‘Less is more?’ – The effects of ICT on Dutch student performance examining the PISA

Master Thesis

Msc Policy Economics

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Abstract

In the limelight of the large-scale investments and dependence on information and communication technology (ICT) by schools, this thesis is composed as an evaluation of the effect of technology on academic performance. By using data from the Programme for International Student Assessment survey (PISA) 2015, a multilevel regression model is applied to assess the effect on math, reading and science performance of Dutch 15-year old students. The results show diverging effects in the type of ICT variable as well as the subject and performance level of the student. Generally, ICT availability at schools as well as ICT use at home for school purposes shows negative effects on the PISA results of the students. While both are significant, the ICT availability at school shows consistent negative results across all models but later robustness test shows that most of this effect is originated from the bottom-performing students. The results provide relevant information for guiding policy decisions for improving the academic performance of students and evidence that solely relying on ICT investments do not guarantee a positive impact on student performance.

Keywords: ICT • Education Outcomes • Home & School • PISA • The Netherlands

Contents

1. Introduction

Preparing its citizenry for life in the 21st century is a key topic in educational policy. Traditionally, education has occurred in classrooms where teachers and students interact face to face on a given subject. The development of information and communication technology (ICT) has changed educational interaction over the past decades with the purpose to change learning methods and effectively improve them. Specifically, in education, ICT has changed how students read, write, compute, and communicate (Zhang, Zhang & Zhang, 2008). Both the educational and recreational use of today's technological assets impacts learning possibilities widely in the form of digital content, online courses, or other computer- and high-tech-assisted curricula (Srijamdee, K., & Pholphirul, 2020). The introduction of technological equipment within classrooms has made a large impact on learning environments and schools are increasingly interested in methodologies for e-learning for educational activities. However, while the usage of ICT has been apparent, the potential effects ICT has on children receive mixed viewing points. Some researchers argue that helping students acquire ICT skills supports their learning processes and learning outcomes in school (Li & Ma, 2010). ICT use in an educational environment is associated with higher student motivation where computers contribute to an interactive and fun learning engagement (Bullock, 2001). Additionally, using computer technology is positively associated with positive emotions when using computers (Ishigaki, Chiba & Matsude, 1996) and engenders creativity, including creative thinking (Clements, 1986, 1995; Clements & Sarama, 2003).

However, the use of ICT in education is also frequently associated with problems. Researchers argue that it distracts or hinders their learning (Abbas et al., 2019 from Lei et al. 2021) and the addiction to ICT could negatively impact students' learning paths (Carbonell et al., 2012). Additional arguments consider the declining writing skills of the students and the financial contributions necessary from students, parents or schools potentially increasing inequality between students' opportunities (Raja & Nagasubramani, 2018). While a number of these critics do not rule out the use of ICT completely and acknowledge a role for the *effective* use of ICT in education, opinions do differ as to how effective use of ICT should be achieved (Williams et al, 2000).

Despite the uncertainty in the effects of ICT in classrooms, countries have made considerable investments in ICT resources, internet connections, and educational software. Additional investments concerning the COVID-19 impact, which positively impacted the ICT facilities in Dutch schools (Inspectie van het Onderwijs (2021), made the societal dependence on ICT even larger. However, the ambiguity in the effects of ICT on educational outcomes demands an evaluation of the effectiveness of these investments.

The objective of this study is therefore to estimate the effect of the use of Information and Communication Technologies (ICT) at school and at home on educational performance. The results are based on the Program for International Student Assessment (PISA) in 2015. By analyzing both the ICT availability and the usage of students, this study evaluates the effects on student performance and indirectly on the quality of Dutch education. Results of this study would contribute to identifying successful educational policies and interventions.

1.2 Societal Relevance

The interest in ICT's impact on education is partially derived from concerns Dutch policymakers have about the current status of the Dutch educational system. Reading scores (PISA, 2020) and math scores (TIMMS, 2019) for Dutch 15-year old's show an increasingly negative trend over the past decades which shows the need to intervene to flatten this downwards curve. Earlier attempts in the Netherlands to increase ICT usage, in the form of the Onderwijs voor de Nieuwe Tijd-schools (O4NT), have stranded due to the high costs and inexperience of the boards (Het Parool, 2017). However, despite the bankruptcy of this initiative, many agreed that the targeted approach on the individual student shows benefits in increased learning. Initiatives surrounding educational improvement base their acts on the monetary and non-monetary returns to education, including higher future earnings, better health conditions, and overall better prospects for their children associated with better schooling (Vila, 2000; Harmon et al, 2001). The contributions in adapting the schooling system to 21st-century labor demands are crucial in maintaining competitiveness for the Dutch working force which is formed in the educational system.

1.3 Scientific Relevance

As previously mentioned, the existing literature on the effect of ICT on educational outcomes is mixed and due to the emergence of ICT as a new concept in the literature, it provides multiple research opportunities to further extend the existing knowledge. Blanskat, Blamire & Kefala (2006), reviewing several studies on the impact of ICTs on schools in Europe, concluded that the evidence is scarce, and comparability is limited since each study used a different methodology and approach so that comparison among countries must be done cautiously. More recently, Fernández-Gutiérrez et al. (2020) also stated that, despite the large investments in ICT by schools, the effect of the use of ICT on educational outcomes is still an open question, both from a theoretical and an empirical point of view. Some researchers have used the PISA database to make a cross-country analysis on a particular subject (e.g., Petko, 2017) but there is still a lack of research providing a comprehensive foundation of the effect of ICT on Dutch pupils. Critics have doubted that more or better ICT means more and better education and some are anti-technology, harking back to an ideal of 'innocent childhood' (Livingstone, 2012). Thus, although societal dependence on ICT is increasing, there are conceptual and empirical challenges to the effect of ICT on educational outcomes which makes further analysis of this relationship valuable.

The ambiguity in the effect of ICT use in education opens opportunities to further extend the existing knowledge on this topic. The research question this paper is trying to answer will therefore be the following: *What is the effect of ICT, based on educational and recreational ICT availability and usage, on educational outcomes of Dutch 15-year-olds?*

To answer the research question, the paper is structured as follows; The next section presents a view of the previous studies conducting the effects of ICT on educational performances, distinguishing the effect of ICT at schools and home. The previous literature will be used to frame the theoretical framework explaining the relationship of interest. Next, the methodological approach and the data used in this analysis will be presented which will be followed up by the results. Lastly, the conclusion from the research will be presented followed up by the discussion and recommendations for future research.

2. Literature Review

As noted already, ICT stands for information- and communication technology and refers in principle to the technologies used for processing information and communicating with others. The technologies could include hardware (e.g., computers and other devices); software applications; and connectivity (e.g., access to the Internet, local networking infrastructure, videoconferencing) (Lloyd, 2006). In most educational circles, it means computer technology, multimedia, and networking, especially the Internet (Anderson, 2008). The societal development increasing the importance of information made the incorporation of ICT structures more important. Next to the societal implications, Anderson (2008) highlighted the implications the knowledge society has on education summarizing the necessary required skills in table 1.

Demands from society	Required skills	Learning strategies
Knowledge as commodity	Knowledge construction	Inquiry, project learning, constructivism
Rapid change, renewal	Adaptability	Learning to relearn, on-demand learning
Information explosion	Finding, organizing, retrieving information; ICT usage	Multidatabase browsing exercises
Poorly organized information	Information management, ICT utilization	Database design and implementation
Incompletely evaluated information	Critical thinking	Evaluation problem solving
Collectivization of knowledge	Teamwork	Collaborative learning

Table 1. Impact knowledge society on education (Source: Anderson, 2008)

As the adaption of ICT in education was getting more influential, educational econometric models started incorporating ICT as a possible variable of influence on educational outcomes. Earlier models in educational outcomes generally integrate personal, teacher, school and family factors as influencing factors on the educational process of students measured directly or as fixed effects (Rivkin, 2005). It was only until the early 2000's that ICT could be a determinant in educational performance, as evidenced by literature studies executed by e.g., Cox (2004) and Condie & Munro (2007). The incorporation of ICT into econometric models made it possible to estimate the magnitude of the relationship. Literature often distinguishes between computers in the classrooms and at home finding different correlation estimates when delving into both cases (See e.g., Fuchs & Woessmann, 2004). The difference in the use of ICT, where ICT at home is mainly for communication and information sharing purposes (Fraillon et al. 2014) and at school for educational purposes shows the necessity to differentiate between the different types of ICT use when studying the ICT use-self-efficacy relation (Rohatgi et al. 2016). This paper, therefore, divides the existing literature similarly to indicate both relations.

Use of ICT in classrooms

One of the main interests in educational research is optimizing educational outcomes within the restricting existing financial and organizational constraints. The theoretical foundation of ICT usage in schools is derived from the standard model of education function (See e.g., Todd & Wolpin, 2003). The binding constraint for these types of models is the budget constraints for the resources of the school and the amount of class time available. With these constraints, the comparison of interest is the effectiveness of a dollar invested in ICT relative to a dollar invested in traditional school resources (Bulman, 2016). Practically, schools foresee opportunities to maximize efficient learning in the destined educational hours given the available resources. On the theoretical ground, ICT can be regarded as a more “productive” input in the student learning process (Spiezia, 2011).

Empirically, the introduction of ICT as a variable of interest in educational literature expanded the determinants of learning and academic performance. As illustrated in the introduction, the empirical evidence is not conclusive and articles highlighting the positive and the negative impact of ICT coexist alongside the absence of significant effects. Earlier meta-analysis shows the widely varying estimates (See Noll et al, 2000) but the more recent ones show more positive signs toward the impact of ICT on education. The more recent meta-analysis highlights the scarce quantity of papers, but the overall tendency shows the positive impact ICT could make if used efficiently (See Zhao, 2003; Means, 2009; Mothibi, 2015).

Using experimental data, these findings are in line with the ones of Barrow et al. (2007). The outcomes of this randomized control trial support the positive influence of computerized instructions on mathematics. This RCT randomly assigned students to computer-instructed classes which in effect scored higher than the students in the control group. Similarly, Banerjee et al. (2007) found that students in India who experienced instructional games and software positively impacted students' math performance. Students were assigned to groups receiving Computer-Assisted Learning (CAL) or traditional classes and tested their math scores before and after the program. The results show a strong positive effect of CAL in comparison to the control group.

Other researchers made use of policy changes to make use of a regression discontinuity design (RDD) before and after the policy implementation. Leuven et al. (2007) use an RDD to estimate the effect of two Dutch subsidies targeted at schools with large proportions of disadvantaged pupils. The results show that the effects of both subsidies are negative and, in some cases, significantly so. The subsidies for computers and computer software were especially for girls' achievement harmful. Goolsbee and Guryan (2006) identically found no positive effect in their work evaluating the effect of the subsidy on Internet investment in Californian public schools, known as E-Rate. While no negative effects were found, there was an absence of significant effects of the E-Rate program, which underlines the doubts about the effect of computers in schools in the earlier decade.

Next to experimental data, researchers have estimated the effect of ICT on educational outcomes using existing data, usually using data from the assessment of the Programme for International Students Assessment (PISA). Using the surveys and the internationally standardized test from PISA, Delen & Bulut (2011) estimated the effect of ICT on students' math and science achievement in Turkey. Using multilevel modelling, they found that exposure to ICT at home and school is a strong predictor of their math and science performance. The effects of the exposure at home were, surprisingly, larger than the impact at school, which is not usual in the existing literature. A possible explanation according to the authors is the lack of integration of ICT in the classroom instruction at schools which is evidently affecting the results. Another example of a paper using the PISA survey is from Spiezia (2010). Using an "endogenous treatment model" where the possibility of endogeneity is treated using a discrete number of frequencies of computer use, a cross-country analysis is made of the impact of computer use on sciences scores. The results show that computer use does have a positive and significant effect on science scores, but this is only due to "home use" of the computer as the computer use at school shows no significant effect on science scores in most countries.

One of the explanations for the differences in results could be the divergence of ICT capabilities of teachers and the extent of incorporating ICT efficiently in the curriculum, which was already outlined by Delen & Bulut (2011). A meta-analysis by UNESCO (2006) identically shows the need for training the teachers to work efficiently with a computer while adaptation and integration of the right materials into the curriculum are crucial in retracting the best results out of the digital opportunities.

Use of ICT at home

The effect of ICT on educational outcomes does not bind itself to the classrooms only. But although extensive literature examines the effectiveness of computer use in the classroom, very little research has focused on the question of whether *home* computers improve educational outcomes (Fairlie, 2012).

According to the literature, there is no clear-cut prediction about the effect of computer ownership on student performance (Pagani et al. 2016). Theoretically, there are reasons to believe that home computers could exert a positive influence on academic performance through the availability of using educational software or, more indirectly, by facilitating access to programs for school assignments and learning. Additionally, increasing the familiarity with computers at home could increase the returns to computer use in the classroom (Underwood et al. 1994). However, the misuse or overuse of computers could negatively influence the performance of children when the time used on the computer is spent on entertainment purposes, potentially displacing time for schoolwork (Jones, 2002). In addition, access to the Internet may expose students to the risk of finding and using information from unreliable sources (Pagani et al. 2016). Empirical analysis is therefore needed to further identify the sign and magnitude of the effect of home computers on educational progress in absence of a clear-cut theoretical prediction.

Although there is a much smaller body of literature dealing with the effects of ICT use at home, there are studies conducted using robust econometric techniques to unravel the relationship. One of the first studies to explore whether home computers have positive educational effects on children was by Attewel and Battle (1999). Using 1988 National Educational Longitudinal Survey data, findings show that school performance among eighth grades is positively related to computer ownership. In contrast, negative effects were found by Fuchs and Woessmann (2004) and suggest that it may be due to the distraction from effective learning. A key concern in most of the previous studies is that they may suffer from reverse causality – specifically the possibility that more educationally motivated students (and their families) are more likely to purchase computers (Pagani, 2016).

To address this limitation, researchers tried to control for endogeneity using either field experiments or altering the empirical model, including instrumental variable (IV) techniques e.g., future computer ownership, falsification test, individual student fixed effects or regression discontinuity designs (RDD). The conducted field experiments provided mixed results, with examples of experiments showing small but positive effects (Fairlie & London, 2012), no effects (Beuermann et al, 2015) or negative effects in certain subjects (Malamud & Pop-Eleches, 2010). The empirical approaches identically provide no consistent results accentuating the ambiguity in this body of educational research. Fairlie (2005) addresses the endogeneity issues by using instrumental variable models with cross-sectional data from the 2001 CPS. Bivariate probit models of the joint probability of school enrollment and owning a home computer show that teenagers who have not graduated from high school have a larger likelihood of enrollment when the students own a computer. Beltran et al. (2010) use a similar bivariate probit model finding similar results. Alternatively, Schmitt and Wadsworth (2006) also address the endogeneity issue and therefore estimate the effects on students' achievement using future computer ownership as a proxy for unobserved household characteristics. The results on past computer ownership were found to be positive and significant whereas the coefficients of future ownership are insignificant. To gain an even more complete view of the impact on educational outcomes, Fairlie et al (2010) use several identification strategies including fixed-effect models, instrumental variables including future computer ownership and 2SLS models. Between the models, there is a general consistency in the sign of the estimates suggesting a positive effect of home computers on educational outcomes.

A key nuance made in later research for both the ICT in school and at home is not only the availability of the computer but also the *degree of usage.* The time spent on computers at home cannot be spent on educational activities where these *time displacement effects* could contribute to lower academic achievement. Earlier research on this topic by the Educational Testing Service (ETS) shows that students who spent more time on school computers score slightly worse than students who spent less time on computers (Wenglinsky, 1998). Similarly, Akhter (2013) examined the relationship between academic performance and internet addiction among university undergraduates. The results show that this high level of computer use is negatively and significantly related to academic performance. Contrary, Biagi and Loi (2013) find that the frequency of different types of internet activities and reading or math literacy is in the general negative in most of the countries examined, except when the computer is used for gaming. Interestingly, Algan & Fortin (2015) also found that everyday computer gaming has neutral or positive effects for boys while general negative effects are found for girls. One of the explanations for the positive effects of the degree of usage on educational outcomes is the development of digital literacy by using ICT at home or school. Research testing the impact of digital literacy on academic performance generally find positive results in overall grade and academic competence (Amiri, 2009; Leung & Lee, 2012)

Rationale and Conceptual framework

The existing literature predicts that ICT plays a role in education, but the sign and magnitude of both relationships (at school and home) remain ambiguous. Its potential impact however is influenced by factors intervening at a school and individual level. The conceptual framework was devised based on these different levels drawn from previous research from the OECD (2005) and later research by Hu et al. (2018) portraying the potential effects of ICT factors on the student performances in mathematics, reading and science (See Figure 3.1).

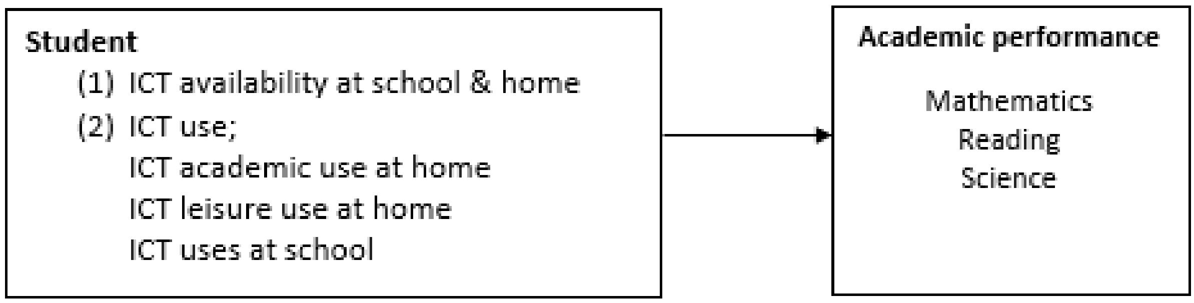

Figure 3.1 Conceptual Framework of the potential influence of ICT on student academic performance

The direction and magnitude need further examination but based on the previous literature, four hypotheses can be proposed which are outlined as follows:

H1. ICT availability at school has a positive impact on student outcomes

H2 ICT availability at home has a positive impact on student outcomes

H3. ICT usage at home has a negative impact on student outcomes regardless of the type of usage

H4. ICT usage at school has a positive impact on student outcomes

The theoretical framework provides the conceptual implication of the main dependent and independent variables used in this research which coexists next to the various school- and student control variables. These control variables are not included in the theoretical framework but are included in the empirical outcomes. Further explanation of the variables used in this research will follow in the methodology section.

3. Empirical Strategy

3.1 Data description

The data for this study come from the 2015 assessment of The Programme for International Student Assessment (PISA) which is an internationally standardized assessment including 79 participating countries. The program from the Organization for Economic Co-operation and Development (OECD) moderates the progress of 15-year-old students tested on the subject's math, reading and science. Besides the assessment of the specified domains, PISA includes student, parent, and school surveys for further information on multiple economic, social, and cultural factors related to the students' home and family backgrounds potentially influencing the relationship of interest. The sample used in this research includes 5,385 Dutch students from 189 schools. Further descriptive statistics from the students used in this dataset can be found in table 3.1.1.

Table 3.1.1 Descriptive Statistics (N = 5,385)

Variables	**Items**	**Frequency**	**Percentage**
Gender	Female	2,700	50.14%
	Male	2,685	49.86%
Index Immigration Status (IMMIG)	Native	4,649	89,25%
	Second-Generation	446	8,56%
	First-Generation	114	2,19%
Community	A village (fewer 3.000)	41	1.06%
	A small town (3.000 – 15.000)	526	13,64%
	A town (15.000 – 100.000)	2.276	59,02%
	A city (100.000 – 1.000.000)	1.013	26.27%
Class size	15 students or fewer	129	3.47%
	16 – 20 students	267	7.18%
	21 – 25 students	1.048	28.18%
	26 – 30 students	2.127	57.19%

	31 – 35 students	64	1.72%
	36 – 40 students	34	0.91%
	46 – 50 students	18	0.48
	More than 50 students	32	0.86%
Ownership	Public school	1.343	38.08%
	Private school	2.184	61.92%

3.2 Methodology

The literature review shows the methodological limitations contained by the earlier empirical methods applied to researching academic performance e.g., reverse causality. To overcome the issue of the principle of independence not being met within the database – where observations from students from the same school show similar characteristics – this research makes use of a multilevel structure. The use of the multilevel model acknowledges that students are embedded within classes and schools. The relative variation in the outcome measures, between students within the same school and between schools can therefore be evaluated (OECD, 2009). They take the form of simple regressions developed for each individual i:

$$Y_{ij} = \beta_{0j} + B_{1j}X_{ij} + r_{ij} \qquad (1)$$

Where Yij is the educational outcome for ith student in school j. Xij is a value of a student predictor, β_{0j} is the intercept for schools effect, B_{1j} is a regression coefficient associated with the student predictor and r_{ij} is the random error. Multilevel modelling, also known as hierarchal modelling, is a widely used method for examining educational outcomes using PISA data (Thorpe, 2006; Delen & Bulut; Song & Kang, 2012). One of the reasons why this method is used is because PISA samples their population in stages; first schools are sampled and then students are sampled in the participating school (OECD, 2009 p. 36). This method of sampling increases the standard errors and makes OLS therefore not an applicable method of research possibly reporting non-significant results as significant because it does not consider homogeneity within each group.

PISA provides three different subjects to be estimated for educational outcomes: mathematics score, reading comprehension score and science score. Therefore, a model will be developed for each subject and the models will be performed on 2 levels: schools and students. Within the models, some variables are specific to each individual student (level 1) and variables that characterize the school (level 2).

The multilevel model used in this research is similar to the one used by Gómez-Fernández & Mediavilla (2018). With the use of the program STATA, the regression equations estimated will be:

Level 1 equation

$$Y_{ij} = \beta_{0j} + \sum_{k=1}^{K} \beta_{kj} X_{kij} + r_{ij} \qquad (1)$$

Level 2 equation

$$\beta_{kj} = \gamma_{k0} + \sum_{q=1}^{Q} \gamma_{kq} W_{qj} + u_{kj} \qquad (2)$$

Where Y_{ij} refers to the score by student "i" at school "j" in a certain subject; X is a set of "k" characteristics of the student i and the school j. The betas are estimate coefficients and r_{ij} are the random effects for level 1. The level 1 coefficients turn into the dependent variable in the level 2 equation. W_{qj} is a vector of q characteristics of school j. γ_{k0} and γ_{kq} are level 2 coefficients and u_{kj} are the random effects for level 2.

To allow for the classification of variables and coefficients in terms of the level of hierarchy they affect, a combined model (i.e., a two-level model) is created by substituting both equations (1) and (2) in the regression model forming the final multilevel model as follows:

Final model

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$$Y_{ij} = \gamma_{00} + \sum_{q=1}^{Q} \gamma_{0q} W_{qj} + \sum_{k=1}^{n} \beta_{kj} X_{kij} + r_{ij} + u_{0j}$$

The model assumes, therefore, a structured population and is composed of two parts: one general part which can be commonly applied to all contexts (the fixed-effects part) and another with represents the specificity of each context (random effects). The following section will provide further elaboration of the variables used within this model.

3.3 Variables

This section provides further explanation of the main independent (ICT), dependent (Student outcomes) and control variables for this research.

ICT

The ICT variables at the student level which were included in this survey are split into two groups: (1) ICT variables concerning the availability of ICT both at school and at home and (2) ICT variables that focus on the intensity of ICT use. This split is implemented to stay in line with the literature providing a nuance for the impact of ICT depending on the degree of usage by the student. For ICT availability, the PISA ICT questionnaire contains the ICTHOME & ICTSCH variables which provide an index for the available ICT objects available for the students at school and at home. For the degree of usage, three variables are used called USESCH, HOMESCH and ENTUSE which are variables containing the degree of usage of ICT at school, the usage of ICT at home for school purposes and the usage of ICT at home for entertainment purposes. A further explanation of variables can be found in appendix 1.

Educational Outcomes

The study uses the students' scores in mathematics, reading and science as the dependent variable in the present study. PISA 2015 uses a rotated-booklet design for testing the individual's literacy and numeracy skills. These results are not expressed by only one value, but by ten denominated *plausible values* randomly obtained from the distribution of test results derived from the answers in each test (Rasch, 1960, 1980), which can be interpreted as the representation of the ability range for each student (Mislevy et al, 1992; Wu and Adams, 2002; from Cordero et al., 2017). Plausible values are therefore constructed to provide estimates of the population as not all questions from the PISA 2015 survey can be answered in the assigned timeframe. For the results, this analysis only makes use of one (the first) of the plausible values and, subsequently, uses the other nine values as a robustness test. The obtained estimates of the first value should be similar to the other values as previous literature found. Validation for this method can be found in Apaircio et al. (2021) comparing different methods for large-scale international assessments of educational data. The metrics of the various values are established so that in the year the scale is first established, the OECD student mean score is 500 and the pooled OECD standard deviation is 100 (OECD, 2009). The average score in this sample for mathematics, reading and science were 515, 505 and 511 respectively. The score distribution for the topics can be found in appendix 3.

Controls

This study uses both individual- and school-level control variables fitting for this type of research. Individual-level variables include gender, the Index Immigration status (IMMIG), and the Index of Economic, Social and Cultural Status (ESCS). School-level variables include school ownership, community size and class size. The controls are chosen in line with similar empirical research (Juhaňák et al. 2018) and are summarized in Table 3.3.1.

Table 3.3.1

Control variables

Variable	Measurement
Controls at the individual level	
Gender	-
Index Immigration Status (IMMIG)	Relating to the country of birth of the student's mother and father (ST019). Calculated based on binary variables and equates to one of three categories: (1) native students; (2) second-generation students; (3) first-generation students.
Index of Economic, Social and Cultural Status (ESCS)	Weighted average of three indices: (1) parental educational attainment (in years); (2) Highest parental occupation; (3) home possessions. The index has a mean of zero and a standard deviation of 1.
Controls at the school level	
School ownership	Management-type (Public / Private)
Community size	Interval variable (ranging from 1=fewer than 3000 people to 5= over 1 million people)
Class size	The average size of the class

4. Results

The upcoming section provides the results from the models explained in the previous section. First, a one-way ANOVA model (the null model) is built to test if the variances at each level of the model are significant for the subjects. This is done to provide the empirical foundation based on these statistics for the use of a multilevel model. The results of the null models show for the different subjects, 57%-60% of the variability of the model can be attributed to the schools. The highly evenly balanced variance between the different levels presents the statistical validation to explore the impact of the predictor on a school- and student-level verifying the use of a multilevel model for this dataset.

Table 4.1 Intraclass coefficient for math, reading and science scores

	Mathematics (Percentage)	Reading (Percentage)	Science (Percentage)
School	4999.61	6060.35	5940.67
Student	3607,32	4188,44	4328,72
ICC	58,1%	59,1%	57,8%

To do this, we first use a baseline two-level model using the ICT variables affecting the student performances in mathematics, reading and science without the control variables (Table 4.2). The ICT variables for all three models indicate various significant outcomes where ICT use at school negatively impacts the student outcomes in all three subjects at a 0.1% significant level. For example, one can interpret the results that if the student scores 1 point higher in the ICT at school index (ranging from 0 to 11), the score of the student decreases with 2.52 in mathematics. This first econometric model gives a preliminary indication of the direction and the magnitude of the relationship of interest.

Table 4.2. Baseline model using the ICT variables affecting student performances in mathematics (M), reading (R) and science (S)

	Model 1 (M)	**Model 1 (R)**	**Model 1 (S)**
Fixed effects	*Coef. (SE)*	*Coef. (SE)*	*Coef. (SE)*
Intercept	532.15 (8.97) ***	549.53 (9.69) ***	543.19 (9.83) ***
ICTHOME	0.16 (0.72)	-2.26 (0.77) **	-1.25 (0.79)
ICTSCH	-2.52 (0.63) ***	-3.27 (0.68) ***	-2.47 (0.69) ***
USESCH	-1.18 (1.66)	-1.59 (1.78)	-4.20 (1.82) *
HOMESCH	-5.54 (1.65) **	-4.67 (1.77) **	-5.33 (1.81) **
ENTUSE	2.39 (1.51)	-1.27 (1.62)	7.94 (1.66) ***
Random effects	***Variance component***	***Variance component***	***Variance component***
Residual variance	3508.35 (75.20)	4028.02 (86.34)	4226.75 (90.60)
Intercept variance	3508.35 (512.74)	5720.42 (613.39)	5676.71 (609.20)
Observations	4.541	4.541	4.541
Number of schools	187	187	187

** $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$*

While table 4.2 gives a small insight into the relationship between ICT and student performances, no other variables potentially intervening in this relationship are controlled for. Table 4.3 adds the control variables as explained in section 3 for level 1 (student) and level 2 (school). With the addition of gender, the IMMIG index and the ESCS for the student level as well as class size, and community type and by differentiating between state-funded and private-funded schools, the relationships of interest are isolated further. The added variables in this model consist of a large amount of the student scores with gender, the IMMIG and the class size as significant predictors of the student scores across all topics. The ICT variables considered in this model show diverging directions of the magnitude of the effect, with some increases and some decreases. The ICT variable that stands out in this is, as the first model, ICT at school. For all three subjects, the availability of ICT at school significantly impacts the student scores negatively with 2.67 – 3.27 points. This deems surprising given the existing literature expecting a small positive effect. Also, the use of ICT at school, although not significant in all subjects, seems to negatively affect the student scores. The strongest effect of ICT on the subjects in this research seems to be reading. Both the ICT availability at school as well as the ICT use at home for school purposes contain a significant negative relationship on the reading scores.

Table 4.3 Models using all ICT variables and control variables affecting student performances in mathematics (M), reading (R) and science (S)

	Model 2 (M)	**Model 2 (R)**	**Model 2 (S)**
Fixed effects	*Coef. (SE)*	*Coef. (SE)*	*Coef. (SE)*
Intercept	387.07 (43.80) ***	365.31 (48.81) ***	392.05 (48.08) ***
Level 1			
GENDER	-12.91 (2.32) ***	11.83 (2.49) ***	-15.52 (2.54) ***
IMMIG	-17.64 (3.27) ***	-20.01 (3.51) ***	-21.35 (3.58) ***
ESCS	6.43 (1.74) **	7.22 (1.87) ***	10.38 (1.91) ***
ICTHOME	-0.08 (0.91)	-1.67 (0.97)	-1.99 (0.99) *
ICTSCH	-2.90 (0.79) ***	-3.27 (0.85) ***	-2.67 (0.86) **
USESCH	-2.79 (2.09)	-3.26 (2.24)	-5.33 (2.28) *
HOMESCH	-2.29 (2.02)	-5.66 (2.17) **	-1.63 (2.21)
ENTUSE	-0.74 (1.97)	0.52 (2.12)	3.45 (2.16)
Level 2			
CLASSSIZE	6.37 (1.04) ***	6.86 (1.16) ***	6.35 (1.14) ***
COMMUNITY	9.47 (8.26)	13.16 (9.22)	12.82 (9.07)
PRIVATE	-12.35 (11.29)	-14.11 (12.61)	-9.34 (12.39)
Random effects	***Variance component***	***Variance component***	***Variance component***
Residual variance	3398.93 (91.96)	3908.71 (105.73)	4067.99 (110.04)
Intercept variance	3320.986 (459.69)	4157.61 (570.63)	4004.69 (552.058)
Observations	2.851	2.851	2.851
Number of schools	117	117	117

** p < 0.05; ** p < 0.01; *** p < 0.001*

4.2 Robustness tests

The robustness tests for this paper are twofold: the literature indicated two potential deviating factors of the impact of ICT on student outcomes which are gender and the performance level of the students. First, to test for the individual effects of gender, five interaction terms are made to test the effect of the ICT variables for females (See Appendix 4 for the model). By multiplying gender times the variables for ICT, one can determine the additional effect of the ICT variables for females specifically. The results show only one significant result for the interaction term which is the positive effect of ICT-use for entertainment purposes for females of 5.82 points for mathematics. For interpretation, this shows that the effect of entertainment use of ICT for men seems to be negative while the effect for women seems to be positive according to the results. While both the effects are significant for ENTUSE as well as the interaction term, careful consideration needs to be placed for the interpretation of the result due to the lower significance levels. Additionally, a Chi-square test was performed to test the joint significance of all the interaction terms on the subjects math ($p = 0.0585$), reading ($p = 0.2810$) and science ($p = 0.2587$). The Chi-square results indicate that for the three subjects the interaction terms are jointly insignificant on a 5% level indicating that ICT depending on gender does not predict the students' scores differences in this sample.

Second, previous studies show the diverging effect of ICT variables on the performance level of the students (Juhaňák et al. 2018) demanding further delving into the data. Tables 4.4 – 4.6 show the separate effects for mathematics, reading and science for the bottom, middle and top performers for each subject. The data is split into tertiles based on the student scores for the subject of interest. The choice of splitting the data into tertiles is to maintain a sufficiently large sample for each group which makes a correct interpretation of the coefficients more plausible. The total observations of 2.851 are therefore split into thirds keeping an observation level of 950 - 951 for each subgroup. Like previous research, the results for each subgroup indeed deviate and, interestingly, for each subject the effect of ICT availability for the bottom performing students is negatively impacting the student outcomes by 3.21 – 4.12 points at a 0.001 significance level. Simultaneously, while the effect for the bottom-performing group is highly significant, the effects for the middle- and the top-performing group becomes insignificant. This gives an interesting nuance to the previous models in this paper showcasing a negative impact of ICT availability at school on the student performance, but this could result solely from the large impact ICT availability at school has on the bottom performing students. Another interesting insight the models provide is the fact that the other two significant coefficients both originate from the top-performing students, namely the ICT use for entertainment purposes within mathematics and ICT use at school for science. While only at a 5% significance level, both coefficients show a large negative impact on the student scores identically showcasing the negative effect ICT potentially has on student performances, being in line with previous models in this paper.

Table 4.4 Models using all ICT variables and control variables affecting the student performances in mathematics by tertiles of performance

	Bottom	Middle	Top
Fixed effects	*Coef. (SE)*	*Coef. (SE)*	*Coef. (SE)*
Intercept	406.70 (23.36) ***	511.77 (9.70) ***	612.00 (21.34) ***
Level 1			
GENDER	-1.09 (2.84)	0.43 (1.52)	-11.89 (2.61) ***
IMMIG	-5.68 (3.32)	-3.03 (2.02)	-12.84 (4.57) **
ESCS	4.18 (2.04)*	3.83 (1.09) ***	5.72 (1.92) **
ICTHOME	-0.30 (1.00)	-0.70 (0.60)	1.38 (1.08)
ICTSCH	-3.21 (0.80) ***	-0.05 (0.48)	-1.82 (1.03)
USESCH	-0.17 (2.04)	0.85 (1.44)	-2.12 (2.83)
HOMESCH	-2.28 (1.81)	-0.26 (1.53)	4.62 (3.32)
ENTUSE	2.26 (1.93)	0.29 (1.42)	-5.91 (2.68)*
Level 2			
CLASSSIZE	3.31 (0.52) ***	0.35 (0.19)	0.44 (0.43)
COMMUNITY	-4.12 (4.24)	4.29 (1.31) **	4.74 (2.75)
PRIVATE	-8.15 (5.95)	0.56 (1.77)	-5.84 (3.59)
Random effects	***Variance component***	***Variance component***	***Variance component***
Residual variance	1638.53 (78.81)	456.51 (22.16)	1383.62 (65.83)
Intercept variance	539.67 (106.66)	21.92 (10.43)	97.37 (34.74)
Observations	950	950	951

** p < 0.05; ** p < 0.01; *** p < 0.001*

Table 4.5 Models using all ICT variables and control variables affecting the student performances in reading by tertiles of performance

	Bottom	Middle	Top
Fixed effects	*Coef. (SE)*	*Coef. (SE)*	*Coef. (SE)*
Intercept	391.31 (27.18) ***	507.80 (12.07) ***	622.24 (20.40) ***
Level 1			
GENDER	9.90 (3.00) **	3.93 (1.73) *	-0.48 (2.71)
IMMIG	-7.99 (3.50) *	-3.74 (2.33)	-12.47 (4.76)
ESCS	-2.58 (2.20)	1.71 (1.23)	7.66 (2.01) ***
ICTHOME	-0.09 (1.07)	0.09 (0.66)	-0.92 (1.16)
ICTSCH	-4.12 (0.84) ***	-0.41 (0.59)	-1.31 (1.02)
USESCH	-0.71 (2.15)	-0.38 (1.71)	-0.99 (2.90)
HOMESCH	-1.10 (1.95)	0.41 (1.73)	1.28 (3.40)
ENTUSE	0.86 (2.08)	-0.84 (1.54)	-1.79 (2.80)

Level 2			
CLASSSIZE	3.08 (0.61) ***	0.23 (0.26)	0.55 (0.38)
COMMUNITY	-3.95 (5.11)	3.69 (1.77) *	5.66 (2.50) *
PRIVATE	-6.64 (7.08)	-0.97 (2.44)	-7.07 (3.06) *
Random effects	***Variance component***	***Variance component***	***Variance component***
Residual variance	1825.99 (87.57)	586.17 (28.75)	1495.71 (71.24)
Intercept variance	772.32 (144.93)	75.20 (21.62)	34.84 (26.01)
Observations	950	950	951

** p < 0.05; ** p < 0.01; *** p < 0.001*

Table 4.6 Models using all ICT variables and control variables affecting the student performances in science by tertiles of performance

	Bottom	**Middle**	**Top**
Fixed effects	*Coef. (SE)*	*Coef. (SE)*	*Coef. (SE)*
Intercept	403.48 (21.68) ***	502.04 (11.56) ***	645.142 (21.19) ***
Level 1			
GENDER	-2.68 (3.02)	0.54 (1.71)	-15.26 (2.90) ***
IMMIG	-8.73 (3.51) *	-2.27 (2.32)	-16.46 (5.18) **
ESCS	2.84 (2.19)	3.38 (1.24)	6.32 (2.14) **
ICTHOME	0.27 (1.08)	-0.28 (0.67)	0.55 (1.18)
ICTSCH	-3.34 (0.83) ***	0.48 (0.59)	-1.80 (1.08)
USESCH	-2.63 (2.13)	-1.32 (1.72)	-6.83 (3.11) *
HOMESCH	0.57 (1.94)	0.11 (1.74)	6.46 (3.63)
ENTUSE	2.31 (2.07)	1.30 (1.66)	-1.68 (2.82)
Level 2			
CLASSSIZE	2.29 (0.46) ***	-0.47 (0.23) *	0.43 (0.42)
COMMUNITY	-4.21 (3.86)	2.57 (1.60)	2.43 (2.61)
PRIVATE	0.16 (5.41)	1.33 (2.19)	-6.00 (3.33)
Random effects	***Variance component***	***Variance component***	***Variance component***
Residual variance	1877.09 (90.29)	606.92 (29.38)	1655.93 (79.18)
Intercept variance	355.36 (459.69)	41.55 (15.41)	48.35 (32.18)
Observations	950	950	951

** p < 0.05; ** p < 0.01; *** p < 0.001*

4.3 The influence of ICT on student performances

The mixed results in earlier literature indicated limited guidelines in the hypothesis for this research. Despite the scarce foundation, four hypotheses were set up to structure the results. First, H1 predicted a positive impact of ICT availability at school on student performances, this hypothesis can be rejected. Table 4.2 provided insights that the effect is generally negative and following the robustness tests, this effect can be generally attributed to low-performing students whereas the other groups provide insignificant results. Similarly, H2 predicted a positive impact of ICT availability at home on student performance and this hypothesis can be rejected as well. Despite a less strong foundation than for H1, Table 4.2 shows a negative effect of ICT availability at home and the robustness test also provided some significant negative effects for this variable indicating a negative relationship. Third, H3 focused on the ICT usage and specifically the usage at home which was predicted to be negative regardless of the usage. This hypothesis can not be accepted nor rejected. Despite some significant positive and negative coefficients in the first tables, the addition of the control variables showed that the effect of ICT use at home was insignificant in impacting student performance, regardless of the subject or the performance level of the student. Finally, H4 predicted that ICT use at school is positively related to student performance and this hypothesis can be rejected. While also not providing a strong foundation, the overall tendency for ICT use at school is negative. Generally, the findings are in line with some of the literature but also provide us with interesting insights which are further elaborated on in the next section.

5. Conclusion and Discussion

ICT plays a key role in preparing students for life in the 21st century and has therefore become a major focus for educational research. The investments by governments and semi-governmental organizations equipping schools with qualitative ICT make the dependency on technology for teaching practices significantly larger. However, the lack of clear evidence on the effect of ICT on educational outcomes has provoked scientific attention towards the investments and the associated dependency of ICT in the educational setting. The mixed results from earlier research, both from experimental and empirical analysis, in combination with the inability for generalizing results from one country towards other countries due to the heterogeneity in educational systems and attitudes towards ICT in school, created the pathway for this research. The findings of this paper, therefore, contribute to the limited knowledge existing concerning the effects of ICT on the Dutch educational system by providing results about the general effect of ICT but also determining the effect of gender and performance level.

The main question of this research was: *What is the effect of ICT, based on educational and recreational ICT availability and usage, on educational outcomes of Dutch 15-year-olds?* The results of the analyses show an overall negative tendency of ICT on educational performance. Especially the availability of ICT at school (ICTSCH) is deemed to have a strong negative impact on the students' outcomes, regardless of the subject. While surprising, the negative effects of the general use of ICT in schools index have been found by earlier research (e.g., Gómez-Fernández & Mediavilla, 2018). A possible explanation can be found in the ineffective usage of ICT. As indicated by research by the OECD (2006) and later outlined by Delen & Bulut (2011), the effectiveness of ICT depends on the ICT capabilities of teachers and the extent of incorporating ICT efficiently in the curriculum. While one can recommend further training for teachers for correct ICT usage, further research needs to be performed in the Dutch educational system to test the general ICT capabilities of teachers. Next, some literature found differences in the effect of ICT on student performance relative to the subject. This paper found however that despite some significant negative subject-specific results, a strong divergence in subjects can not be identified within the significance of the ICT variables. The results, however, suggest that the effect seems to be the largest concerning the reading performance of the students.

For robustness, this research took the gender effect and the student performance into account according to the potential differences in focus groups arising from the literature. First, a strong gender effect could not be found. Despite one significant result, the interaction terms for the ICT variables for females show a general insignificant effect. Contrary, the robustness tests show that the overall effect of ICT availability in school was deemed to be negative, but this was largely attributed to the bottom-performing tertile. A surprising result, but this phenomenon could be explained by intermediate variables like motivation. Academic motivation is known to be an important determinant of academic success in the educational literature (Planta et al. 2013; Steinmayr et al. 2019). One could argue that the displacement effect could be larger for students less interested or motivated in a certain topic and the availability of ICT could hinder the learning outcomes as ICT forms a distraction.

Despite the results, several limitations can be drawn from this research before providing policy suggestions. First, the nature of the measurement of the research is intended to explore the association between the availability as well as the frequency of ICT and academic performance. Although this suggests the impact ICT could have on the performances of students, the skill in ICT could be a possible determinant in effectively using the ICT for its efficient purposes. Future research could delve further into instruments testing the skill level in ICT of the students as mediating factor in the relationship between ICT and student scores. Second, the conclusions of the study can hardly be generalized to other countries since the sample only includes Dutch students and due to the heterogeneity of international schooling systems, the results could differ due to cultural or institutional educational differences. Third, the effect of the availability and the usage of ICT on student performance provides mostly information on the quantity of the ICT. However, one could argue that the quality of the technology could play a pivotal role in the relationship of interest despite the generally sufficient quality of the Dutch schooling system and the large investments in ICT.

Despite the limitations, this paper gives more insight into the limited literature on ICT and student performances and provides policy implications for benefiting from ICT in the Dutch educational system. The main implication can be found that solely investing in more ICT facilities does not guarantee better student outcomes. According to the results, the availability itself does not increase the student scores so alternatively, the Dutch government could focus more on increasing the ICT skills of the students or the teachers to make the pupils and the personnel better equipped in utilizing technology to increase learning outcomes. While educational systems need to adapt to the new needs of the digitalized world and investments in ICT could be helpful, ICT as a learning procedure itself cannot fulfil the potential of an effective learning mechanism if the competencies of the users lack behind.

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7. Appendix

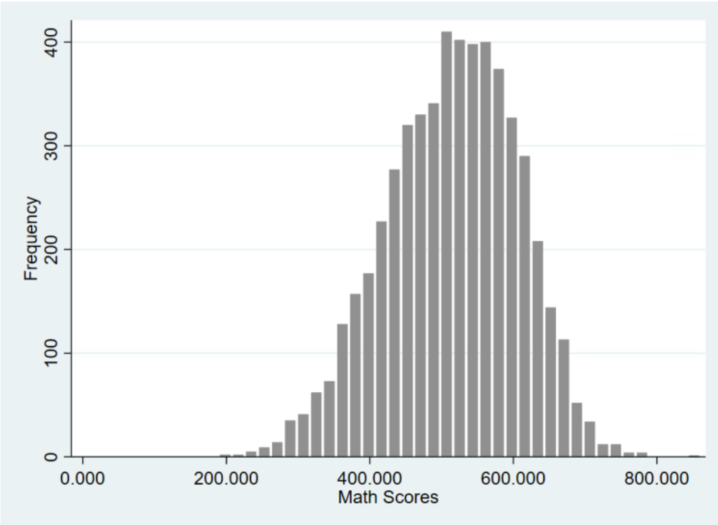
Appendix 1. Definition of ICT variables

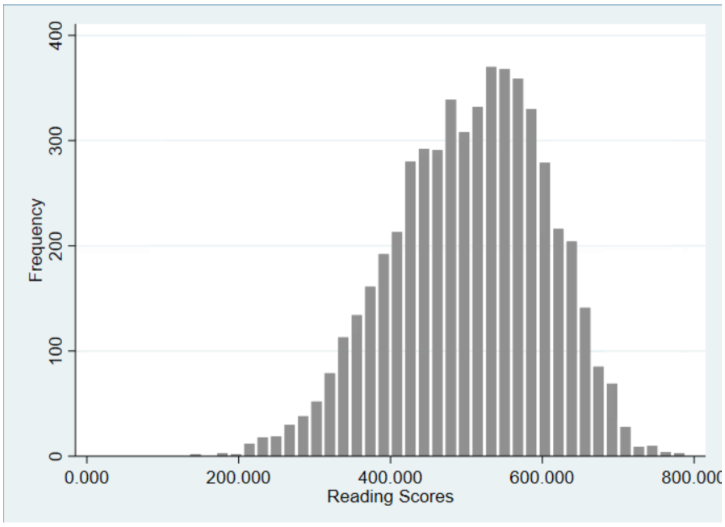
Variable	Definition
ICT availability at School index	Sum of the following items: desktop computer; laptop or notebook; tablet; internet-connected school computers; internet connection via a wireless network; storage space for school-related data; USB stick; eBook reader; Data projector; Interactive Whiteboard.
ICT availability at home index (Sum)	Sum of the following items: desktop computer; laptop or notebook; tablet; internet connection; video games console; cell phone (with and without internet access); portable music player; USB stick; eBook reader
ICT use at school in general	Frequency of use of digital devices (never or hardly ever, once or twice a month, once or twice a week, almost every day, every day) to perform the following activities at school: chat online; use e-mail; browse the Internet for schoolwork; download/upload/browse school webs; post the work on the school's website; play simulations at school; practice and drill, foreign language learning or math; do homework on a school computer; use school computers for group work and communication with other students.
ICT use outside school for schoolwork	Frequency of use of digital devices (never or hardly ever, once or twice a month, once or twice a week, almost every day, every day) to perform the following activities at home: use email or Social Networks for communication with other students or teachers about schoolwork; browse the internet to complete school assignments or follow up lessons; download/upload/browsing school materials from the school's intranet; check the schools' website for announcements; do homework on a computer or a mobile device; download learning apps on a mobile device.
ICT use outside school for leisure	Frequency of use of digital devices (never or hardly ever, once or twice a month, once or twice a week, almost every day, every day) to perform the following activities at home: games (one-player or collaborative); email; chat; social networks; online games

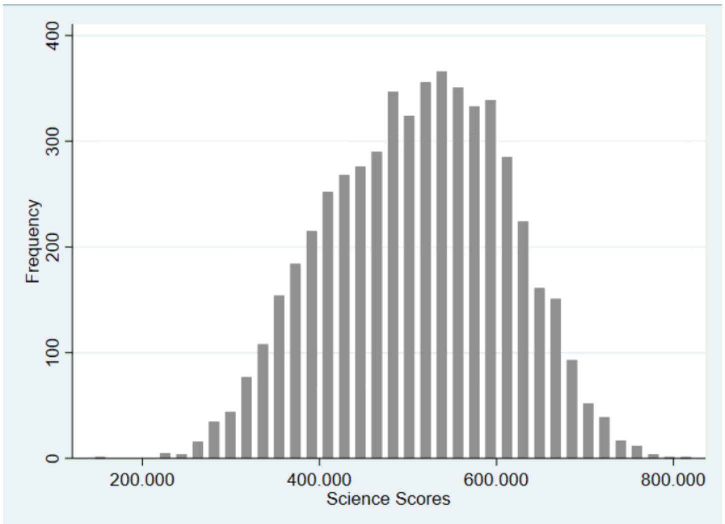
Appendix 2 Correlation matrix ICT variables

	ICTSCH	ICTHOME	USESCH	HOMESCH	ENTUSE
ICTSCH	1.0000				
ICTHOME	0.1647	1.0000			
USESCH	0.2287	0.1088	1.0000		
HOMESCH	0.1191	0.1206	0.5430	1.0000	
ENTUSE	0.1032	0.1218	0.4255	0.4584	1.0000

Appendix 3. Score distribution per subject







*Appendix 4***.** Model using the interaction terms for gender and the ICT variables plus the control variables affecting student performances in mathematics (M), reading (R) and science (S)

	Model 3 (M)	**Model 3 (R)**	**Model 3 (S)**
Fixed effects	*Coef. (SE)*	*Coef. (SE)*	*Coef. (SE)*
Intercept	387.67 (44.66) ***	373.72 (49.65) ***	400.65 (48.97) ***
Level 1			
GENDER	-11.80 (17.92)	-7.91 (19.23)	- 33.37 (19.62)
IMMIG	-18.00 (3.27) ***	-19.68 (3.51) ***	-21.47 (3.58) ***
ESCS	6.52 (1.74) ***	7.20 (1.87) ***	10.38 (1.91) ***
ICTHOME	-0.21 (1.23)	-2.90 (1.32)*	-2.99 (1.35) *
ICTSCH	-2.81 (1.02) **	-2.77 (1.10) *	-2.58 (1.12) *
USESCH	-4.05 (2.81)	-6.97 (3.02) *	-7.26 (3.08) *
HOMESCH	0.36 (2.59)	-4.05 (2.77)	-1.53 (2.83)
ENTUSE	-5.73 (2.64)*	0.31 (2.83)	0.69 (2.89)
G.ICTHOME	0.29 (1.75)	2.61 (1.87)	2.16 (1.91)
G.ICTSCH	-0.31 (1.45)	-1.07 (1.56)	-0.24 (1.59)
G.USESCH	3.20 (4.08)	8.27 (4.38)	4.57 (4.46)
G.HOMESCH	-6.88 (4.14)	-4.01 (4.44)	-8.18 (4.53)
G.ENTUSE	11.55 (3.96)**	0.84 (4.25)	6.68 (4.38)
Level 2			
CLASSSIZE	6.37 (1.04) ***	6.88 (1.16) ***	6.35 (1.14) ***
COMMUNITY	9.54 (8.29)	13.12 (9.25)	12.90 (9.10)
PRIVATE	-12.09 (11.33)	-13.91 (12.64)	-9.11 (12.43)
Random effects	***Variance component***	***Variance component***	***Variance component***
Residual variance	3384.58 (91.57)	3898.88 (105.46)	4057.34 (109.76)
Intercept variance	3349.45 (463.55)	4181.60 (573.87)	4028.95 (555.29)
Observations	2.581	2.581	2.581
Number of schools	117	117	117

** p < 0.05; ** p < 0.01; *** p < 0.001*