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REGULAR ARTICLE

The Mediating Effect of ICT Usage on the Relationship Between Students' Socioeconomic Status and Achievement

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Abstract To find out if information and communication technology (ICT) could narrow the achievement gaps among students caused by variations in their socioeconomic status, this study examines the mediating mechanism of ICT use between students' socioeconomic status (SES) and achievement. Data from the 2012 East Asia Program for International Student Assessment (PISA) were used for the structural equation modeling estimations, drawing on the work of 31,161 students. The results showed that using ICT for information retrieval and social interaction could widen the achievement gaps caused by variations in SES. This study also found that gender could significantly moderate the positive relationship between students' SES and ICT usage for learning, as well as for social interaction.

Keywords ICT in education · Gender difference · Socioeconomic difference · Digital divide · PISA · SEM

Introduction

Student achievement is an important issue that is of concern to researchers, educators, and policy makers, with governments, schools and educators actively working to enhance the equality of educational opportunity, and thus reduce the differences in this. However, despite such efforts, achievement gaps remain a serious educational problem worldwide (Sung et al. 2014). The key factors in achievement gaps may arise at the individual, family, school, and region levels. Sirin (2005) examined journal articles published between 1990 and 2000, and found that there was a medium to strong relationship between socioeconomic status (SES) and achievement. The Organization for Economic Co-operation and Development OECD (2015) also reported that SES has a strong influence on the performance of students across all the domains assessed in PISA.

To narrow SES-based achievement gaps, a number of governments have highlighted the role that computers can play in improving educational performance and enabling students to master the skills and competences needed in today's job market (OECD 2010; Fariña et al. 2015). Parents also tend to place a high value on computer usage, and see it as vital to academic achievement (Ortiz et al. 2011). Moreover, improvements in information and communication technology (ICT) mean that computers have become cheaper and more sophisticated (Delen and Bulut 2011), and thus the differences in computer access caused by SES, or the so-called first digital divide, shrank between 2009 and 2012 in most countries (OECD 2015). While this trend seems to offer a good chance for students to reduce achievement gaps, the OECD recently published a disheartening report that indicated ICT use for educational purposes has not been linked to improved student achievement in reading, mathematics or science (OECD 2015).

Similarly, there has been some debate in the literature as to whether ICT usage might increase opportunities for learning and narrow SES-based achievement gaps (Skryabin et al. 2015; Shank and Cotten 2014), or in fact widen them (Vigdor et al. 2014; Aesaert and Van Braak 2015). To

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investigate this issue in more depth, this research estimates the mediating effect of ICT usage on the relationship between students' SES and achievements.

Achievement Gap: Relationship Between Students' SES and Achievement

Most researchers estimate students' achievement with their school scores, national standard tests (such as SCAAT, NAEP), or international assessments, such as PISA, TIMSS, and PEARL. Among these data sources, the PISA achievement measures are known for having been well-validated psychometrically and thus are often used as the standard for international comparisons (Tucker-Drob et al. 2014). Researchers have found many factors that could influence students' achievements in PISA, such as learning interest, school efficiency, and immigration status. Among these, students' family SES is one of the factors which have been consistently shown to affect learning achievement in PISA (Schulz 2005, April). Shera and Mitre (2012) found that SES was positively related to reading performance in Albania, based on a PISA-plus study. Researchers also revealed the relationship between SES and math achievement in PISA data (McConney and Perry 2010; Cheema and Galluzzo 2013; Erdogdu and Erdogdu 2015). Areepattamannil and Kaur (2013) and Tucker-Drob et al. (2014) found that SES could predict science achievement in the PISA 2006 data.

Moreover, Polidano et al. (2013) found that the reading and mathematics achievements of lower SES students lagged behind those of higher SES students by around 15% in PISA 2003 data for Australia. Zhou and Wang (2015) analyzed PISA 2009 data, and found higher SES students in four Chinese societies have more chance to participate in out-of-school-time lessons, which might enlarge the academic achievement gaps. A review of literature thus shows that students' SES might influence their academic achievements.

Digital Divide: Relationship Between Students' SES and ICT Usage

Students' SES not only has a relationship with their level of achievement, but also relates to ICT access and usage (Stevenson 2011; Hollingworth et al. 2011). This issue is also discussed in terms of a digital divide or digital inequality. In 1990, the digital divide was defined as the gap between those who have and do not have access to computers and the Internet (van Dijk 2006). However, as Rogers noted in the diffusion of innovation theory, this divide is now disappearing due to improvements in hardware and software, and the lower cost of such technologies (Hohlfeld et al. 2008). As such, researchers are now more concerned with whether people can take advantage of the information they obtain from ICT, and variations in this are referred to as the second digital divide (OECD 2010).

Research shows that students with higher SES often have better ICT equipment and access. For example, Mertens and D'Haenens (2010) found that SES affects the ownership and use of digital technologies in Brussels. Moreover, many researchers confirmed the effects of SES on the digital skills of students (Zhong 2011; Claro et al. 2015; Aesaert and Van Braak 2015; Erdogdu and Erdogdu 2015). These researchers aggregated ICT usage as a single index when they examined its relationship with students' SES. However, this aggregation might make it more difficult to clarify whether different relationships exist between students' SES and various different forms of ICT usage.

Researchers often classify ICT use by its frequency, location, and relationship with learning (Aypay 2010; Guzeller and Akin 2014; Kubiatko and Vlckova 2010; Lee and Wu 2012, 2013; Luu and Freeman 2011; Song and Kang 2012). Two studies have attempted to categorize ICT usage in more detailed ways. Biagi and Loi (2013) classified it into gaming activities, communication and collaboration activities, information retrieval activities, the creation of content and problem solving. The other, van Deursen and van Dijk (2014), sorted Internet usage into that related to information, news, personal development, social interaction, leisure, commercial transactions and gaming. In this study, students' ICT usage is classified into learning, information retrieval, social interaction, and leisure purposes.

Unsolved Debate: Relationship Between Students' ICT Usage and Achievements

The impact of ICT on student achievements is still a matter of debate in most large-scale international studies, with researchers using different variables and methodologies (Petko et al. 2017; Erdogdu and Erdogdu 2015). The majority of works find a positive relationship between ICT use and achievement in PISA data (Kubiatko and Vlckova 2010; Delen and Bulut 2011; Luu and Freeman 2011; Erdogdu and Erdogdu 2015). However, Lee and Wu (2012) found that the availability of ICT at home had a negative impact on PISA 2009 reading literacy. Song and Kang (2012) also found that ICT usage at both the student- and school-level had negative impacts on math achievement. Recently, several studies even found both positive and negative relationships between students' ICT usage and PISA achievement, when they analyzed different aspects of such use (Lee and Wu 2013; Guzeller and Akin 2014; Biagi and Loi 2013). Moreover, some studies found no significant relationship between students' ICT use and academic achievement (Fariña et al. 2015; Aypay 2010). Due to these inconsistent results, the relationship between students' ICT use and achievement needs further investigation.

Research Hypotheses

According to the literature reviewed above, we summarize the relationship between students' SES, ICT usage and academic achievement in Fig. 1. It can be seen that relationship between students' SES and achievement (path c) represents an achievement gap, while that between students' SES and ICT (path a) indicates a digital divide. Although the relationship between students' ICT usage and achievement (path b) is still inconclusive, most studies find significant links between them. In an attempt to further clarify this issue, the current study examines the mediating mechanism of student SES through which ICT usage affects their achievement.

Few studies have been conducted on the indirect effects of ICT usage on student achievement, with notable exceptions being Claro et al. (2015) and Cheema and Bo (2013). Claro et al. (2015) used the national standardized tests of Chilean students to compare the effects of SES on their digital skills, mathematics and language performance. Cheema and Bo (2013) used PISA 2003 data from the United States to predict the effects of both the quality and quantity of computer use on academic achievement. Their results showed that the gaps among students from Chile and the United States tended to widen when comparing their performance in mathematics and language with different aspects of ICT usage. However, both works focused on only one county, and did not examine why and how students' SES affects their achievements, as mediated by ICT usage. To clarify the mediating effects of students' ICT usage on the relationship between SES and achievements, this study examines the following hypotheses:

H1 Students' ICT usage for information retrieval (1a), social interaction (1b), learning (1c), and leisure (1d) have significant mediating effects on the relationship between their SES and achievement.

Hypothesis 1 examines the single mediating effect of students' various forms of ICT usage on gaps in their achievement. However, Prensky (2001) observed that the so-called digital natives tend to use ICT with multi-tasking and receive information fast. The following question thus arises: do the four kinds of ICT usage considered in this work influence one another? This study proposed a parallel mediation model of ICT usage for determining whether an overall indirect effect exists, and to determine the relative magnitudes of specific indirect effects (Preacher and Hayes 2008; Hayes 2009; Ding et al. 2014). As such, the second hypothesis is as follows.

H2 The indirect effects of students' ICT usages on the relationship between their SES and achievement have significant differences.

Gender is one factor that might affect students' achievement (Brozo et al. 2014; Buccheri et al. 2011; Kim and Law 2012; Heemskerk et al. 2005; Cheung et al. 2013). In addition to that, researchers also found the effects of socioeconomic status on learning outcomes between countries/economies were significantly different (OECD 2014a; Tsai et al. 2017). Thus, two factors were examined in the following hypotheses.

H3 Gender moderates the mediating effect of ICT usage on the relationship between SES and achievement.

H4 ICT usage has significantly mediating effects between SES and achievement at the regional level.

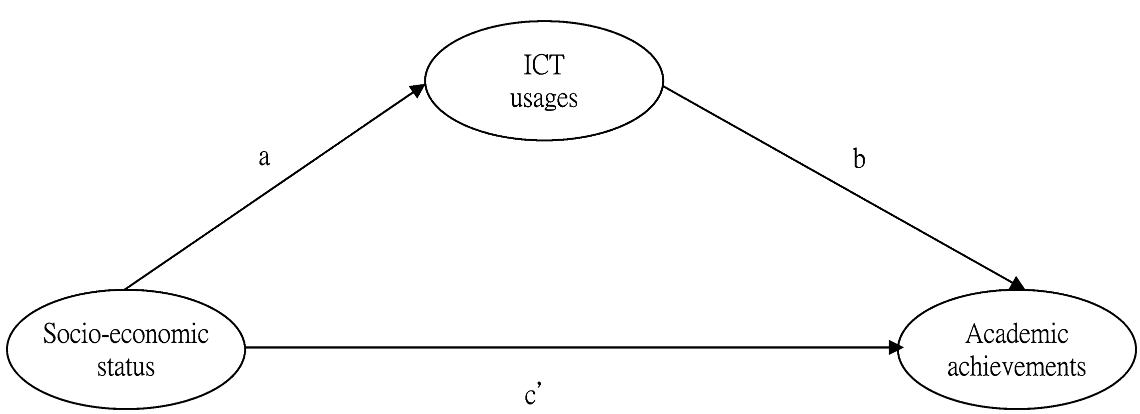

Fig. 1 The relationship between students' SES, ICT usage and academic achievement

Method

To uncover the mediating effect of ICT usage on the relationship between students' SES and achievement, this study used AMOS 21.0 for structural equation modeling (SEM), with the PISA 2012 data used for confirmatory factor analysis (CFA) and to evaluate the model fit with regard to each of the hypotheses.

Sample

The samples in this study were drawn from the PISA 2012 dataset (http://pisa2012.acer.edu.au/downloads.php), in which around 510,000 students completed the assessment. Among the 65 countries and economies included in this dataset, Chinese Taipei, Hong Kong-China, Japan, Korea, Macao-China and Shanghai-China are all among the top ten performers in mathematics, reading and science. In addition to the high level of student performance, these six regions also have many other similarities, such as a common cultural background based on Confucianism, and high ICT Development Index (7.59 $\sim$ 8.81, with Taipei and Shanghai not included in this data). A total of 32,612 students were chosen as the target samples from these six regions in East Asia. After removing missing data, 31,161 students were included in the study, with 50.9% being male and 49.1% female.

Materials and Instruments

SES

Many researchers have defined SES as being composed of household income, parental education level, parental occupation, and household possessions (Aerschot and Rodousakis 2008; Blignaut 2009; Hohlfeld et al. 2010). However, there has been debate over whether SES should be measured reflectively or formatively as a construct (Howell et al. 2007) in SEM. This study followed the suggestion of Edwards and Bagozzi (2000) that SES should be represented indirectly and formatively, so the index of economic, social and cultural status (ESCS) variable in the PISA data was chosen to represent SES. ESCS is calculated based on a number of indices, including the highest educational level of the parents, highest parental occupational status, and household possessions (OECD 2014b).

ICT Usage

The PISA 2012 ICT familiarity questionnaire gathers data on the availability and use of ICT facilities for different purposes at home. Students' ICT usage was measured by a self-reported five-point Likert scale, ranging from "Never or hardly ever" (1) to "Every day" (5).

After analyzing the PISA questionnaire data and carrying out a literature review, this study classified the students' ICT usage as learning, information retrieval, social interaction, and leisure, as shown in Table 1. ICT usage for information retrieval includes details of how often the students read news and practical information on the Internet. ICT usage for learning includes how often they browse the Internet or send emails related to their studies, or share their schoolwork online. ICT usage for social interaction includes how often the students chat and interact with people in their social networks. Finally, ICT usage for leisure includes how often the students browse for and download entertainment resources from the Internet.

Achievements

The OECD focuses on 15-year old students' three achievements in three areas in every PISA assessment, including reading, mathematics, and science. PISA provides each student with five plausible values for each

Table 1 Groups of ICT activities

Factors	Items
Information retrieval	IC08Q07 reading news on the internet
	IC08Q08 obtaining practical information from the internet
Learning	IC09Q01 browsing the internet for schoolwork
	IC09Q03 using email for communication with teachers and submission of homework or other schoolwork
	IC09Q04 downloading, upload or browse material from my school's website
	IC09Q06 doing homework on the computer
	IC09Q07 sharing school related materials with other students
Social interaction	IC08Q04 chatting online
	IC08Q05 participating in social networks
Leisure	IC08Q06 browsing the internet for fun
	IC08Q09 downloading music, films, games or software from the internet

achievement to estimate his/her proficiency. However, these plausible values contain random error variance components, and are not as optimal as scores for individuals (OECD 2014b).

To make the PISA results more accessible to policy makers and educators, the OECD has developed proficiency scales for the various assessment domains (OECD 2009). This study followed the syntax of the second edition of the PISA data analysis manual (OECD 2009) to estimate five proficiency levels for each student. The median of the five proficiency levels was then calculated to estimate students' possible proficiency levels in reading, math and science. This study then followed the advice of Cox et al. (2013) and combined three achievement proficiency levels into one construct to avoid bias from any single discipline.

Moderator

PISA 2012 collected students' contextual information using a student questionnaire, and recorded their gender using item ST04Q01, which refers to the fourth question in the questionnaire: "Are you male or female?"

Analysis

Listwise deletion was executed in SPSS 22.0 to remove those cases which had one or more variables missing. After removing the cases with missing data, the descriptive statistics and correlations among variables were then obtained. This study adopted CFA to assess construct validity and measurement model fit (Kline 2011). The composite reliability (CR) and average variance extracted (AVE) were measured to examine the convergent validity. After confirming the mediation effect of each construct, the parallel mediation model was built. This study used the bootstrap estimation procedure in AMOS (a bootstrap sample of 2000 was specified) to estimate the significance of mediation and gender moderation, because this method provides the most accurate confidence intervals for indirect effects (MacKinnon et al. 2004). To verify and compare specific effects within the SEM model, a phantom model approach (Macho and Ledermann 2011) was used to analyze the data. To examine Hypothesis 4, this study further implemented a multilevel analysis with a 1–1–1 procedure (Ieong et al. 2016; Zhang et al. 2009). The significance of the indirect effect in the 1–1–1 model was examined using a Sobel test, while a 95% distribution of the product confidence limits for indirect effects (PRODCLIN) as used to analyze whether any regional level multilevel mediation effect exists (Tofighi and MacKinnon 2011; MacKinnon et al. 2007b).

Results

Descriptive Statistics and Correlations Among the Variables

The descriptive statistics for the samples' background are presented in Table 2. Most students (91.49%) had Internet access at least 3 years before the PISA test. Table 3 shows the means, standard deviations, skewness, kurtosis, and correlations for all variables. The absolute values of skewness ranged from 0.017 to 1.824, and that of kurtosis from 0.091 to 3.509. The absolute skewness values were less than 2, and the absolute kurtosis values were less than 7, the data met the assumption of a normal distribution that is needed for SEM (Kline 2011).

Confirmatory Factor Analysis

The CFA results (Table 4) show that the factor loadings range from 0.508 (IC09Q03) to 0.929 (PL_SCIE), exceeding the critical value of 0.5, which means each item has a strong association with the related construct. The CR results show that the internal consistency of these constructs was good, and the AVE of the constructs also show that the ratio of the correlation of each construct with its correlation with the other constructs was acceptable (Hair 2010; Fornell and Larcker 1981). The model fit of the CFA measurement model indicates that it fits the data well (GFI = 0.971, AGFI = 0.954, RMESA = 0.048, SRMR = 0.048) and meets the recommended guidelines (Hu and Bentler 1999). All indices in Table 4 and the model fit of CFA indicate that all constructs have good convergent validity, and these data are reliable and meaningful to test the structural relationships.

Direct and Indirect Effects of the Model

The significant direct effects between students' SES with all ICT usage ($p < 0.01$), students' all ICT usage with achievements ($p < 0.01$), and students' SES and achievements ($p < 0.01$) were all confirmed. Hypotheses 1a–d were then tested to assess the strengths of the mediation effects. All the model fits shown in Table 5 fell within the acceptable ranges. However, one offending estimate was found for hypothesis 1c. The indirect effect of students' ICT usage for leisure could not be estimated, and so hypothesis 1c was rejected. Table 6 shows the indirect effects of hypotheses 1a, b, and d were significant with 95% confidence intervals, and so hypotheses 1a, b and d were supported.

Table 2 Study participant characteristics ($n = 31{,}062$)

Variable	n	Percentage (%)
Gender		
Male	15,786	50.80
Female	15,276	49.20
Region		
Hong Kong-China	4303	13.90
Japan	5760	18.50
Korea	4949	15.90
Macao-China	5086	16.40
Shanghai-China	5082	16.40
Chinese Taipei	5882	18.90
First access to Internet		
6 years old or younger	3621	11.66
7–9 years old	13,751	44.27
10–12 years old	11,045	35.56
13 years old or older	2449	7.88
Never	125	0.40
Other	71	0.23
Internet weekday		
No time	6029	19.41
1–30 min	4591	14.78
31–60 min	4207	13.55
Between 1 and 2 h	6738	21.69
Between 2 and 4 h	5862	18.87
Between 4 and 6 h	2177	7.01
More than 6 h	1408	4.53
Other	50	0.16
Internet weekend		
No time	2397	7.72
1–30 min	2517	8.10
31–60 min	3200	10.30
Between 1 and 2 h	6037	19.44
Between 2 and 4 h	7691	24.76
Between 4 and 6 h	4598	14.80
More than 6 h	4582	14.75
Other	40	0.13
Desktop computer		
Yes, and I use it	22,794	73.38
Yes, but I do not use it	2770	8.92
No	5138	16.54
Other	360	1.16
Cell phone with internet		
Yes, and I use it	21,784	70.13
Yes, but I do not use it	3180	10.24
No	5728	18.44
Other	370	1.19

Other including invalid and missing samples

The Parallel Mediation Effects by ICT Usage

The model fit of the parallel mediation model shown in Fig. 2a indicates that this model fit the data well (GFI = 0.939, AGFI = 0.906, RMESA = 0.078). The significant overall indirect effect of the parallel mediation model was 0.021 ($p = 0.001$), less than the sum of each indirect effect of ICT usage (0.26). The result shows that there might be a suppressor variable in the model, which produces inconsistent mediation effects (MacKinnon et al. 2007a). Table 7 shows the results of the analysis for the phantom model shown in Fig. 2b. The mediation effect of ICT usage for learning (− 0.006) was inconsistent with information retrieval (0.007) and social interaction (0.023). The results indicate that three kinds of ICT usage have different mediating mechanisms. ICT usage for learning could reduce students' achievement gaps, but the mediation effect was not significant. Figure 2c shows the phantom model to analyze the difference between social interaction and information retrieval, which might both widen students' achievement gap. The results show a significant difference ($p = 0.003$), which means the most powerful indirect effect between students' SES and achievement was due to ICT usage for social interaction, followed by information retrieval, and thus hypothesis 2 was supported.

The Moderation Effect of Gender

This study did not find any significant moderation effect due to gender with regard to the mediation effect of ICT usage in the overall Chi-square difference test. Therefore, hypothesis 3 was rejected. However, this study further found that gender could moderate two direct effects. Table 8 shows that gender moderated the path from SES to ICT usage for social interaction ($p < 0.05$), which mean the relationship between low SES students and more frequent usage of social interaction ICT was stronger for males than for females. Similarly, gender significantly moderates the paths from ICT usage for learning to achievement ($p < 0.01$). This result shows that female students have a higher chance of getting better achievements through frequent ICT usage for learning than male students.

The Regional-Level Indirect Effect

The intra-class correlation coefficients (ICC_1) of students' reading (0.052), mathematics (0.067), and science (0.066) plausible value in the null model show that there were significant differences between variances for the 1–1–1 multilevel mediation analyses. However, the results for the aggregated characteristics show that only ICT usage for learning ($r^*_{WG(J)} = 0.846$, $ICC_1 = 0.204$, $ICC_2 = 0.999$)

Table 3 Correlations, means, standard deviations, skewness and kurtosis for all observed variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. ESCS	–														
2. IC08Q04	− 0.105**	–													
3. IC08Q05	− 0.100**	0.577**	–												
4. IC08Q06	− 0.038**	0.383**	0.478**	–											
5. IC08Q07	0.081**	0.280**	0.341**	0.439**	–										
6. IC08Q08	0.088**	0.301**	0.343**	0.433**	0.582**	–									
7. IC08Q09	− 0.031**	0.420**	0.395**	0.484**	0.317**	0.385**	–								
8. IC09Q01	0.064**	0.172**	0.224**	0.181**	0.257**	0.302**	0.170**	–							
9. IC09Q03	0.051**	0.117**	0.135**	0.090**	0.166**	0.201**	0.137**	0.375**	–						
10. IC09Q04	0.054**	0.154**	0.188**	0.125**	0.214**	0.262**	0.187**	0.453**	0.499**	–					
11. IC09Q06	− 0.047**	0.174**	0.266**	0.180**	0.225**	0.243**	0.191**	0.529**	0.409**	0.458**	–				
12. IC09Q07	− 0.011	0.265**	0.288**	0.180**	0.228**	0.278**	0.213**	0.396**	0.384**	0.462**	0.449**	–			
13. PL_READ	0.287**	− 0.084**	− 0.036**	− 0.032**	0.080**	0.082**	− 0.127**	0.189**	− 0.035**	0.047**	0.035**	0.018**	–		
14. PL_MATH	0.286**	− 0.038**	− 0.015**	− 0.046**	0.087**	0.084**	− 0.095**	0.209**	− 0.007	0.088**	0.075**	0.067**	0.836**	–	
15. PL_SCIE	0.278**	− 0.071**	− 0.040**	− 0.021**	0.093**	0.091**	− 0.115**	0.178**	− 0.039**	0.040**	0.019**	0.022**	0.850**	0.860**	–
Mean	− 0.400	2.950	3.360	3.410	2.810	2.680	2.960	2.150	1.470	1.680	1.990	1.720	3.310	3.740	3.320
SD	0.911	1.496	1.540	1.231	1.302	1.187	1.206	0.936	0.772	0.894	1.041	1.005	1.166	1.544	1.143
Skewness	− 0.181	− 0.017	− 0.436	− 0.370	0.089	0.257	0.076	0.585	1.824	1.337	0.872	1.335	− 0.204	− 0.341	− 0.278
Kurtosis	− 0.470	− 1.409	− 1.298	− 0.731	− 1.056	− 0.715	− 0.799	0.099	3.509	1.536	0.131	1.058	− 0.405	− 0.575	− 0.091

SD standard deviations

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

Table 4 Composite reliability and average variance extracted estimates for all constructs

Construct	Item	Factor loading	Composite reliability	AVE
Information retrieval	IC08Q07	0.745	0.742	0.590
	IC08Q08	0.790		
Social interaction	IC08Q04	0.714	0.746	0.596
	IC08Q05	0.826		
Learning	IC09Q01	0.735	0.786	0.427
	IC09Q03	0.508		
	IC09Q04	0.644		
	IC09Q06	0.721		
	IC09Q07	0.634		
Leisure	IC08Q06	0.769	0.691	0.528
	IC08Q09	0.682		
Achievements	PL_READ	0.902	0.942	0.845
	PL_MATH	0.926		
	PL_SCIE	0.929		

IC08Q04, IC08Q05, IC08Q06, IC08Q07, IC08Q08, IC08Q09, IC09Q01, IC09Q03, IC09Q04, IC09Q06, IC09Q07 PISA ICT questionnaire variables, *PL_READ, PL_MATH, PL_SCIE* possible proficiency levels of reading, math and science, *AVE* average variance extracted

Table 5 Model fit of hypothesis 1 models

Fit indices	Model				Recommended value
	Model 1a	Model 1b	Model 1c	Model 1d	
GFI	1.000	0.998	–	0.997	> 0.9
AGFI	0.999	0.993	–	0.990	> 0.9
RMSEA	0.014	0.038	–	0.004	< 0.08
SRMR	0.004	0.012	–	0.011	< 0.08

Due to the well-known problem of rejection of true models with large samples, the Chi-square value (χ^2) was excluded. – cannot be estimated

Table 6 Standard direct and indirect effects and 95% confidence intervals for each model

Mediator	Standard direct effect			Standard indirect effect	Percentile 95% CI			Total effect
	a	b	c'		LB	UB	Significance	
Information retrieval	0.113**	0.089**	0.298**	0.010**	0.008	0.012	0.001	0.308
Learning	0.024**	0.428**	0.463**	0.010**	0.005	0.015	0.001	0.473
Social interaction	− 0.175**	− 0.034**	0.476**	0.006**	0.003	0.009	0.001	0.482

CI confidence intervals, *LB* lower bound, *UB* upper bound

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

reached aggregation indices and related criteria proposed by Ieong et al. (2016). Table 9 presents the results of the significance testing of the indirect effects of the 1–1–1 hierarchical linear models. This study did not find any significant indirect effect at the regional level, so hypothesis 4 was rejected. However, the student-level indirect effects on reading, mathematics, and science achievement ranged from 0.9 to 1.436, and these were all significant in the Sobel test ($p < 0.05$) and PRODCLIN (95% confidence).

Discussion

The aim of this study was to clarify the mediating mechanism of ICT use between students' SES and achievement. Based on the parallel mediation analysis, it was found that students' ICT usage for information retrieval and social interaction could widen the achievement gaps. The results of this study agree well with the findings of Vigdor et al. (2014), which stated that home computers and high-speed Internet access would broaden North Carolina students'

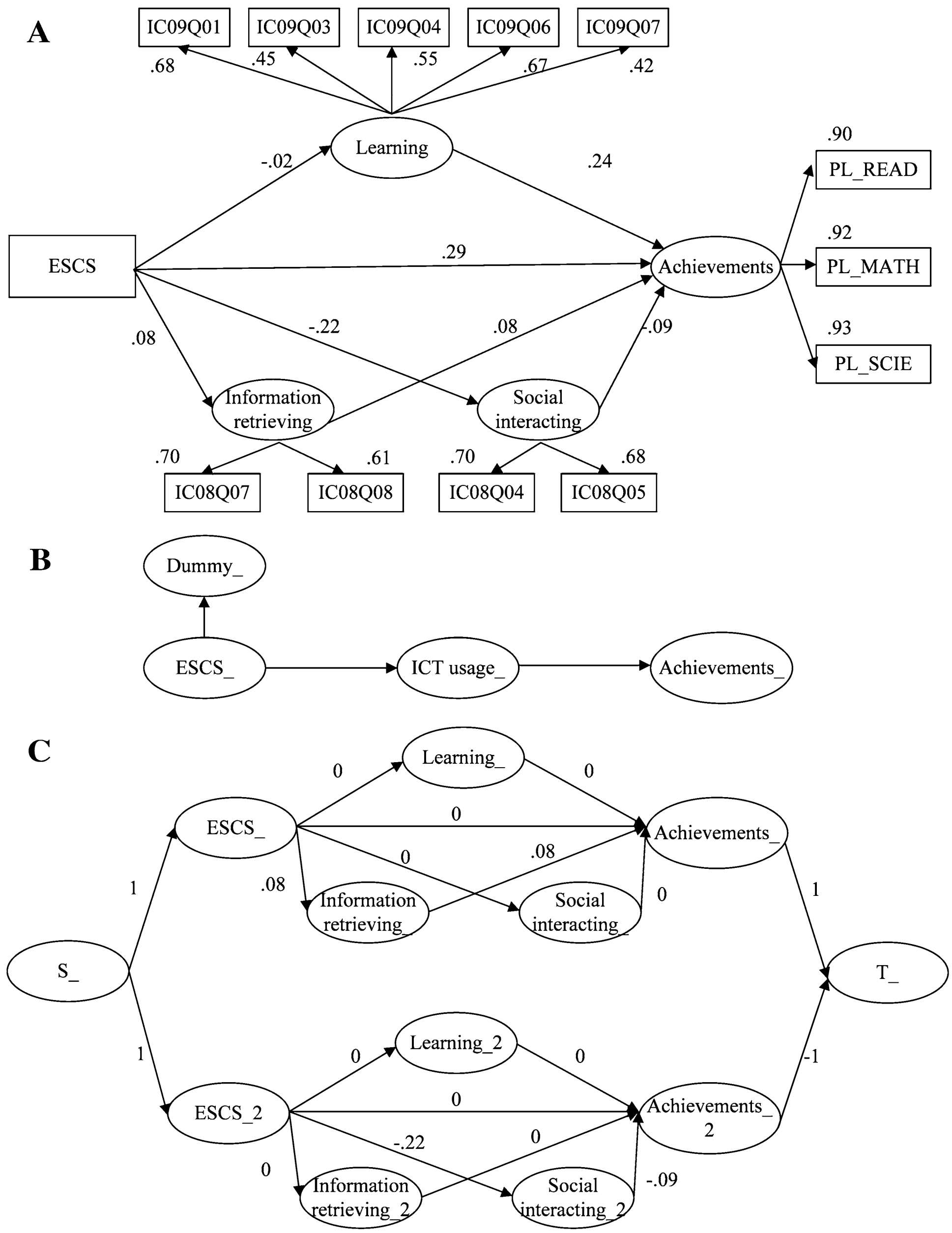

Fig. 2 The SEM model of hypothesis 2 (2a) and two phantom models (2b, 2c)

math and reading achievement gaps for those with different SES. This study was also consistent with Aesaert and Van Braak (2015), which found that SES related differences in ICT competences could widen gaps in academic achievement and maintain SES differences in Belgium. These results correspond with the Matthew effect, which indicates that students from high SES families could get more benefits from ICT usage, while avoiding the negative impacts (Byker 2014). People who hope ICT usage could narrow students' achievement gaps due to SES should, thus pay more attention to this issue.

The study also examined the relative magnitudes of indirect effects of ICT usage between students' achievement gap. The results showed that ICT usage for learning could not effectively reduce the achievement gaps cause by SES. The finding supports the research of Aypay (2010) and Fariña et al. (2015), which showed that there were no significant relationships between students' ICT use and academic achievement. Effective ICT-supported learning needs a better and more integrated design rather than simply providing students with the opportunity of using ICT (Richards 2005). In contrast, students' ICT usage for

Table 7 Estimated specific effects and 95% confidence intervals for model 2

ICT usage	Effect	Percentile 95% CI		
		LB	UB	Sig.
Learning	− 0.006	–	–	–
Information retrieval	0.007*	0.001	0.013	0.013
Social interaction	0.023**	0.010	0.026	0.001

CI confidence intervals, *LB* lower bound, *UB* upper bound, *Sig*. two-tailed significance, – cannot be estimated

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

Table 8 Multi-group analysis of direct effect for gender

Paths tested	Gender			
	Male	Female	CMIN	p value
ESCS—information retrieval	0.122	0.107	1.125	0.289
ESCS—learning	0.028	0.020	0.629	0.428
ESCS—social interaction	− 0.198	− 0.152	6.606	0.010*
Information retrieval achievements	0.139	0.129	0.198	0.656
Learning—achievements	0.359	0.463	8.172	0.004**
Social interaction—achievements	− 0.040	− 0.034	0.154	0.694

CMIN Chi-square, p probability level

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

Table 9 Significance test of indirect effects of ICT usage for learning

Independent variable	Area level			Student level		
	Indirect effect	SE (Sobel)	PRODCLIN (95% CI)	Indirect effect	SE (Sobel)	PRODCLIN (95% CI)
Reading	8.890	9.631	[− 9.064, 31.722]	1.043*	0.457	[0.172, 1.978]
Mathematic	− 14.229	23.511	[− 68.915, 32.518]	1.436**	0.542	[0.172, 1.978]
Science	16.313	10.348	[− 0.552, 41.039].	0.900*	0.455	[0.028, 1.829]

SE standard error, *PRODCLIN* distribution of the product confidence limits for indirect effects, *CI* confidence interval

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

social interaction has the most significant mediation effect in widening students' achievement gaps due by SES. In a Western context, Micheli (2016) also found that Italian teenagers from lower SES families were more enthusiastic about social networking sites, and that this expanded the level of digital inequality compared to those from higher SES families. One possible reason for this result was that students from lower SES families might tend to feel more hopeless and have low self-esteem, so they try to explore their selves and sociability on the Internet (Yuen et al. 2016). However, ICT usage for social interaction could take a lot of time, and so reduce that available to learn or get useful resources on the Internet.

This study found gender significantly moderates the relationship between students' SES and ICT usage for social interaction. High-SES male students had less ICT usage for social interaction, which might thus increase their learning time, compared low-SES ones. However, the correlation for female students was not as strong as for male ones. Similar results were found in earlier works which showed that female students preferred chatting and seeking information online compared to male ones (Li and Ranieri 2013; Pierce 2009). A gender difference was also found in the relationship between students' ICT usage for learning and their achievements, as female students in East Asia who spent more time on ICT for learning could get better academic achievement than male ones. This might be why other research found female students used ICT for learning more frequently than males (Yuen et al. 2016; Lu et al. 2016). As such, female students prefer online social interaction and get more benefits from online learning than males. These gender differences in ICT usage remind researchers to pay more attention to their research designs, and are also worth further study.

This work did not find a significant indirect effect at the regional level, and thus rejected hypothesis 4. Hypothesis 1c was not supported because ICT usage for leisure could not be aggregated in the East Asia data. These results might be due to the diversity of students' ICT usage within regions. Research indicated that income and education still play important roles in the significant digital divides that are seen in Asia countries. The OECD (2015) also reported that differences in the index of computer use for leisure between students at the top and bottom quarters of SES vary among regions. However, some recent researchers found that no SES differences were observed in leisure-related ICT use in Western or Asian societies (Yuen et al. 2016; Gannon 2008). This variety in students' ICT usage within and between regions may be worth further study.

In conclusion, students' ICT usage for information retrieval and social interaction could widen the achievement gaps between those with different SES. The relationship between lower SES students and worse achievement could be amplified with less ICT usage for information retrieval and more ICT usage for social interaction. Governments and educators may not be able to change the SES of students, but they can help parents or students to aware of the importance of ICT use. Policy-makers and educators thus need to provide adequate guidance before providing students with access to ICT.

Limitations

The data used in this study came from the PISA 2012 for East Asia, so the model and the findings are only valid for this area in 2012. The mediation effects of ICT usage with regard to students' achievement gaps in other areas and periods thus need to be analyzed further.

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