benchmark: Countryside)			
Town	0.002	−0.004	−0.013*
	(0.007)	(0.008)	(0.007)
Metropolitan	0.013	0.016*	0.004
	(0.008)	(0.009)	(0.008)
Number of students in class (Benchmark: More than 50 students)			
15 students or fewer	0.052*	0.069**	0.100***
	(0.031)	(0.035)	(0.032)
16–20 students	−0.002	0.022	0.031
	(0.026)	(0.029)	(0.027)
21–25 students	0.050***	0.067***	0.096***
	(0.018)	(0.020)	(0.019)
26–30 students	−0.008	0.003	0.023
	(0.018)	(0.020)	(0.018)
31–35 students	−0.012	0.005	0.024
	(0.017)	(0.019)	(0.018)
36–40 students	−0.001	−0.005	0.031*
	(0.017)	(0.019)	(0.018)
41–45 students	−0.004	−0.013	0.015
	(0.017)	(0.019)	(0.018)
46–50 students	0.007	0.015	0.035*
	(0.018)	(0.020)	(0.019)
The school has an orchestra/band activity (Benchmark: none)	−0.005	−0.010	−0.012
	(0.007)	(0.008)	(0.008)
The school has a musical activity (Benchmark: none)	0.018**	0.012	0.013*
	(0.007)	(0.008)	(0.008)
The school has a year report (Benchmark: none)	0.020***	0.019**	0.033***
	(0.007)	(0.008)	(0.007)
The school has a volunteering or service activity (Benchmark: none)	−0.001	−0.006	0.001
	(0.006)	(0.007)	(0.006)
The school has a science club (Benchmark: none)	−0.007	−0.023**	−0.018**
	(0.008)	(0.009)	(0.009)
The school has science competitions (Benchmark: none)	0.003	0.004	0.009*
	(0.005)	(0.006)	(0.006)

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
The school has a chess club (Benchmark: none)	0.028***	0.017***	0.022***
	(0.005)	(0.005)	(0.005)
The school has ICT (Benchmark: none)	0.014	0.012	0.004
	(0.011)	(0.012)	(0.012)
The school has an art club (Benchmark: none)	0.046***	0.070***	0.047***
	(0.012)	(0.013)	(0.012)
The school has a sport team (Benchmark: none)	0.038	−0.012	0.022
	(0.026)	(0.028)	(0.027)
The school has events held during the school day, such as Candle Festival (Benchmark: none)	−0.096***	−0.065***	−0.039*
	(0.020)	(0.022)	(0.020)
Our school invites specialists to conduct in-service training for teachers (Benchmark: none)	−0.023***	−0.002	−0.002
	(0.008)	(0.009)	(0.008)
Science teaching staff in your school has attended a program of professional development	−0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)
Lack of teaching staff (Benchmark: A lot)			
Not at all	−0.029***	−0.037***	−0.036***
	(0.008)	(0.009)	(0.009)
Very little	−0.008	0.001	−0.012
	(0.008)	(0.008)	(0.008)
Medium	−0.006	0.001	−0.019***
	(0.007)	(0.008)	(0.007)
Poorly qualified teaching staff (Benchmark: A lot)			
Not at all	0.014	0.024	0.029**
	(0.014)	(0.015)	(0.014)
Very little	−0.005	0.012	0.013
	(0.013)	(0.015)	(0.014)
Medium	−0.032**	−0.022	−0.015
	(0.013)	(0.015)	(0.014)
Lack of IT equipment (Benchmark: A lot)			
Not at all	0.008	0.020	0.026**
	(0.012)	(0.014)	(0.013)
Very little	0.018	0.014	0.032**
	(0.012)	(0.013)	(0.012)
Medium	0.026**	0.014	0.035***
	(0.011)	(0.012)	(0.011)
Poorly qualified IT equipment (Benchmark: A lot)			
Not at all	0.004	−0.007	−0.003
	(0.013)	(0.015)	(0.014)
Very little	0.002	−0.009	−0.010
	(0.013)	(0.015)	(0.014)
Medium	0.003	0.005	0.006
	(0.012)	(0.013)	(0.012)

Table 5 (continued)

Variable	2015 PISA Score		
	Reading	Mathematics	Science
Full-time science teaching staff with a bachelor's degree or higher	−0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Part-time science teaching staff with a bachelor's degree or higher	0.000*	0.000	0.000
	(0.000)	(0.000)	(0.000)
Inquiry-based science teaching and learning practices (Benchmark: Never)			
Hardly ever	0.007	0.024***	0.014**
	(0.006)	(0.007)	(0.006)
Sometimes	0.018***	0.032***	0.026***
	(0.006)	(0.007)	(0.006)
Almost every time	0.009	0.031***	0.025***
	(0.006)	(0.007)	(0.006)
Every time	0.010	0.028***	0.023***
	(0.006)	(0.007)	(0.007)
Constant	5.857***	5.869***	5.804***
	(0.060)	(0.067)	(0.062)
R-squared	0.714	0.644	0.682
Observations	3809	3809	3809

Note: Standard errors are in brackets. * Significant at 10%; ** significant at 5%; *** significant at 1%

Source: Calculated by the researcher from 2015 PISA student questionnaire data

Although computer availability/unavailability seemed to have no positive impact on education in Thailand, students who had school Wi-Fi access tended to have better scores in reading (2.4%), science (2.5%), and mathematics (4.7%) than did students who had no access to school Wi-Fi. This is consistent with Delen and Bulut's study (2011) indicating that Internet access is important for useful data searching, which is important for improvements in educational quality.

As for ICT use experience, students who had ICT experience since childhood would be more familiar with adapting it for educational purposes than would students who had just begun using ICT or who had never used it before. Findings reveal that students who had used digital gadgets from age six or younger had better scores in reading (3.9%), mathematics (4.0%), and science (4.6%) than did students who only began to use such devices from age 13 or later or who had never used such devices. Furthermore, students who had used a computer from age six or earlier had better scores in reading (2.2%) and mathematics (3.0%) than did students who had begun to use a computer from age 13 or later or who had never used one, which is consistent with Leino's study (2014) indicating that students who are familiar with reading from a computer also have good reading scores.

In terms of the duration of Internet usage on weekdays in schools, students who used the Internet 1–30 min per day had better scores in reading (1.2%), science

(1.4%), and mathematics (2.1) than did students who did not use the Internet at all. And an examination of Internet usage on weekends indicates that students who used the Internet 2–4 h per day had better scores in science (2.7%), reading (3.0%), and mathematics (3.4%) than did students who did not use the Internet at all.

An analysis of types of usage finds that students who played single-player games almost every day had better scores in mathematics (1.5%), reading (2.2%), and science (2.6%) than did students who never or almost never played a single-player game. But students who played social platform multi-player games every day (or often) suffered negative impacts on education outcomes, especially in reading (a 2.1% decrease) and science (a 1.6% decrease) than did students who never played a social platform multi-player game. We also find that students who surfed the Internet for entertainment, such as watching YouTube once or twice per week, had better scores in mathematics (2.5%), science (2.8%), and reading (3.5%) than did students who never or almost never watched YouTube, which is consistent with Zhang and Liu's (2016) study of the 2000–2012 PISA results, indicating that students who used ICT for entertainment had a positive relationship with mathematics and science because entertainment helps to relieve stress and enhance concentration as they study and to thus enhance their thinking. Similarly, Bulut and Cutumisu's study (2017) indicates that ICT utilization for entertainment purposes had positive impacts on the mathematics and science scores of Turkish students. However, ICT should not be used for entertainment purposes for too long a time since doing so can decrease science scores.

As for study-related communication, students who used ICT lessons and exercises to follow up on their classroom and other studies had better scores in reading (2.1%), science (2.2%), and mathematics (2.3%) than did students who never or almost never used ICT to follow up on their study of a subject. Similarly, students who checked information on their school website almost every day had better scores in mathematics (1.6%), science (2.2%), and reading (2.3%) than did students who never or almost never checked information on their school website. Furthermore, students who did their homework on a computer once or twice per week had better scores in reading (1.5%), science (1.8%), and mathematics (2.4%) than did students who never or almost never did homework on a computer. Moreover, students who did their homework on a mobile phone almost every day had better scores in reading (1.6%), mathematics (1.8%), and science (1.9%) than did students who never or almost never did homework on a mobile phone, which is consistent with Kubiatko and Vickova's study (2010) stating that students who used the Internet and engaged in ICT activities for educational purposes had better science scores than did students who did not and that students who used email at their schools every day had better scores in reading (2.5%), mathematics (2.8%), and science (2.8%) than did students who never or almost never used email at their schools.

As for ICT utilization for non-educational purposes (such as emails, online chats, receiving important data from the Internet or uploading user-created content for sharing), results indicate that students who uploaded user-created content for sharing almost every day turned out to have lower scores in reading (3.2%), mathematics (3.2%), and science (3.8%) than did students who never or almost never uploaded such content. Moreover, we find that students who chatted online almost every day did have

1.6% lower mathematics and science scores than did students who never or almost never chatted online.

Furthermore, reading news, receiving useful information, downloading songs, movies, games, or software from the Internet, and downloading new applications on mobile phones nevertheless had no significant effect on education outcomes. Therefore, in general, it may be concluded that ICT has significant positive impacts on education outcomes when used mainly for educational purposes, while utilization for communication or data searching (including sharing and updating data) has no impact on education outcomes. On the other hand, using emails, online chats, receiving important information from the Internet or uploading user-created content for sharing can have a negative impact on education outcomes.

5 Conclusion and policy recommendations

ICT familiarity plays a key role making it possible to successfully enter into the new economic system that requires technology and digital media (an Innovative and Digital-Driven-Economy). Upgrading ICT familiarity will directly impact human resources of a country, as measured by the education outcomes. Previous studies have dealt mainly with developed countries and have not investigated the impacts of ICT familiarity on education outcomes in developing countries, given their limited access to such technology. This study uses national survey data from Thailand as a case study for developing countries to study ICT familiarity's impacts on education outcomes.

Findings here indicate that students who gain experience and familiarity with ICT from childhood get higher scores in reading, mathematics, and science than do students who are just beginning to use ICT or who have never used it at all. In terms of daily usage, we find that there is a positive effect on education scores as long as usage is limited to 1–30 min per day on weekdays in schools and 2–4 h per day on weekends.

Moreover, interesting study results are found and are consistent with studies done in developed countries. Namely, we find that utilization of ICT that is directly related to education has significant positive impacts on education outcomes while utilization of ICT that is not related to education has no impact in any way (or may even create negative impacts depending on the type of usage) on education outcomes.

Therefore, in order to upgrade education quality for children and youths of the country, the government and related organizations (including families) should ensure that children and youths have an opportunity to utilize ICT mainly for educational purposes and control non-educational use to ensure that it is used appropriately.

As a foundation for specific policy recommendations, we must keep in mind that ICT provides Thailand, as well as other developing countries, many opportunities to transform teaching, learning, and management practices in schools. In a developing country like Thailand, ICT fosters not only critical and creative thinking, capabilities to solve real-world problems, ability to work collaboratively, engagement in ethical decision-making, and adoption of a global perspective towards issues and ideas, but it also provides students from remote areas access to expert teachers and learning resources and gives administrators and policy makers the data and expertise they need to work more efficiently. Therefore, policy recommendations should address both supply-side and the demand-side concerns.

As for the supply side, our results show that merely having computer equipment at home does not contribute to better education scores. But students who used computers in school had better scores in mathematics, reading, and science than did students who had no access to school computers. Therefore, the government should focus on providing better access to ICT in school, especially in rural schools that face infrastructure constraints that impede the use of ICT in the classroom along with a lack of capacity in terms of teachers and school leaders to promote and use ICT to enhance the quality of teaching and learning. In addition, building the capacity of teachers, administrators, and other education leaders to use and integrate ICT in education systems is crucial. In addition, government can boost schools' effective use of ICT by working with tertiary institutions that act as capacity-building providers. In this case, the governments should create incentives for universities to provide training to schools about how to use ICT in education.

In terms of the demand side, since our results show that students who have more experience in using ICT, have better access to the Internet, and use ICT primarily for the purpose of education tend to have better scores in reading, mathematics, and science, the government should provide students, as well as their parents, guidelines on how to utilize ICT in the most appropriate ways. Providing better Internet access, especially to remote areas, would benefit underprivileged students by making it easier for them to gather information from websites, access online education, and use email/text messages for education purposes. This would improve their learning outcomes and narrow thesocioeconomic gaps caused by educational inequality.

In conclusion, ICT provides a developing country like Thailand the opportunity to transform teaching, learning, and management practices in schools. The need for this transformation is urgent, given the increasingly globalized world in which students and teachers now live. Without it, as future graduates they could end up as part of a workforce that cannot keep up with the demands of the twenty-first century.

References

Adam, T., & Tatnall, A. (2017). The value of using ICT in the education of school students with learning difficulties. *Education and Information Technologies, 22*(6), 2711–2726.

Aypay, A. (2010). Information and communication technology (ICT) usage and achievement of Turkish students in PISA 2006. *The Turkish Online Journal of Educational Technology, 9*(2), 116–124.

Biagi, F., & Loi, M. (2013). Measuring ICT use and learning outcomes: Evidence from recent econometric studies. *European Journal of Education Research, Development and Policy, 48*(1), 23–42.

Bulut, O., & Cutumisu, M. (2017). When technology does not add up: ICT use negatively predicts mathematics and science achievement for Finnish and Turkish students in PISA 2012. *Journal of Educational Multimedia and Hypermedia, 27*(1), 25–42.

Delen, E., & Bulut, O. (2011). The relationship between students' exposure to technology and their achievement in science and math. *The Turkish Online Journal of Educational Technology, 10*(3), 311–317.

Eickelmann, B., Gerick, J., & Koop, C. (2017). ICT use in mathematics lessons and the mathematics achievement of secondary school students by international comparison: Which role do School level factors play? *Education and Information Technologies, 22*(4), 1527–1551.

Fasih, T. (2008). *Linking education policy to labor market outcomes*. The World Bank: Washington D.C.

Ilomäki, L., Paavola, S., Lakkala, M., & Kantosalo, A. (2016). Digital competence – An emergent boundary concept for policy and educational research. *Education and Information Technologies, 21*(3), 655–679.

Kingsley, A. (2017). Information communication technology (ICT) in the educational system of the third world countries as a pivotal to meet global best practice in teaching and development. *American Journal of Computer Science and Information Technology, 5*(2). https://doi.org/10.21767/2349-3917.100010 retrieved from http://www.imedpub.com/articles/information-communication-technology-ict-in-the-educational-system-of-thethird-world-countries-as-a-pivotal-to-meet-global-best-pr.php?aid=21571.

Kubiatko, M., & Vickova, K. (2010). The relationship between ICT use and science knowledge for Czech students: A secondary analysis of PISA 2006. *International Journal of Science and Mathematics Education, 8*(3), 523–543.

Leino, K. (2014). *The Relationship between ICT Use and Reading Literacy: Focus On 15-year-old Finnish Students in PISA Studies, Finnish Institute for Education Research*. Jyväskylä: Jyväskylä University Press.

Luu, K., & Freeman, J. G. (2011). An analysis of the relationship between information and communication technology (ICT) and scientific literacy in Canada and Australia. *Journal of Computers & Education, 56*(4), 1072–1082.

Oliver, R. (2002). The Role of ICT in Higher Education for the 21st century: ICT as a Change Agent for Education, retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.83.9509&rep=rep1&type=pdf

Petko, D., Cantieni, A., & Prasse, D. (2017). Perceived quality of educational technology matters: A secondary analysis of Students' ICT use, ICT-related attitudes, and PISA 2012 test scores. *Journal of Educational Computing Research, 54*(8), 1070–1091.

Shields, R. & Chugh, R. (2018). Preparing Australian High School Learners with 21st Century Skills. *2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, Wollongong, NSW, 2018, pp. 1101–1106. https://doi.org/10.1109/TALE.2018.8615207.

Suryani, A. (2010). ICT in education: Its benefits, difficulties, and organizational development issues. *Journal of Social Sciences and Humanities, 3*(1), 106–123.

Thomson, S. & De Bortoli, L. (2007). PISA 2003 Australia: ICT Use and Familiarity at School and Home, *ACER Research Monograph No 62*, Australian Council for Educational Research.

Wittwer and Senkbeil (2008) in reference listWittwer, J. and Senkbeil, M. 2008. Is students' computer used at home related to their mathematical performance at school?, *Computers & Education*, 50(4): 1558-1571.

Zhang, D., & Liu, L. (2016). How does ICT use influence students' achievements in math and science over time? Evidence from PISA 2000 to 2012. *Eurasia Journal of Mathematics Science & Technology Education, 12*(9), 2431–2449.