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The Relationship Between ICT-Related Factors and Student Academic Achievement and the Moderating Effect of Country Economic Indexes Across 39 Countries: Using Multilevel Structural Equation Modelling

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ABSTRACT: This study examined how information and communications technology (ICT) related factors and country-level economic status influence student academic achievement. Two-level structural equation modeling was employed to investigate both student-level and country-level variables, using the PISA 2015 data of ninth-grade students across 39 countries. The findings indicate that: (a) students' interest in ICT, perceived ICT competence, and autonomy had positive impacts on academic performance; (b) GDP per capita had significant interaction effects on the relationship among ICT-related factors (ICT use for studying at school, for entertainment, and perceived ICT autonomy) and academic performance; and (c) a higher level of students' perceived autonomy in ICT resulted in better learning outcomes in countries with less income inequality.

Keywords: Information and Communications Technology (ICT), Multilevel Structural Equation Modeling (MSEM), ICT Competence, ICT Autonomy, Income Inequality

1. Introduction

The integration of information and communications technology (ICT) in teaching and learning has grown in the education field across many countries, not only to promote student achievement but also to enhance equal access to educational platforms and life skills for youths and adults alike (UIS, 2009). It is also believed that the prevalence of ICT in education allows teachers to share their best practices with others, which contributes to the advancement of the overall quality of education (Goktas, Yildirim, & Yildirim, 2009; Murthy, Iyer, & Warriem, 2015). A number of studies have addressed the relationships among ICT-related factors such as frequency of use, availability, interest level, and perceived competence and autonomy in ICT use and academic performance. However, even though the importance and benefits of ICT in education have been widely recognized, no consensus has been reached on how ICT-related factors affect students' academic achievement.

Moreover, most of those studies focused on identifying school- or student-level ICT factors without considering country-level factors (Gómez-Fernández & Mediavilla, 2018), instead of taking a multinational approach. Considering that the national economic status has impacted the country's educational system, including the level of ICT integration in education and students' ICT richness (ITU, 2015), it is crucial to take into account of national-level economic status when probing the impacts of ICT factors on students' achievement Hu, Gong, Lai, and Leung (2018) and Skrybin, Zhang, Liu, and Zhang (2015) analyzed how national level ICT development and students' ICT use influence achievement in reading, math, and science. However, both studies conducted a series of univariate hierarchical linear analyses separately for multivariate outcome variables (math, reading, and science scores), which can inflate the Type I error rate. Moreover, even though the researchers included GDP per capita as a control variable, they did not carefully examine cross-level interactions regarding how a country's economic status can affect the relationships among ICT-related factors and achievement. Inconsistent results on the relationships among ICT-related factors and students' achievement from previous literature can be deeply related to this lack of sufficient and rigid research regarding how national economic status can moderate the overall relationships among ICT-related factors and students' achievement.

Thus, the purpose of this study was to probe the relationship between ICT-related factors and student academic achievement and the moderating effects of country-level economic factors on these relationships. Specifically, (1) each ICT-related factor effect on academic achievement, (2) effect of two country-level economic factors (GDP per capita and the GINI index) on academic achievement, (3) and the cross-level interaction effects will be examined.

2. Theoretical framework

2.1. Student-Level ICT factors and academic achievement

2.1.1. Students' ICT use for entertainment

Students' frequent ICT use for entertainment includes playing games, chatting, or browsing the Internet for fun. Previous studies related to ICT use for entertainment showed contradictory findings regarding its impact on academic achievement. Bulut and Cutumisu (2017) found that ICT use in Finland for entertainment did not benefit academic achievement in mathematics and science. However, several studies found a positive relationship between ICT use for entertainment and student achievement (Gumus & Atalmis, 2011). Other studies reported a nonsignificant relationship between use of ICT for entertainment and student performance (Hu et al., 2018; Juhaňák, Zounek, Záleská, Bárta, & Vlčková, 2018).

2.1.2. Students' interest in ICT use

Student interest in ICT use describes intrinsic motivation toward using ICT. ICT interest is related to positive emotions and enjoyment of using ICT-based products such as mobile devices or computers (Zylka et al., 2015). Interest level is a facet of positive attitudes towards ICT (Hu et al., 2018) that also showed a strong correlation with student engagement in using ICT (Zylka, Christoph, Kroehne, Hartig, & Goldhammer, 2015). Previous studies have had mixed findings regarding the effect of ICT interest on student learning outcomes (Lee & Wu, 2012; Meng, Qiu & Boyd-Wilson, 2019). Some studies showed that ICT interest was positively related to reading literacy (Lee & Wu, 2012; Xiao & Hu, 2019) and mathematics achievement (Meng et al., 2019). However, other studies concluded that ICT interests had no significant impact on mathematics, reading, and science achievement (Juhaňák et al., 2018).

2.1.3. Students' perceived ICT competence

Students' perceived ICT competence refers to their ICT-based knowledge and skills that can be used to perform ICT-related tasks (Meng et al., 2019). There have been conflicting findings regarding the effect of perceived ICT competence on student academic performance. For example, the study by Juhaňák et al. (2018) found that ICT competence had no significant impact on student performance. However, a study by Hu et al. (2018) showed that ICT competence had significant associations with student academic performance in mathematics, reading, and science. Interestingly, Xiao and Hu (2019) found negative associations between reading scores and perceived competence.

2.1.4. Students' perceived ICT autonomy

Students' perceived ICT autonomy can be defined as students taking control of learning via the use of ICT (Fu, 2013). Previous studies showed that students' perceived ICT autonomy had a significantly positive impact on student enjoyment of learning science and interest in science topics (Areepattamannil & Santos, 2019; Hu et al., 2018; Meng et al., 2019). Xiao and Hu (2019) also found a positive relationship between ICT autonomy and reading scores. This might be because students with a high level of autonomy in ICT use can complete learning tasks effectively by doing ICT-related activities such as searching for useful materials (Cárdenas-Claros & Oyanedel, 2016).

2.1.5. ICT academic use at home/school

ICT academic use includes student use of computers or other technologies to do homework or to communicate with friends or teachers regarding schoolwork. The effect of ICT academic use on student achievements is still a matter of debate. Many studies, especially those that employed large-scale data such as the Programme for International Student Assessment (PISA) or the Trends in International Mathematics and Science Study (TIMSS), found a positive relationship between ICT academic use and achievement (Kubiatko & Vlckova, 2010; Delen & Bulut, 2011; Luu & Freeman, 2011). However, some studies found that ICT use for studying had a negative or no significant relationship with academic achievement (Chiao & Chiu, 2018; Park, 2020). Song and

Kang (2012) also suggested that there were trivial but negative relationships between ICT use and achievement in math.

2.2. Country-level economic development factors

This paper explored the moderating effects of two country-level economic development factors (the GINI index and GDP per capita) on the relationship between ICT-related factors and students' academic achievements. The GINI index is a popular measure for income inequality, or the degree to which income is distributed in an unequal manner across a population (Voitchovsky, 2005). It is a measure of statistical dispersion representing the income or wealth distribution in a country (Gastwirth, 1972). It can be calculated by the Lorenz curve framework which produces the comparison of cumulative proportions of the population against cumulative proportions of received income (De Maio, 2007). GDP per capita is regarded as a core indicator of economic performance and used as an aggregate measure of average living standards (OECD, 2009a). In terms of the relationship between GDP per capita and the GINI index, income inequality is known to have a negative impact on economic growth (Cingano, 2014). This relationship indicates that increases in the level of income inequality result in lower transitional GDP per capita growth and have a negative effect on the level of GDP per capita in the long term (Brueckner & Lederman, 2015; Mo, 2000).

2.3. Country-level economic development and student-level ICT factors

Previous research findings have shown that a country's economic development status can affect its ICT access or usage (Aduwa-Ogiegbaen & Iyamu, 2005). ICT access and usage within a country can vary based on the level of economic development because well-developed countries are more likely to better support ICT usage and develop ICT infrastructure in the nation. This can yield higher academic performance because students in wealthy countries may have better ICT-related experience using rich ICT resources that can improve their ICT-related skills (Heinz, 2016).

A country's economic development status influences not only its ICT access or usage but also the country's ICT development level (Skryabin et al., 2015). National ICT development includes readiness of the ICT infrastructure, ICT-trained teachers, ICT support staff, educational software, virtual learning environments, and the impact of these elements on learning (UIS, 2009). A country's economic development status and its national ICT level mutually affect each other; wealthier countries allocate more resources to improve ICT development and overall ICT development plays an important role in promoting the national economy (Luu & Freeman, 2011).

2.4. Country-level economic development factors and students' academic achievements

The effects of country-level economic development status on students' academic achievements have been analyzed in diverse studies in the education field. However, no consensus has emerged on whether or how countries' wealth affects student academic performance (Ensminger, Fothergill, Bornstein, & Bradley, 2003). Some studies have shown that students in high-income countries generally have significantly higher academic achievement than those in low-income countries (Chiu, 2007; Sutton & Soderstrom, 1999). This is because wealthier countries are highly likely to secure a high-quality educational infrastructure including facilities, learning materials, and teachers by increasing spending on education (Saha, 1983; UNICEF, 2001). Other studies suggested that there is a trivial or insignificant relationship between a country's economic status and student academic achievement (Ripple & Luthar, 2000; Seyfried, 1998). This is because the impact of better schools or teachers can vary across countries with different income levels. In developed countries, family background has more of an influence on student academic outcomes than school or teacher factors (Heyneman & Loxley, 1983).

Research concerning the relationship between income inequality and student learning also showed inconsistent results. Income inequality within a country is recognized as one of the strongest factors that can explain differences in student academic achievement. The impact of the income gap on students' academic achievement is more than twice as large as the impact of racial background on academic achievement in the United States (Reardon, 2011). However, cross-national studies regarding the relationship between income inequality and academic outcomes have shown mixed results. Some studies found a modest positive association between income inequality and achievement (Chmielewski & Reardon, 2016). These studies also suggest that income inequality is largely associated with income segregation and child poverty rates, which can affect educational opportunities. On the other hand, several studies, including PISA and TIMSS reports, found that a country's income inequality had a very weak or no effect on student achievement (Dupriez & Dumay, 2006; Marks, 2005; OECD, 2010)

2.5. Rationale for the conceptual framework of the current study

Based on the literature discussed above, ICT-related factors are regarded as having great potential for improving student achievement; however, the effects of these factors on learning have been controversial and need further investigation. Previous research has focused on identifying school- and student-level ICT factors. Few studies consider country-level economic factors that can not only influence school and family ICT richness but also student ICT competence (ITU, 2015). The current study examines the relationship between ICT-related factors and student academic achievement and analyzes the moderating effects of country-level economic factors. The conceptual framework for the study (see Figure 1) includes five ICT factors at the student level: use for study, use for entertainment, interest level, perceived competence, and perceived autonomy. As country-level economic indicators, we measured the country's wealth by using GDP per capita and its economic inequality with the GINI index. Analyzing these student-level ICT factors and country-level economic factors within a model provided us with a comprehensive understanding of how each factor interacted with other factors at the national level and contributed to student learning.

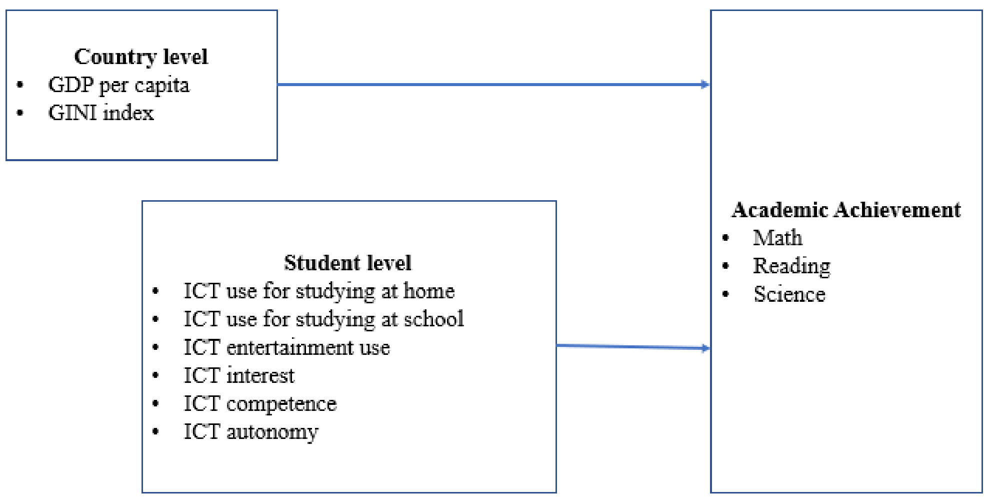

Figure 1. A conceptual framework of the potential influence of ICT factors on academic achievement

Summarizing the purpose of this study and the conceptual framework, we listed two main research questions (RQs) and related hypotheses below:

RQ1: Are student-level ICT variables associated with student academic achievement?

H1a: Higher ICT use at school will be correlated with better academic performance.
H1b: Higher ICT use at home will be correlated with better academic performance.
H1c: Higher students' ICT use for entertainment will be correlated with better academic performance.
H1d: Higher students' interest in ICT use will be correlated with better academic performance.
H1e: Higher students' competence in ICT use will be correlated with better academic performance.
H1f: Higher students' perceived ICT autonomy will be correlated with better academic performance.

RQ2: Does the impact of six ICT-related variables on student academic achievement vary among countries with different levels of economic development?

H2a: The relationship between ICT variables and student academic achievement is stronger in countries having higher GDP.
H2b: The relationship between ICT variables and student academic achievement is stronger in countries having lower GINI.

3. Method

3.1. Data source

This study employed datasets from the OECD's PISA 2015 database and the World Bank. The PISA 2015 dataset assessed 15-year-old students' knowledge and skills in the domains of mathematics, reading, and science across 72 countries and regions. The ICT familiarity questionnaire was optional, so students from some countries completed it. We extracted two country-level indices from World Bank datasets: (1) the national gross domestic product (GDP) per capita and (2) the GINI index representing the income distribution of residents within a nation. Several countries and regions in PISA data were excluded due to a lack of GDP per capita or GINI index information. The excluded countries and regions are Hong Kong, Chinese Taipei, Macao, Spain (regions), Singapore, China (Beijing-Shanghai-Jiangsu-Guangdong), and New Zealand. As a result, a total of 168,098 students from 39 countries were retained in the sample (see Appendix A).

3.2. Instruments

Our study employed student-level and country-level variables following the proposed conceptual framework for examining the relationship between ICT-related factors and student academic achievement. The student-level variables were from the PISA 2015 dataset, while country-level variables were from the World Bank database. The outcome variables evaluated student performance on literacy in mathematics, reading, and science in the PISA 2015 dataset. The PISA 2015 provided 10 plausible values for each student to maximize the estimation of student performance. These plausible values show the distribution of potential scores for students in the population with similar attributes and patterns of item response (OECD, 2009b). According to the PISA data analysis manual (OECD, 2009b), using one plausible value can still provide an unbiased estimate of population parameters. It showed that using one plausible value does not yield a significant difference in the mean estimates or in the standard error estimates with a sample size of 6,400 students (OECD, 2009b). The imputation error of employing one plausible value is also relatively small when the dataset is large and does not make a significant change in the Type I error (OECD, 2009b). Thus, we employed the first plausible value of math, reading, and science for data analysis. Because the scores on math, science, and reading were highly correlated (see Table 1), we created the latent factor "Achievement" using three scores to address multiple outcome variables concurrently.

Student-level ICT-related factors included use or perceptions of studying at school (STUSCH), studying at home (HOMESTU), entertainment (ENTUSE), interest level (INTICT), competence (COMPICT), and autonomy (AUTICT). The related survey items for each of these variables are listed in Appendix B. We generated STUSCH and HOMESTU by averaging the scores of the original survey items, which were only related to the study purpose. The other four ICT variables (i.e., ENTUSE, INTICT, COMPICT, AUTICT) were generated by using weighted likelihood estimates (WLE) (Warm, 1989) and applying a transformation formula (see Figure 2) to the scores of related survey items. All these ICT-related variables in the analysis were group-mean centered by students' countries. At the student level, gender and family socioeconomic status (SES) were included as control variables. The variable of student's family SES was measured by the PISA index of economic, social, and cultural status (ESCS). The scale of ESCS is a transformed WLE score that considers the indicators of parental education, highest parental occupation, and home possessions. The coding of all variables in the multilevel model is presented in Table 2.

$$\delta_f' = \frac{\delta_o - \bar{\delta}_{OECD}}{\sigma_{\delta_{OECD}}}$$

where δ_f' is the final WLE score after transformation, δ_o is the original WLEs in logits, $\bar{\delta}_{OECD}$ is the OECD average of logit scores with weighted country samples, and $\sigma_{\delta_{OECD}}$ is the corresponding standard deviation of the initial WLE score.

Figure 2. The formula of transformation

At the country level, we utilized the logarithm of 2015 GDP per capita and the grand-mean centered 2015 GINI index of each country when creating the GDP and GINI index variables. In addition, we excluded cases with missing data from the analyses. We employed the variance inflation factor (VIF) to check multicollinearity. No VIFs exceeded 10 in the study.

Table 1. Correlations

	Math	Science	Reading	GINI	GDP	STUSCH	HOMESTU	ENTUSE	COMPICT	AUTICT	INTICT
Math	1										
Science	.932	1									
Reading	.865	.919	1								
GINI	-.413	-.324	-.276	1							
GDP	.27	.222	.196	-.467	1						
STUSCH	-.107	-.119	-.141	.015	.051	1					
HOMESTU	-.1	-.105	-.016	.125	-.105	.43	1				
ENTUSE	.015	.008	-.016	-.035	-.002	.31	.415	1			
COMPICT	.083	.098	.081	.014	.028	.187	.215	.374	1		
AUTICT	.149	.16	.112	-.044	.081	.163	.183	.383	.643	1	
INTICT	.044	.085	.063	.039	.049	.17	.195	.377	.527	.443	1

Table 2. Coding of variables

	Scale	Range	Mean	*SD*
Level 1 variables				
STUSCH	1: Never or hardly ever…5: Everyday, centered	[-2.808; 3.812]	0.000	0.941
HOMESTU	1: Never or hardly ever…5: Everyday, centered	[-2.826; 3.576]	0.000	0.998
ENTUSE	1: Never or hardly ever…5: Everyday, WLE	[-4.083; 5.294]	0.000	1.007
INTICT	1: Strongly disagree…4: Strongly agree, WLE	[-3.336; 3.050]	0.000	0.98
COMPICT	1: Strongly disagree…4: Strongly agree, WLE	[-3.047; 2.859]	0.000	0.961
AUTICT	1: Strongly disagree…4: Strongly agree, WLE	[-2.839; 2.456]	0.000	0.98
Gender	1: female, 2: male, standardized	{1; 2}	1.493	-
SES	Index of economic, social and cultural status, WLE	[-6.656; 3.567]	-0.101	1.006
Level 2 variables				
GDP	GDP/c; logarithm	[1.993; 2.446]	2.205	0.105
GINI index	Grand-mean centered	[-9.764; 16.136]	0.000	7.09

3.3. Data analysis

We conducted multilevel structural equation modeling (MSEM) to account for moderation effects of country-level predictors in the relationships among ICT-related factors and achievement. The model was a random-intercepts-random-slopes model (see Figure 3). In the model, the slopes of all ICT-related variables were estimated as random in the within part, which allowed the variables to have different effect sizes across the countries. We labeled the slopes "S_n" between each ICT-related variable and students' achievement. In the between-part of the model, we tested the moderator hypothesis, which was the effects of the level 2 predictors on the slopes "S_n" as well as the mean values of ICT-related variables and student achievement. The multivariate model also included student gender and family social economic status as control variables.

Table 3 shows the changes in intraclass correlation based on different models. In the baseline model, 17.7% of the variation in student science achievement remained unexplained, which can be attributed to the grouping variable (country characteristics). In the within-part of the multilevel model (Level 1) after controlling for gender and SES and adding ICT variables, the unexplained variation was reduced to 12% for science achievement. In the between part of the model (Level 2), this variation was reduced to 11.9%. Likewise, the baseline model showed 23.2% variation in math achievement and 13.6% variation in reading achievement, which was respectively decreased to 16.1% and 8.2% in both the Level 1 and Level 2 models.

Table 3. The results of intraclass correlation

Variable	Baseline Model	Level 1 of the multilevel model	Level 2 of the multilevel model
Math	0.232	0.161	0.161
Science	0.177	0.12	0.119
Reading	0.136	0.082	0.082

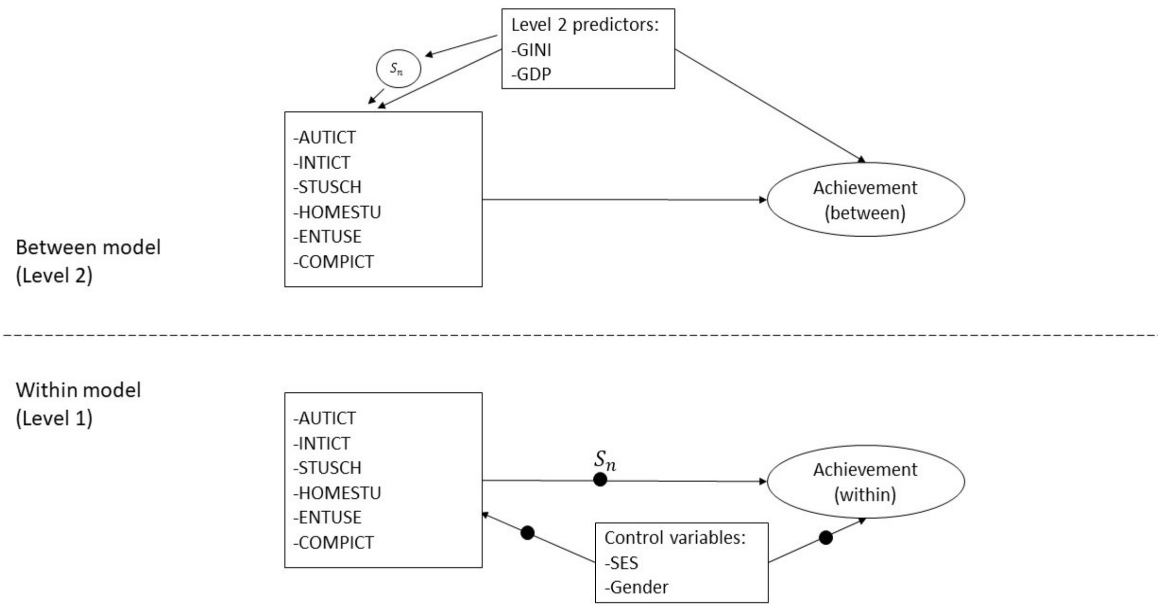

Figure 3. The path paradigm of the MSEM model

4. Results

4.1. Student-level ICT factors

Table 4 reports the estimation result of the multilevel structural equation model using Bayes estimator with Mplus 8.4 (Muthén, 2010). Since the Bayesian 95% credibility intervals (C.I.) of the residual variances do not include zero, all random slopes and intercepts vary across countries even when the country-level predictors are included (Muthén, 2010; Mayerl & Best, 2019). At the within-country level, holding country-level economic factors constant, all ICT-related factors showed significant effects on achievement based on Bayesian 95% credibility intervals. Both STUSCH and HOMESTU negatively correlated with overall achievement at the within-country level. However, both path coefficients (STUSCH = -0.134, HOMESTU = -0.052) were trivial (Cohen, 1992). Students' ICT use for entertainment (ENTUSE) was also negatively associated with achievement, and its effect size was small as well (-0.073). On the other hand, attitudes toward ICT such as students' interest in ICT, perceived competence and autonomy in ICT showed significantly positive relationships with academic achievement. Those variables regarding ICT attitudes showed positive small effects on academic achievement. The path coefficients were 0.045 (INTICT), 0.022 (COMPICT), 0.122 (AUTICT) respectively. Overall, we found that ICT related variables have small but significant impacts on achievement within-country level. However, since there are significant interaction effects of GDP per capita or GINI index, the effects of STUSCH, ENTUSE, and AUTICT on achievement are conditional and the interpretation of these random intercepts depend on the value of the country's GDP per capita or GINI index.

4.2. Country-level economic factors as moderators

While GDP per capita had no significant effect on academic achievement (p = .225, Bayesian C.I. includes zero), the GINI index had a significant negative path coefficient (-0.440, p < .001). Thus, we found that the income inequality of a country had a medium negative effect on achievement.

In terms of cross-level interactions, GDP per capita exhibited a significant interaction effect on the relationship between achievement and students' ICT use for studying at school. The path coefficient was 0.328, implying that a country's national wealth has a moderately positive effect on the relationship between students' achievement and their ICT use for studying at school. GDP per capita also had a moderately positive interaction effect (0.251, p = .027) on the relationship between achievement and their ICT autonomy. However, GDP per capita showed a moderately negative interaction effect (-0.473, p < .001) on the relationship between achievement and their ICT use for entertainment. The GINI index showed a moderately negative interaction effect (-0.417, p < .001) on the relationship between achievement and perceived ICT autonomy, but a moderately positive interaction effect (0.327, p < .001) on the relationship between achievement and ICT use for entertainment.

Table 4. Multilevel SEM Results

	Within-Country Model		95% C.I.	
	Standardized Estimate	Posterior *SD*	Lower 2.5%	Upper 2.5%
Achievement by				
Math	0.936***	0.000	0.936	0.937
Reading	0.920***	0.000	0.936	0.937
Science	0.990***	0.000	0.990	0.990
Level 1 predictors				
STUSCH → Achievement	-0.134***	0.002	-0.139	-0.129
HOMESTU → Achievement	-0.052***	0.003	-0.057	-0.047
ENTUSE → Achievement	-0.073***	0.003	-0.078	-0.067
INTICT → Achievement	0.045***	0.003	0.040	0.050
COMPICT → Achievement	0.022***	0.003	0.016	0.029
AUTICT → Achievement	0.122***	0.003	0.115	0.128
Gender → Achievement	0.028***	0.002	0.024	0.032
SES → Achievement	0.359***	0.002	0.355	0.363
Residual Variances				
MATH	0.123***	0.001	0.122	0.125
READ	0.153***	0.001	0.151	0.154
SCIENCE	0.020***	0.000	0.019	0.021
Achievement	0.795***	0.002	0.792	0.798
	Between-Country Model		**95% C.I.**	
	Standardized Estimate	Posterior *SD*	Lower 2.5%	Upper 2.5%
Achievement by				
Math	0.926***	0.362	0.024	0.125
Reading	0.949***	0.023	-0.998	-0.914
Science	0.985***	0.016	-0.999	-0.921
Level 2 predictors				
Gini → Achievement	-0.440***	0.139	-0.598	-0.067
GDP → Achievement	-0.082	0.103	-0.280	0.115
Cross-level interactions				
Gini*STUSCH → Achievement	-0.016	0.119	-0.245	0.218
GDP*STUSCH → Achievement	0.328***	0.110	0.084	0.516
Gini*HOMESTU → Achievement	0.060	0.120	-0.181	0.291
GDP*HOMESTU → Achievement	-0.032	0.132	-0.293	0.222
Gini*ENTUSE → Achievement	0.327***	0.108	0.093	0.514
GDP*ENTUSE → Achievement	-0.473***	0.105	-0.642	-0.238
Gini*INTICT → Achievement	0.189	0.117	-0.054	0.404
GDP*INTICT → Achievement	0.064	0.124	-0.190	0.292
Gini*COMPICT → Achievement	0.150	0.121	-0.096	0.374
GDP*COMPICT → Achievement	-0.129	0.129	-0.366	0.130
Gini*AUTICT → Achievement	-0.417***	0.103	-0.590	-0.192
GDP*AUTICT → Achievement	0.251	0.122	-0.005	0.474
Residual Variances				
MATH	0.142***	0.356	0.065	1.000
READ	0.066***	0.042	0.004	0.165
SCIENCE	0.051***	0.040	0.003	0.151
Achievement	0.735***	0.083	0.567	0.885
STUSCH	0.851***	0.094	0.632	0.984
HOMESTU	0.972***	0.041	0.846	0.999
ENTUSE	0.753***	0.086	0.577	0.907
INTICT	0.934***	0.069	0.747	0.997
COMPICT	0.953***	0.046	0.827	0.998
AUTICT	0.835***	0.069	0.683	0.951

Note. $^{***}p$ < .001 (one-tailed p-value based on the posterior distribution). The *p*-value is the proportion of the posterior distribution that is below zero for a positive estimate.

5. Discussion

5.1. Student-level ICT factors and academic achievement

5.1.1. Students' ICT use for entertainment

At the within-country level, students' ICT use for entertainment showed negative associations with achievement. This result was consistent with those of other studies such as Bulut and Cutumisu (2017), Petko, Cantieni, and Prasse (2017). Following the result of this study and supportive results from other literature, students' ICT use for entertainment seems to negatively affect students' academic performances. Considering that students' ICT use for entertainment includes playing games, browsing the Internet for fun, and downloading and enjoying movies/music, ICT use for leisure can distract students from learning activities or schoolwork. As ICT advances, students can more easily access a variety of materials for fun by using ICT. Thus, the possibility that students' learning can be harmed by ICT entertainment use also tends to be higher than before.

5.1.2. Students' interest in ICT use

Students' interest in ICT exhibited significant positive relationships with achievement. This result supports other studies' results that interest in ICT has a positive relationship with academic achievement (Hu et al., 2018; Scherer, Rohatgi, & Hatlevik, 2017). Some of the studies showed that ICT interest had no significant impact on student's academic performance (Juhaňák et al., 2018), but most of those studies only analyzed a specific country. According to the result of this study and other literature, students with higher interests in ICT use were highly likely to have better learning outcomes. This can be explained as students with a higher interest in ICT will engage in learning activities using computers or the Internet more often than other students (Lee & Wu, 2012; Scherer et al., 2017). Moreover, these students would be more motivated and have more positive attitudes toward learning with technology.

5.1.3. Students' perceived ICT competence

Students' perceived ICT competence also showed a significant positive impact on students' academic performance. This result is also consistent with other studies such as Hosein et al. (2010), Hu et al. (2018), or Selwyn and Husen (2010). According to these findings, students with higher perceived competence in ICT were more likely to frequently use software or online resources for studying than those with lower ICT competence (Hosein et al., 2010). However, some studies claimed that ICT competence had no or negative relationship with achievement (Juhaňák et al., 2018; Xiao & Hu, 2019). The results can differ depending on students' grade levels and what country the study analyzed. Students' perceived ICT competence in their academic achievement tends to diminish as the academic year progresses because students become more competent as they get older (Selwyn & Husen, 2010).

5.1.4. Students' perceived ICT autonomy

The result showed that students' perceived ICT autonomy had a significant positive effect on students' academic performance, and its effect size is larger than ICT interest or competence. This result supports other literature that ICT autonomy had a significantly positive relationship with academic achievement (Cárdenas-Claros & Oyanedel, 2016; Xiao & Hu, 2019; Meng et al., 2019). Students with higher autonomy in ICT use have a tendency to take more control of their learning process with technology. Autonomy implicates that students can regulate their learning and can use ICT toward completing tasks and achieve mastery (Fu, 2013). Thus, ICT autonomy can have a more powerful impact on students' learning outcomes than other attitudes regarding ICT use, which are not always related to students' learning activities. Furthermore, once students recognize that they can control their learning with ICT, then they can strengthen their autonomy in ICT use and obtain more knowledge by using ICT effectively (Serhan, 2009).

5.1.5. ICT academic use at home/school

Students' ICT academic use at home and school showed negative relationships with their academic achievement. This result is in agreement with previous studies that ICT academic use had a negative effect on students' academic performances (Song & Kang, 2012; Chiao & Chiu, 2018; Park, 2020). Some studies found that there might be a positive relationship between students' academic use and achievement (Luu & Freeman, 2011; Delen & Bulut, 2011). However, Luu and Freeman (2011) analyzed only Canada and Australia, and Delen and Bulut's work (2011) also solely used Turkey data. Thus, we can find that students' ICT academic use is likely to decrease achievement across countries according to literature. One possible explanation of why it showed a negative impact on achievement would be regarding the PISA ICT questionnaire. Questions that are related to students' academic use only ask the frequency of using ICT. The frequent ICT use for doing homework or searching for studying resources cannot guarantee the quality of students' ICT use for learning. The frequency of ICT academic use cannot provide us with information concerning how much students can focus on tasks while using ICT for studying or how much time they spend studying with the use of ICT.

5.2. Moderating effects of country-level economic factors on the relationship between ICT factors and academic achievement

In terms of GDP per capita, it had no significance on students' academic achievement, which aligns with previous research findings (e.g., Ripple & Luthar, 2000). Even though the wealthier countries may have better ICT infrastructure for education (UNICEF, 2001), the impact of a country's economic size turned out to be insignificant. We also found that the influence of students' ICT use for studying at school and perceived ICT autonomy on achievement was stronger in countries with higher GDP per capita. This supports the idea that a country's economic development levels are associated with student achievement as it affects school-level ICT resources and skills such as infrastructure, ICT support staff, and educational software. Furthermore, ICT richness in school and classroom environments allow students to have more opportunities to complete schoolwork independently and to reflect on their learning progress using technology-mediated communication.

Our findings showed that students in a country with less income inequality would have better academic achievement than those in a country with more income inequality. Therefore, income inequality can lead to a significant academic achievement gap (Reardon, 2011). Income inequality showed positive interaction effects on the impacts of students' perceived ICT competence and ICT interest on academic performance even though these factors were not statistically significant. This reveals that students' perceived attitudes toward ICT can more greatly impact academic performance in countries with higher income inequality than other countries. This shows that students who can exert a higher level of autonomy in ICT use are likely to get better learning outcomes in countries with less income inequality based on the negative and significant effects of a country's income inequality on the relationship between students' perceived ICT autonomy and academic achievement.

Overall, we found that income inequality has broader and more extensive impact on the relationship between ICT-related attitudes and students' achievement than a country's wealth itself. This suggests that students from lower-income families in these countries are highly likely to lag behind academically due to a lack of ICT or resource availability. Indeed, Rideout and Katz (2016) found that around 40% of parents without computers or Internet access cannot afford to provide their children necessary resources. Several studies have also reported that funding is the primary obstacle creating a digital divide, which is a gap between students who can utilize technology to acquire knowledge and those who cannot (Rideout and Katz, 2016). Hence, to solve this educational inequality based on addressing income inequality and the digital divide, it is essential to promote equitable access to digital technologies through related policies, including discounted internet access and expanding ICT infrastructure in public areas such as schools or libraries for low-income families (Kelley-Salinas, 2000). To support the ICT competence, interest, and autonomy of students from low-income families, supporting a variety of education programs that can improve students' ICT attitudes and skills that can lead to improving their learning is important (Koh, Chai, & Lim, 2017). This can also be obtained by improving teachers' ICT skills through professional development opportunities and continuous support from government, district, and school communities (Akbaba-Altun, 2006; Jung, 2005).

6. Conclusion

This study contributes to the education field via multilevel analysis of the relationship between student-level ICT factors and academic achievement and of the moderating effect of national-level economic indices on these relationships. The results indicate that students' use of ICT for both studying and entertainment had a negative association with their academic achievement; however, interest, perceived competence, and autonomy in ICT use showed a positive impact on students' learning. We employed two national-level economic indices, GDP per capita and the Gini index, to analyze how a country's economic status can moderate the relationships between

ICT-related factors and achievement. GDP per capita showed significant interaction effects on the relationship between achievement and students' ICT use for studying at school, entertainment, and perceived ICT autonomy. The GINI index also showed medium interaction effects on relationships between achievement and ICT variables (ICT use for entertainment and students' perceived ICT autonomy). This suggests that the effects of ICT-related factors on achievement should be interpreted carefully in the context of national-level wealth and income inequality.

This study has a few limitations. First, we analyzed the responses of students from countries that participated in the PISA ICT questionnaire. Because not all countries responded to the ICT questionnaire, the results of this paper are limited to those selected countries. Second, the PISA ICT questionnaire consists of questions on frequency or the availability of ICT use, which cannot capture the quality of ICT use. For future studies, more factors related to the quality of student ICT use should be explored to analyze their influences on students' learning outcomes. Variables at other levels (e.g. teacher or school) that might influence the relationship between ICT-related factors on student academic performance should also be developed.

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Appendix A: Country and sample of the study

Country	Sample size
Australia	8,298
Austria	4,346
Belgium	5,882
Bulgaria	3,076
Brazil	6,847
Switzerland	3,619
Chile	4,597
Colombia	6,833
Costa Rica	3,594
Czech Republic	4,617
Denmark	4,385
Dominican Republic	1,996
Spain	4,679
Estonia	4,023
Finland	4,273
France	3,765
United Kingdom	3,665
Greece	3,654
Croatia	3,860
Hungary	3,681
Ireland	3,942
Iceland	2,326
Israel	3,990
Italy	7,609
Japan	5,085
Korea	4,645
Lithuania	4,316
Luxembourg	3,079
Latvia	3,497
Mexico	5,194
Netherlands	4,115
Peru	4,070
Poland	3,378
Portugal	5,204
Russia	3,838
Slovakia	4,030
Slovenia	4,068
Sweden	3,299
Uruguay	2,723

Appendix B: Description of ICT variables and survey items

Variable	Item code	Survey item
STUSCH	IC011Q03TA	Browsing the Internet for schoolwork.
	IC011Q07TA	Practicing and drilling, such as for foreign language learning or mathematics.
	IC011Q08TA	Doing homework on a school computer.
	IC011Q09TA	Using school computers for group work and communication with other students.
HOMESTU	IC010Q01TA	Browsing the Internet for schoolwork (e.g., for preparing an essay or presentation).
	IC010Q02TA	Browsing the Internet to follow up lessons, e.g., for finding explanations.
	IC010Q03TA	Using email for communication with other students about schoolwork.
	IC010Q04TA	Using email for communication with teachers and the submission of homework or other schoolwork.
	IC010Q05NA	Using social networks for communication with other students about schoolwork (e.g., <Facebook>, <MySpace>).
	IC010Q09NA	Doing homework on a computer.
	IC010Q10NA	Doing homework on a mobile device.
	IC010Q11NA	Downloading learning apps on a mobile device.
		How often do you use digital devices for the following activities outside of school?
ENTUSE	IC008Q01TA	Playing one-player games.
	IC008Q02TA	Playing collaborative online games.
	IC008Q03TA	Using email.
	IC008Q04TA	<Chatting online> (e.g., <MSN®>).
	IC008Q05TA	Participating in social networks (e.g., <Facebook>, <MySpace>).
	IC008Q07NA	Playing online games via social networks (e.g., <Farmville®>, <The Sims Social>).
	IC008Q08TA	Browsing the Internet for fun (such as watching videos, e.g., <YouTube>.
	IC008Q09TA	Reading news on the Internet (e.g., current affairs).
	IC008Q10TA	Obtaining practical information from the Internet (e.g., locations, dates of events).
	IC008Q11TA	Downloading music, films, games or software from the internet.
	IC008Q12TA	Uploading your own created contents for sharing (e.g., music, poetry, videos, computer programs).
	IC008Q13NA	Downloading new apps on a mobile device.
		Thinking about your experience with digital media and digital devices: to what extent do you disagree or agree with the following statements?
INTICT	IC013Q01NA	I forget about time when I'm using digital devices.
	IC013Q04NA	The Internet is a great resource for obtaining information I am interested in (e.g., news, sports, dictionary).
	IC013Q05NA	It is very useful to have social networks on the Internet.
	IC013Q11NA	I am really excited discovering new digital devices or applications.
	IC013Q12NA	I really feel bad if no internet connection is possible.
	IC013Q13NA	I like using digital devices.
		Thinking about your experience with digital media and digital devices: to what extent do you disagree or agree with the following statements?
COMPICT	IC014Q03NA	I feel comfortable using digital devices that I am less familiar with.
	IC014Q04NA	If my friends and relatives want to buy new digital devices or applications, I can give them advice.
	IC014Q06NA	I feel comfortable using my digital devices at home.
	IC014Q08NA	When I come across problems with digital devices, I think I can solve them.
	IC014Q09NA	If my friends and relatives have a problem with digital devices, I can help them.
		Thinking about your experience with digital media and digital devices: to what extent do you disagree or agree with the following statements?
AUTICT	IC015Q02NA	If I need new software, I install it by myself.
	IC015Q03NA	I read information about digital devices to be independent.
	IC015Q05NA	I use digital devices as I want to use them.
	IC015Q07NA	If I have a problem with digital devices I start to solve it on my own.
	IC015Q09NA	If I need a new application, I choose it by myself.