ICT Self-Efficacy and ICT Interest Mediate the Gender Differences in Digital Reading: A Multilevel Serial Mediation Analysis

Hangyan Yu, Jie Hu[✉]
School of International Studies, Zhejiang University, Hangzhou, China
`huj@zju.edu.cn`

Abstract—With an increasing number of information disseminated in the digital form, digital reading, a sub-construct of ICT literacy, is significant for young generations to succeed in the digital era. Gender differences, however, are observed in students' digital reading performance which calls for meticulous examination. This study aimed to explore whether ICT self-efficacy and ICT interest could explain the gender differences in digital reading, and how ICT self-efficacy and ICT interest are associated in explaining the gender differences in digital reading. Data of 6,173 samples from 192 schools in New Zealand who took part in the Programme for International Student Assessment (PISA) 2018 were collected. Multilevel serial mediation analysis showed that both ICT self-efficacy and ICT interest mediated the gender differences in digital reading, and the lower level of ICT self-efficacy and ICT interest girls had could explain the decrease of their digital reading performance. Results also indicated that girls were not inherently less interested in ICT, and the seemingly less ICT interest girls had was largely owing to their lower level of ICT self-efficacy shaped by the general sex-role stereotype of computer use. Pedagogical intervention on strengthening girls' ICT self-efficacy was suggested to increase girls' ICT interest and their digital reading performance to empower them in the digital era.

Keywords—digital reading, gender differences, ICT interest, ICT self-efficacy, mediation analysis, PISA reading

1 Introduction

Information and communications technology (ICT) has revolutionized our mode of assessing information from print reading to digital reading [1-3]. With an increasing emphasis on digital reading, researchers found non-negligible gender differences in digital reading performance. A large corpus of studies found that girls outperform boys remarkably both in print and digital reading [4-6]. While girls generally have an advantage over boys in both media, girls turn out to be less proficient readers in digital reading when their print reading performance is controlled [7-9]. Several studies have explored different perspectives to explain this relative disadvantage for girls in terms

of digital reading. For example, researchers found that boys' relative better performance in digital reading could be explained by the extra time spent on computer game-playing among boys which assumed to promote certain digital reading skills such as visual-spatial and image-reading skills [8]. Another study also replicated this result indicating that video gaming might cultivate students' navigation and spatial skills [7]. A study on Hong Kong students found that online reading engagement behaviors could explain the narrower gender gap in digital reading than print reading because boys engaged more frequently in online reading which promoted their digital reading performance [4]. In addition, although girls have better command of metacognitive strategies in print reading than boys, this gender gap in digital reading was shown to be smaller between girls and boys, and even nearly negligible [10]. In addition to the above-mentioned behavioral factors which might be tentative explanations for the underachievement of girls in digital reading compared to print reading, cognitive factors can also provide plausible explanations to this finding. A wealth of studies suggest that ICT self-efficacy and ICT interest, among other factors, are significant determinants of gender differences in ICT literacy [11]. Existing studies have explored the respective impact of ICT self-efficacy and ICT interest as the predictors of ICT achievement, instead of their interrelationships [12], and even fewer research investigated their interaction in explaining the gender gap in digital reading. This study, therefore, aimed to unveil the interrelation of ICT self-efficacy and ICT interest to explain the gender gap in digital reading, and thus insightful understanding on the mechanism of this construct could be achieved.

1.1 ICT self-efficacy, ICT interest and digital reading

Self-efficacy is defined as individuals' perceptions on their ability to perform a task [13]. Additionally, ICT self-efficacy is task-specific and refers to one's perceptions on their capabilities to execute specific computer-related tasks [14]. Rich inventory of studies have testified that ICT self-efficacy is a positive determinant of ICT literacy [14-15]. The possible reasons for ICT self-efficacy to exert positive effect on student's ICT literacy might be that ICT self-efficacy reduces computer anxiety [11] and serves as motivational drive toward ICT usage [16]. As an important aspect of ICT literacy, digital reading requires readers to search for online texts, to assess the quality and credibility of online information, and to resolve possible discrepancies and conflicts [5]. Therefore, it is tentative to assume that ICT self-efficacy could positively predict students' digital reading performance. To the best of our knowledge, however, there is limited number of research that explicitly addresses the relationships between ICT self-efficacy and digital reading [17], which prompts the current study. With respect to interest, previous literature demonstrated strong predictive power of interest on students' learning performance in a general sense [18]. Focusing on the particular domain of ICT, studies also showed strong correlation between students' ICT interest and their ICT competence [19-20] including their digital reading performance [17], for the reason that having interest in learning is a positive attitude which were testified of being associated with higher digital reading performance [21].

1.2 Gender differences in ICT self-efficacy and ICT interest

Regarding the gender differences in the contexts of ICT self-efficacy and ICT interest, meta-analyses of studies over decades showed a reoccurring result that, compared to girls, boys reported higher level of ICT self-efficacy and ICT interest than them [22-23]. Studies suggest that the relative positive attitude that males hold towards computers might be attribute to the gender stereotyping of computers which is deemed as a "masculine" domain [23]. Specifically, the use of computer has long been considered as a "masculine" subject that males are more capable of [24]. This gender stereotype of computers has been further entrenched by the portrait of mass media [25]. A longitudinal study showed that the gender gap in ICT self-efficacy was relatively small in primary education while it became widened in secondary education [26]. The accumulation of stereotype in favor of males might be the possible reason why the gender gap widened with students' growth. The acceptance of the stereotype of gender differences in ICT dampened females' positive attitudes towards computers, which further led to the fewer engagement of computer-related behaviors resulting in a "technological gender gap" [27] and a prevention of taking the field of ICT as a potential occupational choice [28].

1.3 The impact of students' ICT self-efficacy on their ICT interest

Although both ICT interest and ICT self-efficacy have been referred as the cognitive or motivational construct of ICT disposition, which are the building bricks for the development of ICT literacy in a self-regulated way [29], existing literature mostly explored their respective effect on students' performance, with few attentions paid to their interactive relation and their effects on the outcomes [12]. Previous studies have demonstrated that there is moderate positive relationship between ICT interest and ICT self-efficacy [16, 30]. In addition, a study on 30 Organization for Economic Co-operation and Development (OECD) countries showed that the relationship between students' ICT interest and ICT self-efficacy was mediated by ICT-related behavioral factors, especially the ICT use for recreation and social interaction [12]. Moreover, considering that gender differences in ICT self-efficacy influenced gender groups' general attitudes towards their ICT use [22], e.g., reduced anxiety [11], it is presumably reasonable to build the relationship between students' ICT self-efficacy and their ICT interest regarding their influence on the gender differences in digital reading performance.

2 Research

2.1 Hypotheses and research questions

As indicated by the previous literature, both ICT self-efficacy and ICT interest underpin the foundation of ICT literacy and provide plausible rationale to the gender gap of ICT literacy. Digital reading performance, an important aspect of ICT

literacy, presents prominent gender gap that females underachieve in digital reading after balancing out their advantages in print reading compared to males. Furthermore, ICT self-efficacy and ICT interest demonstrate strong relation and ICT self-efficacy is assumed to have predictive power on ICT interest. Based on the literature reviewed and research gaps identified, the following hypotheses were raised in this study:

- Hypothesis 1: The discrepancy in ICT self-efficacy and ICT interest between boys and girls could explain the gender gap in digital reading, i.e., females' ICT self-efficacy and ICT interest is less positive compared to boys which explains the corresponding variance in digital reading performance in favor of boys.
- Hypothesis 2: The presumed girls' lower level of ICT interest could be explained by their lower ICT self-efficacy compared to boys. Moreover, the effect of ICT interest on student's digital reading performance could be explained by their ICT self-efficacy.

In correspondence to the above hypotheses, research questions (RQs) were developed as follows:

- RQ 1: Can ICT self-efficacy and ICT interest mediate the gender differences in digital reading?
- RQ 2: Is the mediating effect of ICT interest on the gender differences in digital reading influenced by students' ICT self-efficacy?

2.2 Data source and samples

The data source of this study was the latest release of Programme for International Student Assessment (PISA) (URL: http://www.oecd.org/pisa/data/2018database/). PISA 2018 is the seventh and the most recent cycle of PISA, and reading is the major domain of assessment for this cycle, in which seventy-nine countries/regions have participated. PISA allows the comparison across different participating countries/regions [31], and has strong educational implication for educators and policy makers worldwide [32-33]. 6,173 samples with a balanced gender ratio (51.09% for girls) from 192 schools in New Zealand were selected in this study. In New Zealand, schools implement one-device-per-child provision to offer students ubiquitous access to digital devices for learning [34-35]. This indiscriminate accessibility of digital devices for all students could largely mitigate the undesirable variation of possible different digital device accessibility among genders. Additionally, students in New Zealand ranked high among all the participating countries in the digital reading test. Selecting samples from New Zealand, one of the top countries in digital reading education, might give enlightenment to other countries or regions.

2.3 Variables

Five variables concerning samples' demographic and ICT information were retrieved from PISA 2018 student questionnaire and ICT familiarity questionnaire. The

independent variable, namely, student gender (ST004D01T), was collected in the student questionnaire, in which female students received the value of 1 and male students received the value of 2. With respect to the dependent variable, digital reading scores (PV1READ) were used. Students were scored based on their performance in reading passages by navigating the online assessment system. Two mediating variables were retrieved from the ICT familiarity questionnaire. Students were asked to think about their experience in using digital media and digital devices and answer four-point Likert scale of "strongly disagree" "disagree" "agree" and "strongly agree" on several statements. The variable related to students' ICT self-efficacy (COMPICT) was derived from 5 questions, e.g., "to what extent do you disagree or agree with the statements of 'I feel comfortable using digital devices that I am less familiar with.'" The variable related to students' ICT interest (INTICT) was derived from 6 questions, e.g., "to what extent do you disagree or agree with the statements of 'I like using digital devices.'" Students' economic, social, and cultural status (ESCS) has been proved to influence their digital reading performance [36]. To control students' individual background, the index of ESCS was included in the model as the control variable. Apart from the independent variable of gender is a dichotomous variable presenting the information that 51.09% of the total samples are girls, the rest of four variables are all continuous variables, the descriptive statistics of which were COMPICT (Mean=0.16, SD=0.88), INTICT (Mean=0.17, SD=0.89), ESCS (Mean=0.17, SD=0.96), PV1READ (M=507.89, SD=104.49), which are also presented in Table 1.

Table 1. Descriptive statistics

Country	N (students)	Female %	COMPICT		INTICT		ESCS		PV1READ	
			Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
New Zealand	6,173	51.09	0.16	0.88	0.17	0.89	0.17	0.96	507.89	104.49

2.4 Multilevel serial multiple mediator model

Since PISA data has hierarchical feature that data of student level are nested at the school level, multilevel analysis is imperative when intraclass correlation coefficient (ICC) is larger than 0.1 [37]. An ICC result of 0.2025 of this study indicated that 0.2025 of the total variances could be explained in the school level, therefore, multilevel analysis should be put forward. To explore the mediating effects of ICT self-efficacy and ICT interest on the gender differences in digital reading, multiple mediator model is imperative. Compared to parallel multiple mediator model which assumes no interaction among mediators, serial multiple mediator model allows the quantification of the association among mediators which meets the purpose of this study to examine the interaction between ICT self-efficacy and ICT interest [38]. Based on the hierarchical feature of the data and the presumed interaction among mediators, multilevel serial two-mediator model was used in the current study (see Figure 1).
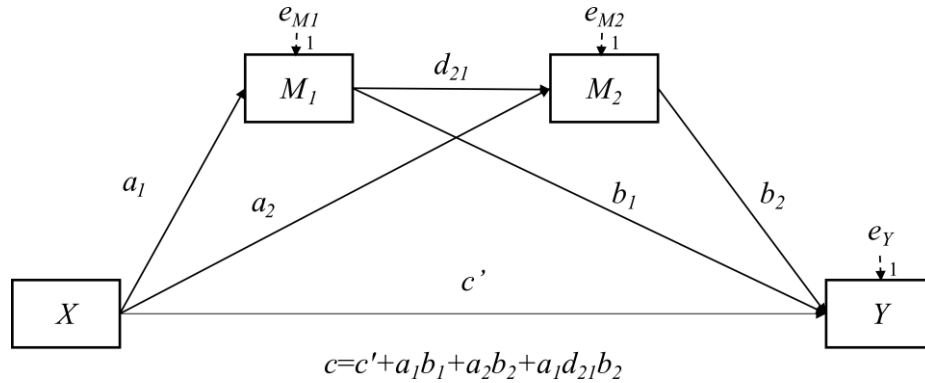
$$c=c'+a_1b_1+a_2b_2+a_1d_{21}b_2$$

Fig. 1. Conceptual diagram of multilevel serial two-mediator model

Figure 1 depicts the two-mediator model in the current study, where X affects Y through two mediators in four pathways, the three of which are indirect with the remaining one being direct. The first indirect pathway starts from X to Y through M_1, the second indirect pathway runs through M_2, and the third one runs through both M_1 and M_2 in a serial way. The direct pathway of X affecting Y does not pass through any mediator. According to Hayes [38], This model could be translated into the following three equations:

$$M_1 = i_{M_1} + a_1X + e_{M_1} \tag{1}$$

$$M_2 = i_{M_2} + a_2X + d_{21}M_1 + e_{M_2} \tag{2}$$

$$Y = i_Y + c'_X + b_1M_1 + b_2M_2 + e_Y \tag{3}$$

where

i_{M1}, i_{M2}, and i_Y are the constants of each regression;

e_{M1}, e_{M1}, and e_Y are errors in the calculation of M_1, M_2 and Y;

a_1 and a_2 quantify the effects of X on M_1 and M_2 respectively;

d_{21} quantifies the effect of M_1 on M_2;

c' quantifies the direct effect of X on Y when the effects of mediators on Y are controlled; and

b_1 and b_2 quantify the effect of M_1 and M_2 on Y when the other variables are controlled.

Suggested by Hayes [38], the indirect effect of X on Y through M_1 is a_1b_1, the indirect effect of X on Y through M_2 is a_2b_2, and the indirect effect through both M_1 and M_2 in a sequential order is $a_1d_{21}b_2$. In the mediation analysis, the total effect of X on Y is the sum of direct effect and indirect effect(s) [38], therefore the equation of calculating the total effect (c) of serial two-mediator model is presented as:

$$c = c' + a_1b_1 + a_2b_2 + a_2d_{21}b_2 \tag{4}$$

2.5 Data processing

Before the stage of data processing, data were first preprocessed with the check of some basic assumptions. PISA data have a small proportion of missing data which need to be imputed. Imputation with nearest neighbor classification, also K-nearest neighbors (KNNs), was used [39]. The foundation of KNN imputation is using the values and the weighted average of the neighbors to fill in the target value, and K refers to the number of neighbors. What has been proven is that KNN imputation is a robust method for missing value compared to the the commonly used row average method or singular value decomposition [40]. In this study, KNN imputation was realized with the function of *knnImputation*in in the *DMwR* package in R [41]. *DMwR* is the abbreviation of *Data Mining with R* which is one of the most often used package for data processing and data mining. Considering gender is a dichotomous variable, therefore, female is dummy coded as 0 and male as 1 to avoid multicollinearity [42]. Since the sampling of PISA was not evenly distributed, to ensure that samples are representative of the population and to obtain unbiased population-level parameters, student weight was processed in R [43]. Since mediation analysis is fundamentally an extension of ordinary least squares (OLS) regression [38], the basic assumptions of OLS regression were checked first, the results of which showed that assumptions were met. The correlations among the variables were calculated and presented in Figure 2 which were all in the acceptable range.
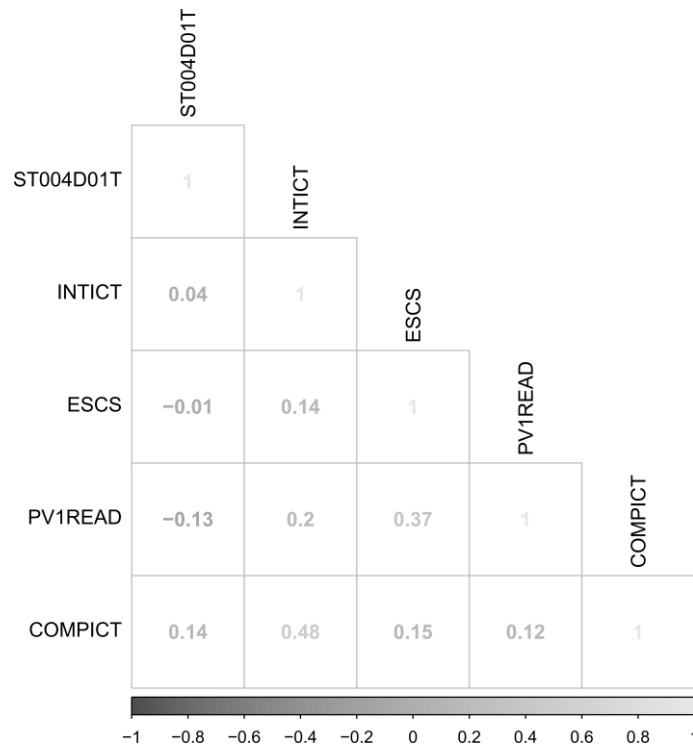

Fig. 2. Correlation matrix of variables

In the current study, to realize the multilevel modeling, scores of ESCS, COMPICT, INTICT and PV1READ were clustered in the school level, the results of which were to be used in the between-level data analysis. The serial two-mediator model in the current study were run at the within- and between-level spontaneously, so that the variance of different levels could be quantified respectively. The multilevel serial mediation analysis was performed in R [43] using the structural equation model (SEM) approach in *lavaan* package [44]. SEM can not only quantify the total, direct, and indirect effects of X on Y [45], which are fundamental to mediation analysis [46], but is also applicable for hierarchical data [47].

3   Results and discussion

Results of the goodness-of-fit indices of this study are χ^2 (18, 5316) = 2855.82, p = 0.000, CFI = 0.997, TLI = 1.000, RMSEA = 0.000, SRMR (within) = 0.007, SRMR (between) = 0.106, which jointly indicate good fitness of the hypothesized model [48]. To answer the RQs concerning the mediating effects of ICT self-efficacy and ICT interest and their association, a statistical diagram with coefficients of different paths were presented in Figure 3.

Regarding the RQ 1 on whether ICT self-efficacy and ICT interest mediate the gender differences in digital reading, the pathways of X to Y through M_1 and M_2 were examined respectively. Results of the total effect of X on Y (c) showed a negative association between gender and students' digital reading performance (β = -0.2360, CI = [-0.2950, -0.1770], p = 0.0000, SE = 0.0302), indicating boys scored lower than girls by 0.2360 unit, which is consistent with a bulk of previous studies [4-5]. To quantify the mediating effect of ICT self-efficacy between X and Y, two pathways were identified, namely, starting from X to Y through M_1 and starting from X to Y through M_1 and M_2 in serial. It was calculated by adding the results of a_1 multiplied by b_1 and a_1 multiplied by d_{21} and b_2 together. The mediating effect of ICT self-efficacy showed that girls had lower level of ICT self-efficacy which led to a decreased value of 0.0331 (CI = [0.0231, 0.0431], p = 0.0000, SE = 0.0051) in digital reading compared to boys. In quantifying the mediating effect of ICT interest without the influence of ICT self-efficacy, two pathways from X to Y through M_2 and from X to Y through M_1 and M_2 in serial were identified. The mediating effect of ICT interest between X and Y could therefore be quantified by summing the results of a_2 multiplied by b_2 and a_1 multiplied by d_{21} and b_2 together, the value of which was 0.0086 (CI = [0.0010, 0.0163], p = 0.0264, SE = 0.0039).

The mediating effects of both ICT self-efficacy and ICT interest in this study confirmed the hypothesis that girls had lower level of ICT self-efficacy and ICT interest which were negatively associated with their digital reading performance. The total variance that ICT self-efficacy and ICT interest explained in mediating the relationship between X and Y was 0.0213 (CI = [0.0093, 0.0335], p = 0.0005, SE = 0.0062), which explained 9.04% of the total gender differences in digital reading. One tentative explanation of these results is that girls deem computer use as male-dominated and feel less competent or even lose interest in ICT use. This acceptance of gender stereotype of

gender differences in ICT dampened girls' positive attitudes towards computers, which further lead to the decrease in their digital reading performance. This finding contributed to the existing literature on the following aspects: 1. Consistent with previous studies, this finding corroborated that there were significant gender differences in ICT self-efficacy and ICT interest among boys and girls [22-23]. 2. the significant mediating effect of ICT self-efficacy and ICT interest further testified that the gender differences in these two domains could explain the gender difference in ICT literacy [14, 15, 19, 20]. This finding provided novel perspective from ICT self-efficacy and ICT interest to explore the reasons behind the narrowing gender gap in digital reading compared to the print reading [4, 7, 8].
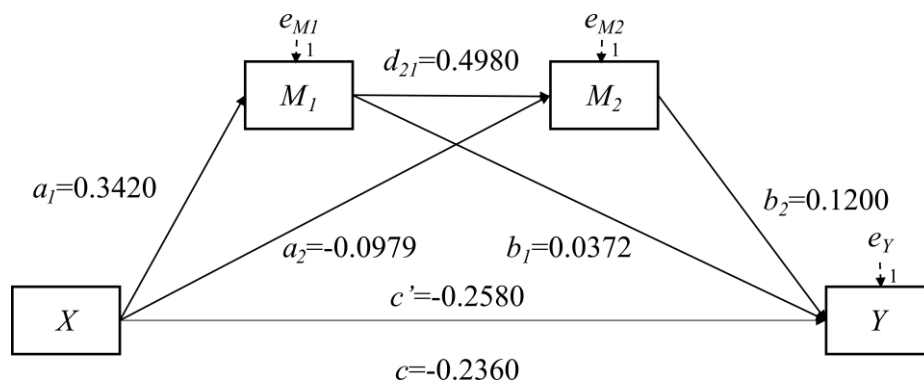

Fig. 3. Statistical diagram of multilevel serial two-mediator model

In answering the RQ 2 on whether the mediating effect of ICT interest on the gender differences in digital reading is influenced by students' ICT self-efficacy, the association between ICT self-efficacy and ICT interest was examined. If M_1 was not included in the model, the total effect of X on M_2 could be calculated by summing the indirect effect of X on M_2 through M_1 (a_1*d_{21}) and the direct effect of X on M2 (a_2), and the coefficient of the total effect of X on M_2 was 0.0721 (CI = [0.0105, 0.1340], $p = 0.0217$, SE = 0.0314), the result of which was statistically significant. These results showed that there is a gender differences in ICT interest, specifically, girls' interest toward ICT use was less than boys by 0.0721 unit. After integrating M_1 into the model however, M_1 played a significant role in mediating the relationship between X and M_2, in which the mediating effect of M_1 was 0.1700 (CI = [0.1390, 0.2010], $p = 0.0000$, SE = 0.0159). After accounting for the mediating effect (indirect effect) of X on M_2, the direct effect of X on M_2 was -0.0979 (CI = [-0.1520, -0.0438], $p = 0.0004$, SE = 0.0276), indicating that girls' ICT interest was 0.0979 higher than boys after controlling the effect of ICT self-efficacy.

As literature indicates, gender differences in ICT self-efficacy influences gender groups' general attitudes towards ICT use [22]. Plausible explanation to this finding might be that girls are not inherently less interested in ICT use, but when they perceive themselves as less competent in ICT use, their interest towards it decreases and is even less than their male counter-parts. This novel finding enlightened our understanding on

girls' ICT interest, i.e., the seemingly less ICT interest girls held was largely influenced by their lack of confidence in ICT use. Based on this finding, pedagogical intervention in establishing girls' ICT self-efficacy could be an effective method to increase their ICT interest and thus improve girls' digital reading performance.

Summing up, the relative lower level of girls' ICT self-efficacy and ICT interest and its negative effect on girls' digital reading performance found in RQ 1 is consistent with the first hypothesis that the discrepancy in ICT self-efficacy and ICT interest between boys and girls could explain the gender gap in digital reading. In addition, the result that girls' ICT self-efficacy largely influenced their ICT interest found in RQ 2 is also in line with the second hypothesis that the presumed girls' lower level of ICT interest could be explained by their lower ICT self-efficacy compared to boys.

4   Conclusion and implication

This study had two-fold objectives, namely, to explore whether ICT self-efficacy and ICT interest mediate the gender differences in digital reading, and to investigate the relation between ICT self-efficacy and ICT interest in explaining the gender differences in digital reading. Consistent with the hypotheses, major novel findings of this study are listed as follows:

The results of RQ 1 showed that both ICT self-efficacy and ICT interest mediate the gender differences in digital reading, in which girls had lower level of ICT self-efficacy and ICT interest which explained the decrease of their digital reading performance. The results of RQ 1 showed that the seemingly less ICT interest girls had was largely owing to girls' perception of their incompetence in ICT use. With the effect of ICT self-efficacy being controlled, girls presented higher level of ICT interest which could facilitate their digital reading performance. Pedagogical intervention on strengthening girls' ICT self-efficacy was suggested. The above findings are novel in the existing literature which deepened our understanding on the gender difference in ICT self-efficacy and ICT interest and has significant practical implications for girls to be equipped with healthy and positive attitudes towards ICT and therefore help them succeed in the digital era.

This study has the following two limitations: first, there may be spiraling effects involved between ICT self-efficacy and ICT interest. Although this study mainly focused on the direction that ICT self-efficacy influencing ICT interest, and provide practical implication on the improvement of ICT self-efficacy to promote ICT interest, Chen and Hu [12] found a converse direction of impact that ICT interest influenced ICT self-efficacy through ICT-related behavior factors. It is difficult to ascertain their relation in a blatant way, and therefore, corresponding suggestion should be carefully examined. Second, the impact of students' psychological status differs significantly by cultural background [49-50] and subject [51, 52]; thus, the results based on New Zealand students' digital reading performance should be applied with caution to other countries or regions.

5 Acknowledgement

6 Reference

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7 Authors

Hangyan Yu is a Master's student, supervised by Prof. Jie Hu, studying at the Department of Linguistics, the School of International Studies, Zhejiang University, Hangzhou 310058, China. Her research interests lie in second language acquisition, computer-assisted English language learning, and educational data mining (email: yhyan@zju.edu.cn).

Professor Jie Hu, Ph.D., is a professor working at the Department of Linguistics, the School of International Studies, Zhejiang University, Hangzhou 310058, China. She has been focusing on English language education for more than 10 years after her Ph.D. graduation from the University of Warwick, U.K. Her research interests include ICT-based English language education, second language acquisition, educational data mining and learning analysis (ORCID: https://orcid.org/0000-0003-2219-2587).

8   Appendix

Appendix 1. The description of variables

Variables	Description
Independent variable	
ST004D01T	Index of students' household economic, social and cultural status
Mediating variables	
COMPICT	Students' ICT self-efficacy
INTICT	Students' ICT interest
Controlled variable	
ESCS	Students' economic, social, and cultural status
Dependent variable	
PVREAD	Students' digital reading scores