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The role of computer game playing and reading attitudes in digital reading achievement: evidence from Hong Kong 15-year-olds

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Abstract

The present study aimed to examine the associations among digital reading achievement, computer game playing, and reading attitudes using the Hong Kong data taken from the Programme for International Student Assessment (PISA) 2018 dataset. Both confirmatory factor analysis and structural equal modeling were adopted: 1) to identify the correlation among the three latent factors (i.e., digital reading achievement, computer game playing, and reading attitudes), 2) to measure the mediating effects of reading attitudes, and 3) to investigate the mediation relationship after controlling for gender difference. The results confirmed the importance of computer game playing and reading attitudes towards digital reading achievement. Specifically, computer game playing negatively correlated with digital reading achievement and reading attitudes, whereas reading attitudes positively correlated with computer-mediated reading performance even after gender was controlled. Interestingly, reading attitudes were found to mediate the magnitude of the impact of computer game playing on digital reading achievement. Taken together, the findings suggest: 1) excessive time spent in playing computer games results in poor performance in digitally assessed reading, 2) positive reading attitudes attenuate the negative effects of playing computer games against digital reading achievement, 3) such offsetting effect is even larger when controlling for gender.

Keywords: Digital reading achievement, Computer game playing, Reading attitudes, PISA 2018, Structural equation modeling

Introduction

The past two decades have witnessed a surge of interest in digital reading in tandem with the increasing accessibility of information and communication technology (ICT). The change towards digitalization enables individuals to access new technologies as well as



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reshapes the ways people read and communicate information in social, career, and academic contexts (Lim & Jung, 2019; Naumann & Sälzer, 2017). From 2009 to 2018, the household computer ratio has risen from 85% to over 95% for countries belonging to the Organization for Economic Cooperation and Development (OECD) (OECD, 2018). In this sense, digital literacy becomes an integral part of modern life, such that cultivating digital reading skills is essential for people worldwide (OECD, 2018; Rasmusson & Åberg-Bengtsson, 2014). Accordingly, schools guarantee wider ICT availability, providing essential reading resources (Rasmusson, 2016; Rouet & Le Bigot, 2007). Consequently, students need to meet the new requirements (aka enhancing digital reading literacy), including honing parallel skills to decode digital materials and solving problems in a digital environment (Coiro et al., 2008; Wirth & Klieme, 2003). In line with this trend, Programme for International Student Assessment (PISA), a triennial international and large-scale assessment scheme, has been treating computer-delivered reading performance as the primary assessment domain since 2009.

In definition, traditional reading literacy refers to understanding, utilizing, and evaluating texts for multiple aims, such as achieving reading goals, broadening knowledge, and participating in society (OECD, 2018). In comparison, digital reading literacy conflates both traditional reading ability and ICT skills (da Costa & Araújo, 2016; Lim & Jung, 2019). Particularly, digital reading literacy integrates how readers consume, produce, and communicate multimedia text on digital platforms (Coiro, 2021). For assessing digital reading literacy, PISA 2018 distributed two types of questionnaires: 1) the student questionnaire that collected demographic and attitudinal data, and 2) the optional ICT familiarity questionnaire that obtained information about ICT resources, ICT use (both at school and outside school), and ICT abilities (OECD, 2018). It is worth noting that these two questionnaires allowed insights into the associations among various factors at the student level.

As one of the participating economies in PISA 2018, Hong Kong completed both the digital reading assessment and questionnaires that measured students' digital reading achievement, ICT-related information (e.g., the frequency of computer game playing), and reading attitudes. Besides, as the official documents reported that Hong Kong had scored above the OECD average (OECD, 2018), it is vital to take a closer look into the Hong Kong data, especially into the association between digital reading and relevant factors. In addition, PISA 2018 reported that girls outperformed boys in digital reading, implying that gender difference might affect the associations between digital reading achievement and the related factors (OECD, 2018). Prior studies in digital reading achievement mainly examined digital reading achievement's direct interaction with other elements such as the frequency of playing video games (e.g., Borgonovi, 2016; Rasmusson & Åberg-Bengtsson, 2014), reading attitudes (e.g., Huang et al., 2013; Tveit & Mangen, 2014), and gender

differences (e.g., Lim & Jung, 2019; Naumann & Sälzer, 2017; Rasmusson & Åberg-Bengtsson, 2014). However, mediating/indirect effects between these factors have hitherto received relatively scant attention (e.g., Cheung et al., 2013; Chiao & Chiu, 2018). The purpose of the current research was threefold. First, the present study identified if the critical factors (i.e., computer game playing, reading attitudes) were directly relevant to digital reading achievement. Second, this study also probed whether mediating relationships exist between the three factors. Third, the current study examined whether gender differences influenced the associations among these factors. For addressing these research goals, the current project analyzed Hong Kong PISA 2018 data with the help of confirmatory factor analysis and structural equation modeling techniques.

Literature review

The theoretical rationale for the current study is grounded in the notions of digital reading (Coiro, 2021; Lim & Jung, 2019; OECD, 2009), computer game playing (Borgonovi, 2016), reading attitudes (Swalander & Taube, 2007), as well as gender difference (Liu & Huang, 2008). This section is organized as follows: the theoretical underpinnings are first introduced and the connections among them are then reviewed to uncover the research gaps and implications of the study.

Digital reading performance

In the information age, digital text is ever more prevalent (Reiber-Kuijpers et al., 2020). For reflecting this trend, education begins to integrate information with ICT, which enriches the concept of reading by taking into account print reading and digital reading (Brečko et al., 2014; Hu et al., 2018; Lim & Jung, 2019; OECD, 2018; Pérez-Sanagustín et al., 2017).

Studies viewed reading as an interface between the text and the reader's mind, i.e., decoding and comprehension (Hoover & Gough, 1990). Singer and Alexander (2017) expanded this idea by including both synthesizing and evaluating text information. As a result, the extended model of digital reading comprises both print reading and novel digital reading activities (Li et al., 2020). Specifically, digital reading refers to various multimedia meaning-making experiences whereby readers engage with hypertexts (i.e., embedded links to other texts) from the Internet in a nonlinear fashion (Coiro, 2021; Lim & Jung, 2019).

Digital reading literacy conceptualizes digital reading in a more comprehensive way by regarding reading as literacy that consists of the ability to integrate and construct diverse texts for special purposes (Coiro, 2021; Frankel et al., 2016). In other words, digital reading requires the reader to be familiar with explicit and embedded hyperlinks, non-sequential page structures, and electronic devices (OECD, 2009). Thus, the visual-spatial capacity to

manage the non-sequential page structures and navigate the hypertexts may be involved to a larger extent in digital reading compared to traditional reading (Rasmusson & Åberg-Bengtsson, 2014). Moreover, it is crucial for digital readers to critically distinguish between fact and opinion when reading online in addition to understanding and communicating complex information (OECD, 2018).

Traditional and digital reading should not be considered dichotomous, but build upon print reading (Reiber-Kuijpers et al., 2020). According to Lim and Jung (2019), print and digital reading are comparable in cognitive operations. For example, they both demand the ability to decipher, interpret and integrate texts. By the same token, digital reading skills involve identifying essential questions, locating, comprehending, synthesizing, and exchanging information (Leu et al., 2004). As the cognitive processes contained in digital reading abilities share many commonalities with print reading, it is reasonable to predicate digital reading achievement by traditional reading literacy (da Costa & Araújo, 2016; OECD, 2015). In the present study, digital reading achievement, an endogenous factor, was represented by students' scores on the reading section in PISA 2018.

However, reading printed and digital texts differ in one significant feature, i.e., reading digital texts demands more cognitive load to deal with the nonlinearity caused by the hypertext structures (DeStefano & LeFevre, 2007). When reading print texts, readers engage information linearly and sequentially without assessing the credibility of sources and omitting information based on their precise reading purpose (Walsh et al., 2007). In contrast, digital texts contain multimodal messages with the amalgamation of texts, pictures, sounds, and videos on one page (Lim & Jung, 2019; Walsh, 2006). Thus, in comparison to traditional reading, readers need to devote more effort to deducing essential ideas because they need to negotiate multiple modes of information while navigating search engines and websites (too many distractions) (Coiro, 2021). Despite the disadvantage caused by different cognitive loads, digital reading proffers several attractive benefits that are absent in traditional paper-based reading, such as nonlinearity, instant information, and the merging of text, image, audio, and radio (Reiber-Kuijpers et al., 2020). In summary, digital reading literacy reflects the societal trends and provides both challenges and benefits for readers, which makes itself worth investigating.

Factors associated with digital reading

Computer game playing

Computer games are programs that allow players to interact with the virtual environment for entertainment. Playing video games has become a favorite leisure-time activity among teenagers worldwide (Borgonovi, 2016). Due to the addictive nature of computer games, researchers have raised concerns about their potentially negative consequences on

academic performance, including reading achievement (Barlett et al., 2009; Drummond & Sauer, 2014; Gentile et al., 2004; Weis & Cerankosky, 2010). Playing computer games immoderately might: 1) deflect students' attention in school (Ferguson & Olson, 2014), 2) occupy the original home-study time (Kowert et al., 2015), 3) cause sleep problems (King et al., 2014), and 4) weaken the perseverance in learning (Swing et al., 2010).

Apart from the adverse outcomes caused by playing excessively, moderate playing could positively influence students' academic learning (Borgonovi, 2016). Many cross-sectional and experimental studies suggest that playing computer games with appropriate learning principles can arouse students' cognitive operation, psychosocial adjustment, and thereby promoting problem-solving and spatial capabilities (Adachi & Willoughby, 2013; Connolly et al., 2012; Spence & Feng, 2010; Subrahmanyam & Greenfield, 1994). Likewise, playing computer games has proved to effectively enhance visual attention, as it helps players keep track of many different processes simultaneously, and playing a non-violent computer game could improve the visual ability to read images (Greenfield et al., 1994). In sum, playing computer games is advantageous for enhancing problem-solving skills, visual-spatial ability, and visual attention.

To date, a large amount studies have established a positive link between visual-spatial ability and digital literacy (e.g., Castelli et al., 1998; Protopsaltis & Bouki, 2009; Zhang & Salvendy, 2001). In the study of Castelli et al. (1998), the importance of spatial skill in dealing with hypertext among middle-school students was identified. They found that boys with better spatial ability outperformed girls in navigation, whereas girls with higher logical efficiency performed better than boys on the tasks with hypertexts. Based on this research, Zhang and Salvendy (2001) investigated the impact of visual-spatial ability on information-search tasks, and indicated that students with high visual-spatial ability had better digital reading achievement than the low spatial-ability group. In other words, the visual-spatial ability would positively affect information search skills. Along the same line, Shen et al. (2007) further examined students' digital literacy using a web-based learning material. Results showed that students with high spatial ability maintained outstanding digital performance comparing with other students. Collectively, these studies imply that navigating hypertext and learning online might benefit from good spatial abilities (Rasmusson & Åberg-Bengtsson, 2014). As aforementioned, computer game playing promotes visual-spatial ability, so it is reasonable to regard it as a predictor of digital reading achievement.

In addition, different patterns of games develop different reading strategies (Borgonovi, 2016). Rasmusson and Åberg-Bengtsson (2014) explored the mediating role of computer game playing in accounting for the gender difference in digital literacy and found that the types of video games could explain the gender gap in digital reading proficiency to a large extent. Likewise, single-player games could foster students' individualistic learning and

problem-solving strategies given clear instructions and goals (Borgonovi, 2016). In comparison, collaborative online games that require students to work cooperatively with shared goals would promote cooperative and collaborative learning strategies (Kreijns et al., 2003). However, playing collaborative games might result in a steep reduction in students' ability to comprehend, utilize, reflect on and engage with texts (Borgonovi, 2016). The present study considered both types of games, as they both reflected the time that students spent playing computer games.

Reading attitudes

Attitudes towards reading are known to be one of the most critical factors that influence reading performance and achievement (Lim et al., 2015). Swalander and Taube (2007) defined reading attitude as one's un/favorable disposition towards reading. Students with positive reading attitudes regard reading as a pleasurable activity, whereas those with negative attitudes do not enjoy reading (Lim et al., 2015). In other words, the reading attitude represents students' intrinsic motivation. Motivation is crucial to reading (Conradi et al., 2013; Van Staden & Bosker, 2014). Thus, reading attitudes is able to act as a predictor of reading achievement. However, the relationship between reading attitudes and reading achievement is paradoxical.

On the one hand, reading attitudes are believed to maintain a positive correlation with reading achievement, i.e., the better reading attitudes students have, the more likely they engage reading activities (Logan & Johnston, 2009; Martinez et al., 2008; Sainsbury & Schagen, 2004). On the other hand, McKenna et al. (1995) summarized the negative associations between reading attitudes and reading activities. First, good-performing readers have poor attitudes towards reading, whereas low achievers showed favorable attitudes (Kush & Watkins, 1996). Second, McKenna et al. (1995) proposed that negative reading attitudes resulted in the loss of interest in reading and the tendency to engage in other activities, even for good readers. Hence, poor readers incline to avoid reading, exerting a deleterious impact on their reading achievement (McKenna et al., 1995; Sölpük, 2017). Third, low achievers' reading attitudes decline more sharply than high achievers, which would broaden the attitudinal gap among students (Martinez et al., 2008; McKenna et al., 2012). The research to date has focused on the link between reading attitudes and printed reading. What is not yet clear is whether the impact of reading attitudes still exists when reading online. The current research filled this gap by investigating the relationship between reading attitudes and digital reading.

Gender is a determining factor relating to reading attitudes (Lim et al., 2015). Past findings indicate that girls tend to be more friendly towards reading than boys (McKenna et al., 1995; Sainsbury & Schagen, 2004; Swalander & Taube, 2007). One of the satisfactory explanations lies in the diverse beliefs about gender stereotypes apropos to

reading (McGeown, 2015). Precisely, boys are believed to perform better in science and math, whereas girls' strengths are in the language, arts, and writing (Guthrie et al., 2009). According to Wilson and Casey (2007), boys usually perceive the reading activity as a feminine undertaking, such that they are likely to shun it (OECD, 2009). Such bad reading attitudes would further result in low reading achievement of boys (OECD, 2009). However, this does not necessarily mean that boys do not read at all. In fact, boys are captivated by recreational reading in digital settings, such as reading comic books online, while girls prefer printed reading to digital reading (McKenna et al., 2012; Wilson & Casey, 2007).

In PISA 2018, students' reading attitudes demonstrated a pronounced shift (OECD, 2018). As shown by the result of the student questionnaire, 24% of boys and 44% of girls regarded reading as one of their favorite hobbies. Besides, more than a half of boys, and one third of girls agreed that they only read to obtain necessary information. As compared to PISA 2009, both boys and girls adopted worse reading attitudes in PISA 2018 with less interest in reading. What remains identical is that girls were still more willing to devote time to read than boys (OECD, 2018).

The foregoing presents that boys tend to profit more from playing computer games, but girls still overtake boys in digital reading achievement in PISA 2018. Considering the better reading attitudes possessed by girls, the prominent difference in the relationship between computer game playing and digital reading achievement might be partially explained by the reading attitudes. Thus, the current study examined the mediating effect of reading attitudes in elucidating the indirect impact of computer game playing on digital reading achievement.

Gender

As mentioned in previous sections, the gender difference is indispensable for analyzing reading achievement. Empirical studies demonstrated that girls were advantageous to boys in reading so that girls were considered to be more proficient and engaged readers than boys (e.g., Brozo et al., 2014; Chiu & McBride-Chang, 2006; Gubbels et al., 2020). However, the literature reveals that females have a stronger preference for paper-based reading (featuring linear and thorough reading), while males exhibit a higher degree of satisfaction with digital reading (nonlinear and active reading) (Liu & Huang, 2008). In PISA 2018, the gender difference was smaller than the former assessments (OECD, 2018). There are plausible dual reasons for this phenomenon.

Firstly, both ICT use out of school has reshaped their reading attitudes and familiarized them with digital devices, which improves their digital reading literacy and further narrows the gender gap in digital reading achievement (e.g., Cheung et al., 2013; Liu & Huang, 2008). In detail, compared to their female counterparts, boys spend more time surfing the Internet and playing computer games (Drabowicz, 2014; Notten et al., 2009). Therefore,

they are more acquainted with online activities. After investigating the ICT skills and practices of students in Finland, Hakkarainen et al. (2000) stated that boys perceived themselves as experts in ICT operations, which makes boys hold confident attitudes towards digital reading. In line with Hakkarainen et al. (2000), Tveit and Mangen (2014) reported that boys preferred reading on an e-book device to reading a paper book. Furthermore, boys were more interested in ICT and had better navigation skills, one of the most significant abilities involved in digital reading (Tveit & Mangen, 2014). In Sweden, boys even outperformed girls in digital reading achievement when print reading performance was controlled for (OECD, 2011; Rasmusson & Åberg-Bengtsson, 2014). In general, the positive reading attitudes and preferences in digital reading enable boys to surpass girls. However, boys spend relatively less time reading than girls as they consider reading does not match their masculinity than playing computer games (Tømte & Hatlevik, 2011; Warrington et al., 2000). Different self-concept might underlie why girls still have the advantage in digital reading.

Secondly, the narrowing gender gap in reading performance reflects the increasing demand for visual-spatial ability in digitalized society (Shen et al., 2007). Prior researchers have shown that girls were good at making constructed responses but worse in assessments that required visual-spatial ability, while boys performed better in multiple-choice tasks (Castelli et al., 1998; Lafontaine & Monseur, 2009; Oakhill & Petrides, 2007; Schwabe et al., 2015). Moreover, boys tend to outshine girls in answering questions demanding a large amount of abstract information processing, e.g., memorizing a visual-spatial image or generating and manipulating the information in a mental representation (Borgonovi, 2016; Halpern & LaMay, 2000).

The noteworthy gender difference is proved to be influential in affecting the factors in the present study, i.e., computer game playing, reading attitudes, digital reading achievement. Thus, gender can be regarded as a common characteristic that may conditionally affect the relationship among factors in this study, i.e., a covariate. In order to increase the reliability and accuracy of this experiment, gender is controlled as a covariate when analyzing the data.

Rationale for the current study

In sum, the current literature suggests that digital reading is partly different from traditional reading, so it requires different skills such as navigating through different web pages. It has also been established that computer game playing could boost visual-spatial ability, which plays a critical role in the digital environment. Besides, existing research has recognized the importance of reading attitudes in predicting digital reading performance. Moreover, extensive research has indicated that the multifarious gender differences in digital reading

achievement. It cannot be simply concluded as girls on average outperform boys in reading assessments.

Although the existing body of research has established the theoretical and empirical background of the present study, it also indicates some research gaps and conflicts which need to be addressed. First, scholars have argued that computer game playing would generate visual-spatial ability, which could further affect certain aspects of digital literacy. So far, there has been little agreement on whether computer game playing directly influences digital reading achievement. Second, reading attitudes have been proved to affect reading performance. However, several divergent accounts of the relation between reading attitudes and reading proficiency have been proposed, creating numerous controversies. What is more, previous studies focused on the bivariate associations, and there is a paucity of studies that seek to identify the mediating effect of reading attitudes. Third, the gender difference has been found to exist in all the three aforementioned factors (i.e., digital reading achievement, computer game playing, reading attitudes). Boys tend to play more video games that enhance digital capacity, but girls still outperform boys in digital reading. This result suggests the possible existence of an attitudinal mediator favoring girls in the explanation of the relationship between computer game playing and digital reading achievement. Thus, an interesting thread to follow is whether the relationship between computer game playing and digital reading achievement will change if gender is controlled.

Research goals for the present study

Taking advantage of PISA 2018 dataset, this study has investigated the factor structure and Hong Kong 15-year-olds' digital reading achievement with the conditioning effects of gender being controlled. PISA 2018 findings also proffer an insight into the mediated associations between digital reading achievement and relevant factors such as attitudes towards reading. In this study, attention has been given to student-level analysis. Specifically, the following questions were formulated:

First, is it possible to find significant associations between computer game playing, reading attitudes, and digital reading achievement? It was hypothesized that digital reading achievement would positively correlate with reading attitudes but negatively associate with computer game playing. Besides, computer game playing would negatively associate with reading attitudes.

Second, do reading attitudes mediate the relationship between computer game playing and digital reading achievement? It was hypothesized that reading attitudes would mediate the relationship between computer game playing and digital reading achievement, with both the direct effect (computer game playing → digital reading achievement) and the

indirect effect (computer game playing → reading attitudes → digital reading achievement) being statistically significant.

Third, will the relationship between computer game playing and digital reading achievement change if gender is controlled? It was hypothesized that after taking gender into consideration, the mediation effect would disappear because of the enormous gender difference.

Methods

Sample

The present study took the Hong Kong sample from PISA 2018, which was the latest PISA dataset released by OECD in December 2019. PISA is a triennial survey that intends to exam the academic achievements of 15-year-olds in reading, mathematics, science, and collect relevant demographic, instructional, and attitudinal variables through questionnaires across OECD countries and partner countries since 2000 (OECD, 2011). Though all three academic domains are tested every three years, the test focus is divergent for each circle, such that the same test focus is only repeated in a nine-year circle. For example, reading was the major domain in PISA 2009 and became the major domain again in PISA 2018 (Lim & Jung, 2019). In addition, online reading was introduced to the reading assessment of PISA in 2009 for the first time (Rasmussen & Åberg-Bengtsson, 2014), and the reading test stayed digital in most participating countries from then on (Xiao et al., 2019). Moreover, Hong Kong completed all the questionnaires that reveal the students' basic information (region, gender), reading attitudes, and ICT use. Thus, the present study employed Hong Kong sample using PISA 2018 to analyze Hong Kong students' digital reading achievement. In total, PISA 2018 comprises data of 6,037 Hong Kong 15-year-olds who are secondary school students.

Variables

The present study utilized student-level variables from the student questionnaire and the ICT familiarity questionnaire of Hong Kong in PISA 2018. There were three sets of factors included in this study, namely digital reading achievement, computer game playing, and reading attitudes.

First, digital reading achievement consisted of three components that evaluated students' computer-assessed reading performance: locating information (RCLI), understanding (RCUN), and evaluating and reflecting (RCER). The test reliability of the three variables was 0.97 (as measured by Cronbach's alpha). It is worth noting that all the three elements were represented by the plausible values that were essentially multiple imputations used for approximating students' real digital reading performance (OECD, 2012). In this setting,

the present study employed all ten plausible values of RCLI, RCUN, and RCER for the unbiased parameter estimation, consistent with the recommendations for dealing with plausible values in large-scale international assessments (OECD, 2012; Rutkowski et al., 2010). Second, computer game playing referred to the latent factor that reflected how frequently students play computer games. This factor contained IC008Q01TA, IC008Q02TA, and IC008Q07NA, each of which was measured on a five-point Likert scale (1 = never or hardly ever; 2 = once or twice a month; 3 = once or twice a week; 4 = almost every day; 5 = every day). The internal reliability of the three selected variables was 0.66. Third, reading attitudes reflected students' inclination towards reading activity. It consisted of ST160Q01IA, ST160Q02IA, ST160Q04IA, and ST160Q05IA, each of which was measured on a four-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree. These four variables). Except for ST160Q02IA, all other three variables required inverse coding because of their negative phrasing. The reliability of the four selected variables was 0.81, indicating a fair internal consistency. Moreover, gender (ST004D01T) was chosen as a covariate, as its inclusion might exert some conditioning effects to the proposed mediation effects mentioned in the research questions.

Table 1 showed the selected variables including their descriptive statistics (i.e., mean, standard deviation, minimum, maximum). The hypothetical relationships among the three latent factors and the one covariate variable were: 1) computer game playing exerted direct and negative effects on reading attitudes and digital reading achievement; 2) reading attitudes had positive impacts on digital reading achievement; 3) reading attitudes mediated the relationships between computer game playing and digital reading achievement); 4) gender conditioned the associations and mediations of the three latent factors.

Preprocessing

The data preprocessing took multiple steps. First, as PISA adopts a two-stage stratified sampling scheme, the present study incorporated both the final student weight (W_FSTUWT) and the 80 replicate weights (W_FSTURWT 1-80) to obtain unbiased parameter estimates and correct standard errors, in compliance with PISA standardized

Table 1 Observed variables for the present study

Factor/variable	Variable code	Description	Mean	SD	Min	Max
Digital Reading Achievement (DRA)	RCLI	Locating Information	530.13	99.12	87.66	840.41
	RCUN	Understanding	531.80	100.84	177.93	836.10
	RCER	Evaluating and Reflecting	535.30	98.40	172.80	838.60
Computer Game Playing (CGP)	IC008Q01TA	Playing one-player games.	2.9655296	1.4229086	1	5
	IC008Q02TA	Playing collaborative online games	3.012228	1.52	1	5
	IC008Q07NA	Playing online games via Social Networks.	2.6125202	1.53	1	5
Reading Attitudes (RA)	ST160Q01IA	I read only if I have to.	2.41	0.89	1	4
	ST160Q02IA	Reading is one of my favourite hobbies.	2.66	0.86	1	4
	ST160Q04IA	For me, reading is a waste of time.	1.91	0.85	1	4
	ST160Q05IA	I read only to get information that I need.	2.42	0.87	1	4
Gender	ST004D01T	Gender	/	/	0	1
Final Student Weight	W_FSTUWT	Final trimmed nonresponse adjusted student weight	/	/	/	/
Replicate Weight	W_FSTURWT1-80	Final trimmed nonresponse adjusted student replicate brr-	/	/	/	/

procedure (Oberski, 2014; OECD, 2015). In practice, both types of weights were added by the `svrepdesign` function from the survey package (Lumley & Scott, 2017) in R (R Core Team, 2018). Second, ST160Q01IA, ST160Q04IA, and ST160Q05IA went through reverse coding such that the negative items were rephrased positively, i.e., a higher score indicates better reading attitudes. Third, the present study scaled and centered the selected variables before statistical analysis, as 1) the selected variables were not of the same scale (scale-dependent estimates were not appropriate for between-variable comparison), and 2) multicollinear relations, if existed, would hamper the statistical analysis (Hu et al., 2018). Fourth, missing data would also constitute a problem if not appropriately handled since the missing data of the present study accounted for 5.28% of the total dataset, and the missingness was even worse for the variables belonging to computer game playing (between 7% to 8%). In this case, missing data were imputed at the student level by using the Full Information Maximum Likelihood (FIML) method, as past studies featuring structural equation modeling found such a technique more appropriate than other techniques such as listwise and pairwise deletion (Enders & Bandalos, 2001).

Modeling

The present study adopted both confirmatory factor analysis and structural equation modeling techniques to analyze the Hong Kong dataset. In total, there were three hypothetical, student-level models pending verification. First, Model 1 was built for answering the first research question. It is a confirmatory factor analysis that examined whether the respective observed variables could appropriately measure their corresponding latent factors, i.e., computer game playing, reading attitudes, and digital reading achievement. Model 1 entailed unit variance loading that standardized factor variances for model identification (Rosseel, 2012), and it allows the latent factors to co-vary with each other. Second, Model 2 was made to address the second research question. It included converted factor covariances in Model 1 to path coefficients, intending to probe the mediation effect of reading attitudes on the relationship between computer game playing and digital reading achievement, out of the hypothesis that the mediator (i.e., reading attitudes) passed its impact on the independent variable (i.e., computer game playing) to the dependent variable (i.e., digital reading achievement). Partial mediation was identified when the indirect effect from computer game playing to digital reading achievement via reading attitudes reached statistical significance while the direct effect from computer game playing to digital reading achievement remained significant but reduced in magnitude. Alternatively, full mediation existed if the direct effect was no longer significant after the introduction of significant indirect effect. Third, Model 3 was constructed to solve the third research question. Dissimilar to Model 2, Model 3 took gender as a dichotomously coded predictor (girl = 0, boy = 1) to verify gender's conditioning effect on the mediated relation

described in Model 2. Gender was said to condition the mediation effect if its inclusion influenced either the magnitude or significance of the mediating effect. Last but not least, the present study did not consider multiple-group analysis as a possible alternative because the measurement invariance was not establishable, in light of the complexity of the current model and the heterogeneity between two gender groups.

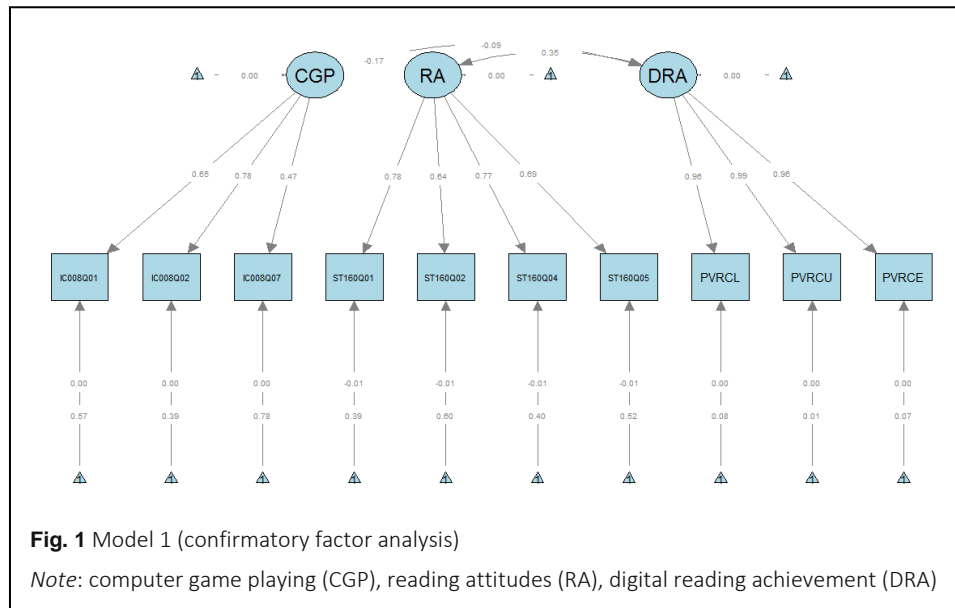
As for analytical tools, the main statistical analysis was conducted by using the lavaan (Rosseel, 2012) and lavaan.survey (Oberski, 2014) packages in the R environment (R Core Team, 2018), with the maximum likelihood parameter estimator.

Results

Prior to statistical analysis, the Hong Kong dataset was tested against the statistical assumptions. The assumptions were met for both multivariate normality and homogeneity of co/variance matrices. In the presentation below, the latent factors were indicated by the blue ovals whereas the observed variables were illustrated in the blue rectangles. The independent variables (computer game playing and reading attitudes) pointed the single-headed straight arrows towards the dependent variables (digital reading achievement and reading attitudes) whereas the covariances were reflected by the double-headed bent arrows. The residuals were indicated by the blue triangles.

The measurement model

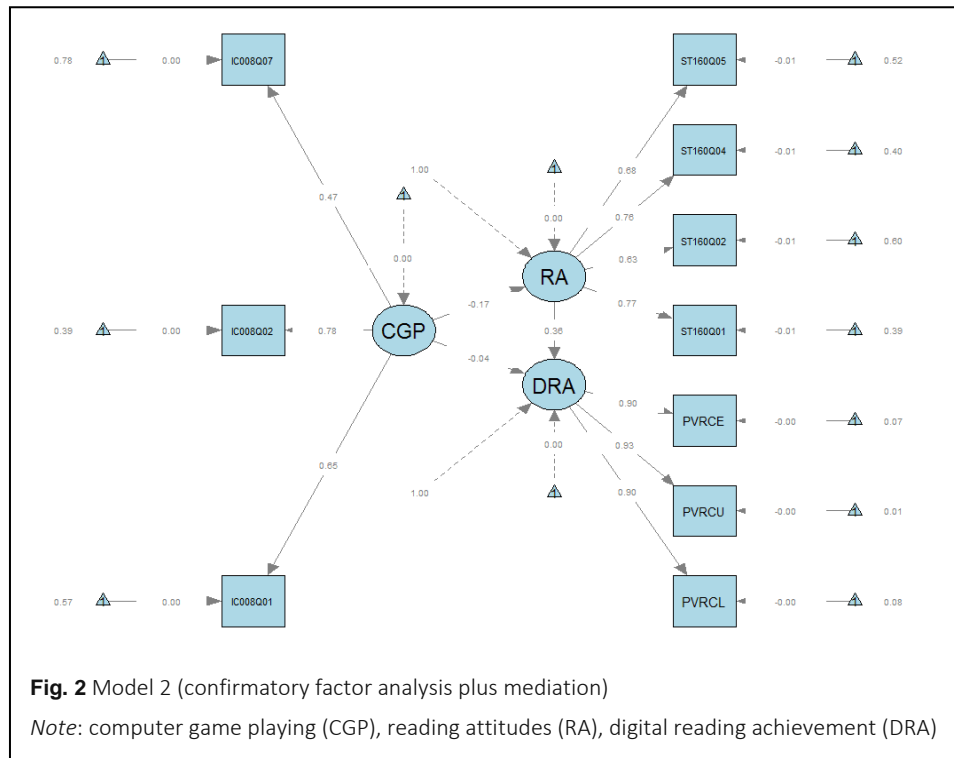
According to Model 1 (Figure 1), the factor loadings (i.e., relationships between latent factors and observed variables) were both substantial and statistically significant. In addition, Chi-square goodness of fit test was significant, $\text{Chi-square}(32, N = 6037) = 438.00, p < .001$, implying unsatisfactory goodness-of-fit in that that reproduced covariance matrix was significantly different from the ideal covariance matrix. However, as Chi-square test is very stringent and rejection is likely to happen, goodness-of-fit indices therefore would be provided as complementary indicators of the model goodness-of-fit (Schumacker & Lomax, 2004, p. 92). Specifically, other fit indices indicated the current model had a decent fit: goodness of fit index (GFI) = .99, adjusted goodness of fit index (AGFI) = .97, normed fit index (NFI) = .99, relative fix index (RFI) = .99, non-normed fix index (NNFI) = .99, incremental fit index (IFI) = .99, comparative fit index (CFI) = .99, standardized root mean squared residual (SRMR) = .04, root mean square error of approximation (RMSEA) = .05. In this case, the observed variables still had decent measurements of their corresponding latent constructs. In addition, the correlations among the latent factors were also statistically significant between: computer game playing and digital reading achievement ($\beta = -.09, SE = 0.02, p < .001$), reading attitudes and digital reading achievement ($\beta = .35, SE = 0.02, p < .001$), computer game playing and reading attitudes ($\beta = -.17, SE = 0.01, p < .001$).



In sum, the negative association between computer game playing and reading attitudes suggested that students who spend more time playing computer games had a lower willingness to read. Moreover, the negative association between computer game playing and digital reading achievement suggested that the time spent on computer games had an adverse impact on students' digital reading achievement. Last, the strong and positive correlation between reading attitudes and digital reading achievement suggested that if students had better reading attitudes, they would be prone to perform better in the digitally assessed reading test.

The structural equation model

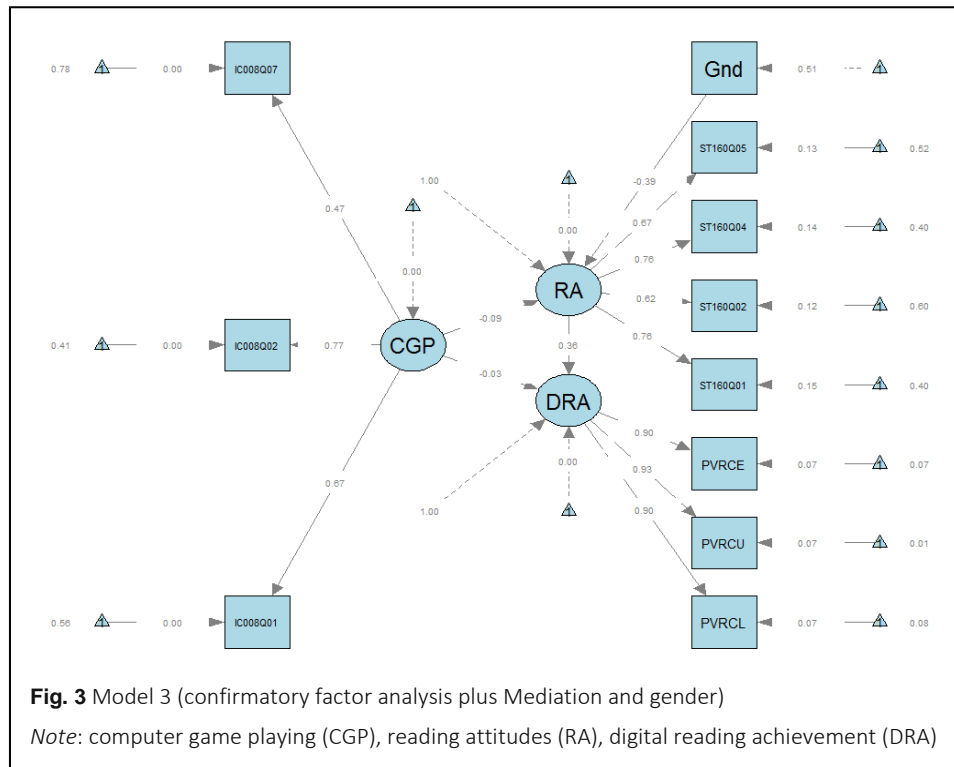
The model specification of Model 2 resembled that of Model 1, except that the covariances among the three latent factors (computer game playing, reading attitudes, digital reading achievement) were updated as the path coefficients. In this case, the model fit was identical to those from Model 1. For the path coefficients (as illustrated in Figure 2), statistically significant relationships were identified between: computer game playing and reading attitudes ($\beta a = -.17$, $SE = 0.02$, $p < .001$), reading attitudes and digital reading achievement ($\beta b = .36$, $SE = 0.02$, $p < .001$), computer game playing and digital reading achievement ($\beta c = -.04$, $SE = 0.02$, $p = .02$). As a result, all direct effect (c), indirect effect ($\beta a * b = -.06$, $SE = .01$, $p = .02$), and total effect ($\beta c + a * b = -.10$, $SE = 0.02$, $p < .001$) reached statistical significance. Additionally, the direct effect (βc) was smaller in magnitude than the association between computer game playing and digital reading achievement in Model 1 ($\beta = -.09$). Taken together, these results suggested that reading attitudes could partially mediated the relationships between computer game playing and digital reading



achievement by reducing the negative association between computer game playing and digital reading achievement by .05 in magnitude. In other words, when the effects of reading attitudes were removed, the negative correlation between computer game playing and digital reading achievement became larger.

The structural equation model plus gender difference

Model 3 added gender as a covariate to Model 2 with the aim of testing the conditioning effect of gender difference. For Model 3 (as illustrated in Figure 3), the factor loadings (relationships between latent factors and observed variables) were both substantial and statistically significant, and the model fit was also fair, Chi-square(41, N = 6037) = 1569.00, $p < .001$, goodness of fit index (GFI) = .95, adjusted goodness of fit index (AGFI) = .91, normed fit index (NFI) = .96, relative fit index (RFI) = .95, non-normed fit index (NNFI) = .95, incremental fit index (IFI) = .97, comparative fit index (CFI) = .97, standardized root mean squared residual (SRMR) = .07, root mean square error of approximation (RMSEA) = .08. To compare with Model 2, the information criteria decreased from Model 1 (AIC = 124358.2, BIC = 124579.5) to Model 3 (AIC = 124201.5, BIC = 124381.6). The results suggested that Model 3 fitted the data better than Model 1 did, probably because Model 3 adopted gender as the conditional variable. As for the path coefficients, significant associations were found between: computer game playing and reading attitudes ($\beta_a = -.09$, $SE = .02$, $p < .001$), reading attitudes and digital reading



achievement ($\beta b = .34$, $SE = .02$, $p < .001$), computer game playing and digital reading achievement ($\beta c = .01$, $SE = .02$, $p = .60$). In addition, the direct effect (c) turned insignificant while the indirect effect (a*b) remained statistically significant ($\beta a*b = -.03$, $p < .001$) in the presence of the potential mediator (reading attitudes) and the conditional covariate (gender), suggesting that reading attitudes fully mediated the relationships between computer game playing and digital reading achievement when controlling for gender. To be more specific, gender difference was in favor of girls with regard to reading attitudes because gender (girl = 0, boy = 1) negatively correlated with reading attitudes ($\beta = -.37$, $SE = .03$, $p < .001$), implying that when the factor of computer game playing was brought under control, boys were much less willing to read in comparison to girls.

Discussion

To sum, the present study intended to scrutinize: 1) the factor associations between digital reading achievement, computer game playing, and reading attitudes, 2) whether reading attitudes mediated the relationships between computer game playing and digital reading for the Hong Kong PISA 2018, and 3) whether gender affected such a mediating relationship. For addressing the three research questions, the present study adopted both confirmatory factor analysis and the structural equation modeling methods. The findings were primarily three-fold. First, computer game playing was proved to negatively correlate with reading achievement and reading attitudes, while reading attitudes positively correlate

with reading achievement. Second, the results revealed that reading attitudes played a partial mediation between computer game playing and digital reading achievement in that playing computer games had a weak but still significant impact on the indirect relationships between computer game playing and digital reading achievement. Third, reading attitudes were found to fully mediate the association between computer game playing and digital reading achievement after controlling gender. In other words, the indirect path between computer game playing and digital reading achievement maintained significance while the direct path turned insignificant.

Factor structure of digital reading achievement

Firstly, the negative relationship between computer game playing and digital reading achievement in the measurement model suggests that spending time in video games would impair students' digital reading performance. On the one hand, this outcome seems to be different from that of Rasmussen and Åberg-Bengtsson (2014), who found positive associations between playing computer games and digital reading achievement among Swedish 15-year-olds dating back to 2009. On the other hand, moderate playing could promote students' academic learning (Borgonovi, 2016), whereas excessive playing would harm the digital reading achievement because of the addiction to video games (Barlett et al., 2009; Drummond & Sauer, 2014; Gentile et al., 2004; Weis & Cerankosky, 2010). Thus, the discrepancy might be explained by the fact that secondary school students in Hong Kong, in comparison to students from other regions (e.g., Sweden in 2009), play computer games in a more frequent and unrestrained fashion, as manifested by their higher scores in the ICT familiarity questionnaire. Moreover, the present study did not distinguish different types of computer games, but the effect of computer game playing on digital reading achievement was considered to vary between one-player games and collaborative games (Borgonovi, 2016; Kreijns et al., 2003). Further studies could: 1) identify an acceptable range of frequency and time spent on games that are beneficial to students' digital reading achievement, and 2) differentiate one-player games and collaborative games in their abilities to facilitate learning processes. Such a result implies that adolescents' computer game playing should be guided appropriately by advocating moderate game playing as well as discouraging immoderate playing. There are three ways to achieve this aim. First, game developers can supervise teenagers who use their online gaming services additively (Leung, 2021). The Democratic Alliance for the Betterment and Progress of Hong Kong (DAB) has conducted an online poll about 463 parents' views towards the online game addiction among teenagers in Hong Kong from September 6 to 10, 2021 (Chan, 2021). More than 50 percent of parents reported that the time their kids spent on playing online games exceeded three hours a day and nearly 20 percent said their children played more than five hours every day. Besides, more than 95 percent of local parents wanted the

authorities in Hong Kong to impose measures against video game addiction among adolescents. In Mainland China, the gaming time for kids was limited to three hours a week through strictly implementing real-name registration and login systems for all the games. In order to better monitor the regulation, the public is also encouraged to report the irregularities of protecting minors from video gaming addiction. Meanwhile, the lawmaker of DAB, Vincent Cheng Wing-shun, urged Hong Kong authorities to introduce regulations to tackle gaming addiction among minors as Mainland China do (Leung, 2021). Taken together, regarding the necessity of regulating adolescents' video game playing emphasized by both the parents and lawmakers, it is necessary to develop parent awareness programs to monitor children's use of Internet services and gaming systems (Wong & Lam, 2016). Second, parents could not only initiate a mutual agreement with their children on how much time they should spend on playing video games but also help these young people to find health-enhancing alternatives that children are interested in such as bike riding, hiking (Wong & Lam, 2016). For parents in Hong Kong, Mama (2021) offers various indoor and outdoor activities that are suitable for teenagers. Third, instructors are recommended to elaborate the corrupting influence of playing computer games immoderately to adolescents at school, thereby guiding students to form healthy habits in gaming.

Secondly, this study observed a significant positive correlation between reading attitudes and digital reading achievement. Furthermore, reading attitudes had a more substantial effect on digital reading achievement compared to computer game playing. From one perspective, this accords with earlier observations that demonstrate solid while positive prediction of reading attitudes to reading achievement (Logan & Johnston, 2009; Martinez et al., 2008; Sainsbury & Schagen, 2004). This outcome is also in line with Lim et al. (2015), who stated that reading attitudes were predominantly vital for developing reading literacy. From another perspective, this finding is contrary to previous studies which suggest that there exist negative associations between reading attitudes and reading performance (Kush & Watkins, 1996; Martinez et al., 2008; McKenna et al., 2012; McKenna et al., 1995; Sölpük, 2017). Such conflicting results might associate with the way of measuring reading attitudes. For instance, reading attitudes in McKenna et al. (2012) were revealed by students' feelings towards recreational reading and academic reading from a six-point Likert scale. In contrast, the current study evaluated reading attitudes by accessing students' inclination towards general reading from a four-point Likert scale. Besides, the present study also extends the concerned positive correlation to the digital reading context. Considering the dominant influence of reading attitudes, teachers could enhance student attitudes towards reading by encouraging them to read more frequently. According to Xu and Huang (2021), children's reading attitudes are significantly affected by the reading experience, reading confidence, parent support, and teacher instruction,

which provides suggestions to schools, parents and instructors. First, secondary schools should realize the importance of developing students' favorable reading attitudes and optimizing the reading environments conducive to mastery of extensive reading. Hong Kong Baptist University Affiliated School Wang Kam Fai Secondary and Primary School has set a superb example (HKBUAS, 2021). It organizes a series of reading programmes that provide opportunities for 1) teachers to share their favorite books with students and enjoy reading together; 2) students to engage in reading activities such as reading games; 3) parents to be updated with the book recommendations. Moreover, it also offers the book disinfection machine, multi-touch electronic reader, and e-books platform for students and teachers to encourage digital reading under the COVID-19 pandemic. Second, parents could build a literacy-rich environment at home, read a lot, exhibit good reading habits and behaviors, and interact with their children through various reading activities (Klauda & Wigfield, 2012; Puccioni et al., 2019). This is because that children can notice and imitate their parents when their parents' preferences, attitudes, and beliefs towards reading are demonstrated in front of them (Merga & Mat Roni, 2018). Third, teachers should get involved in students' reading activities and provide support (Xu & Huang, 2021). For instance, teachers can share the reading experience with students, and thereby enhance students' positive attitudes towards reading (HKBUAS, 2021). Likewise, teachers can provide a wide range of books covering multifarious topics for students to select out of their interests, which not only guarantees the quality of the books but also cope with students' individual interests. In this way, students may find the pleasure of reading and enjoy reading.

Thirdly, a statistically significant negative association was found between computer game playing and reading attitudes. One tentative explanation of this result is that students who play video games more tend to devote less effort to study and read. Such ignorance towards reading would result in unfriendly attitudes. This intriguing finding draws our attention on the importance of mentoring students to play computer abstemiously and form favorable reading attitudes.

The mediation role of reading attitudes in the computer game playing effect on digital reading achievement

Regarding the mediation role of reading attitude in the relationship between computer game playing and digital reading achievement, this study found that computer game playing significantly predicated digital reading achievement both directly and indirectly via reading attitudes under the framework of structural equation modeling. That is, reading attitudes partially mediated the effect of computer game playing on digital reading achievement.

One possible explanation is that students who play video games more tend to behave badly in reading activities. The poor reading performance inversely correlates with pessimistic attitudes. This way of reasoning is in line with prior studies that found the damaging impact of playing computer games (Ferguson & Olson, 2014; Kowert et al., 2015; Swing et al., 2010), and the positive correlation between reading behavior and reading attitudes (Logan & Johnston, 2009; Martinez et al., 2008; Sainsbury & Schagen, 2004). Alternatively, playing online games has a negative and more minor impact on digital reading achievement than the significant and substantial effect of reading attitudes (this accounts for that the negative correlations between computer game playing and reading achievement turned out to be larger when mediator was not considered). In other words, if one is willing to read, the degree of the catastrophic effect from computer games will be lessened since reading attitudes have a more powerful influence on digital reading achievement than computer game playing. Last, one of the issues that emerge from this finding is that instructors could diminish the disruptive impact of computer game playing on digital reading achievement by facilitating students to establish a favorable reading attitude. According to the front-line experience of Joe Tang Chun-yu, who runs the NGO's Online Addiction Counselling Centre in Hong Kong, young people indulge in gaming to relieve stress and boredom (Leung, 2021). Therefore, viable alternative activities can be held by schools to help students engage in interactions with their peers and alleviate their negative feelings. For example, instructors from Tuen Mun Catholic Secondary School in Hong Kong and Kaohsiung Municipal Ruesiang Senior High School in Taiwan co-designed the Reading Activity with Taiwan Students using an online reading platform (Chu et al., 2011). Under this scheme, students from the two regions can write book reviews or respond to the comments written by other students online. The reading themes range from parental love to travelling and dining literature. This activity enables adolescents to generate in-depth understandings of the books and establish positive reading attitudes. At the same, students can share their feelings with their peers who are in the same situation as them to alleviate their stress.

Gender gaps in the mediating relationship

The study investigated whether the mediating role of reading attitudes existed in accounting for the relationship between computer game playing and digital reading achievement when controlling the gender differences. Surprisingly, reading attitudes' partial mediation turn to full mediation when gender was controlled as a covariate. Such a change is accountable in that reading attitudes have more profound effects on magnitude and significance of digital reading achievement, in comparison to computer game playing whose effects become trivial and even negligible after the gender mediator was added.

Gender effect also suggests that girls were more willing to read than boys when the frequency of video game playing was equal. This result confirms the interpretation of PISA 2018 that although both boys and girls tend to be less likely to read in their free time, girls still adopted better reading attitudes than boys (OECD, 2018). Additionally, the result matches with previous observations in which girls tend to be more optimistic towards reading than boys (McKenna et al., 1995; Sainsbury & Schagen, 2004; Swalander & Taube, 2007). Tentatively, this implies that perhaps girls have acquired additional skills apart from visual-spatial ability by playing computer games to a greater extent than boys. Thus, it is worth exploring the exact reading strategies gained from playing online games for future studies.

The result of gender gaps exists in digital reading achievement highlighted the urgency of elevating boys' reading literacy competencies in Hong Kong through supporting the wide and regular online reading of a variety of texts related to boys' individual interests (Brozo et al., 2014). For example, when learning history, primary documents, graphic novels, and related websites can also be provided to enhance learning and reading. In Hong Kong, a wide range of supplementary materials are provided on the website of *EDB One-stop Portal for Learning & Teaching Resources* and *EDB Educational MultiMedia*.

Conclusion

To conclude, digital reading achievement was shown to negatively associated with computer game playing but positively correlated with reading attitudes. The results also demonstrated significant mediating effect of reading attitudes in the relationship between computer game playing and digital reading achievement by adjusting the original magnitude of the effect of computer game playing and digital reading achievement. When gender was controlled, the negative effects of playing computer games disappeared. These results suggest: 1) excessive game playing would negatively affect the reading performance, 2) positive reading attitudes would alleviate the negative impacts of playing computer gaming against digitally assessed reading, 3) gender difference was so large in reading attitudes that the effects of computer game playing on reading attitudes became negligible. The present study had shed new light on the mediated relationships among the three aforementioned latent factors, as previous efforts for measuring the concerned relationship between computer game playing and digital reading achievement were anecdotal.

The present study had several limitations as well as suggestions for future studies. Above all, the present study provided a comprehensive picture of Hong Kong 15-year-olds' digital reading and relevant factors, primarily focusing on student-level characteristics. First, future studies could conduct an in-depth analysis for Hong Kong educational system by including school- or culture-related variables. Second, a cross-sectional comparison could be made by including the data from a wide variety of economics. Third, future researchers

might look into how such mediation is moderated by gender compared to a covariate in the present study.

Regardless of the above limitations, this study also provided several meaningful insights and implications. Theoretically, the present study extended our knowledge of the role of computer game playing and reading attitudes in digital reading achievement by identifying the mediation effect of reading attitudes in the relationship between computer game playing and digital reading achievement. Methodologically, in order to improve the accuracy and power of the analysis, gender was controlled as a covariate when exploring the mediated relationships. Pedagogically, this study offered several suggestions for Education Bureau, parents, and teachers. First, Education Bureau might highlight the importance of ICT in the curriculum, as well as adopt the assessments in line with this new demand. In Hong Kong, Education Bureau has launched a series of measurements to address the significance of digital reading. Starting from 2018, the Education Bureau of Hong Kong has disbursed the Promotion of Reading Grant to all public sector schools to support them in strengthening the development of reading and encourage students to form good reading habits at a young age (Education Bureau, 2021). With respect to teachers, the Education Bureau of Hong Kong provides *Recommended Professional Development Programmes and Activities for Teacher-librarians* to promote teachers' ICT skills, thereby improving their education quality in the digital era. Regarding parents, the Education Bureau of Hong Kong offers e-bulletin and parents' talk for them to support their supervision of students' home learning. In terms of students, they can find substantial resources available online to guide their e-learning. Second, parents should facilitate students to manage the time spent on computer game playing to reduce its negative effect on digital reading performance by consulting a time limit of video gaming and accompanying their kids to do interesting alternative activities. Third, school teachers should guide students to establish positive reading attitudes through encouraging and supporting since reading attitudes could significantly develop students' digital reading literacy. In detail, teachers can participate in reading activities together with students and share the reading experience with them to set a model of good reading attitudes to students.

Abbreviations

PISA: Programme for International Student Assessment; ICT: Information and communication technology; OECD: Organization for Economic Cooperation and Development; FIML: Full Information Maximum Likelihood; GFI: Goodness of fit index; AGFI: Adjusted goodness of fit index; NFI: Normed fit index; RFI: Relative fit index; NNFI: Non-normed fit index; IFI: Incremental fit index; CFI: Comparative fit index; SRMR: Standardized root mean squared residual; RMSEA: Root mean square error of approximation; AIC: Akaike information criterion; BIC: Bayesian information criterion; SE: Standard error; DAB: The Democratic Alliance for the Betterment and Progress of Hong Kong.

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Authors' contributions

Both authors have substantially contributed to conducting the underlying research. Both authors read and approved the final manuscript.

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Availability of data and materials

PISA 2018 Database. <https://www.oecd.org/pisa/data/2018database/>. Accessed October 2020.

Declarations**Competing interests**

The authors declare that they have no competing interests.

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