Digital competence as a protective factor against gaming addiction in children and adolescents: A cross-sectional study in Hong Kong

Winnie W.Y. Tso,[a,b,1] Frank Reichert,[c,1] Nancy Law,[c] King Wa Fu,[d] Jimmy de la Torre,[c] Nirmala Rao,[c] Lok Kan Leung,[a] Yu-Liang Wang,[a] Wilfred H.S. Wong,[a] and Patrick Ip[a,*]

[a]Department of Paediatrics and Adolescent Medicine, LKS Faculty of Medicine, The University of Hong Kong
[b]State Key Laboratory of Brain and Cognitive Sciences, The University of Hong Kong
[c]Faculty of Education, The University of Hong Kong
[d]Journalism and Media Studies Centre, The University of Hong Kong

The Lancet Regional Health - Western Pacific 2022;20: 100382
Published online 2 February 2022
https://doi.org/10.1016/j.lanwpc.2022.100382

Summary

Background Digital competence can help children and adolescents engage with technology for acquiring new knowledge and for broadening social contact and support, while reducing the risk of inappropriate media use. This study investigated the effects of digital competence on the risk of gaming addiction among children and adolescents. We explored whether students with good digital competence were protected from the adverse effects of media use and the risk of gaming addiction.

Methods 1956 students (690 primary and 1266 secondary) completed a digital competence assessment and a self-report questionnaire on their mental health status, use of digital devices, and experiences of cyberbullying. Multiple regression analyses with further mediation and moderation analyses were performed to investigate the association of digital competence with gaming addiction and mental health in children and adolescents.

Findings Regression analyses showed that children and adolescents with better digital competence were less likely to develop gaming addiction (β = -0.144, p < 0.0001) and experienced less cyberbullying behaviour as perpetrators (β = -0.169, p < 0.0001) and as victims (β = -0.121, p < 0.0001). Digital competence was found to mediate the relationship between digital device usage time and gaming addiction.

Interpretation Digital competence is associated with less gaming addiction and could potentially lead to better mental wellbeing by reducing the risks of gaming addiction and cyberbullying. Education that promotes digital competence is essential to maximize the benefits of media use, while reducing the potential adverse effects from the inappropriate use of digital devices.

Funding This study was supported by a grant from the Research Grants Council of the HKSAR Government (#T44-707/16N) under the Theme-based Research Scheme

Keywords: Digital competence; Gaming addiction; Cyberbullying; Mental health; Digital device; Digital literacy

Introduction

Technology plays an increasingly large role in today's world. Children and adolescents are exposed to digital media at a very young age and social media is becoming a big part of their lives. As a result, the influence of media on children has been gaining increasing attention among parents, educators, and healthcare professionals. Overuse of media and increased screen time are known to have detrimental effects on children's physical and mental health, including the lack of physical exercise, sleep deprivation, and decreased face-to-face social interactions.[1]

Although video gaming and internet surfing have become popular recreational activities for children and adolescents, there are growing concerns about gaming

*Corresponding author contact details: Dr Patrick Ip, MBBS, Department of Paediatrics & Adolescent Medicine, Room 115, 1/F, New Clinical Building, 102 Pokfulam Road, Queen Mary Hospital, Hong Kong.
E-mail address: patricip@hku.hk (P. Ip).

[1] Co-first authors

Research in Context

Evidence before this study

We searched PubMed, Web of Science and Google Scholar until 1st August 2021, for studies regarding the impact of digital competence on mental health and/or gaming addiction. The search terms were digital competence, game or gaming disorder, gaming or internet addiction or mental health or mental wellbeing AND children or adolescents, primary school or secondary school students. Studies on the association between digital competence and gaming addiction in children are lacking, though there were limited studies suggesting digital literacy could be beneficial for adolescents to achieve better health and well-being.

Added value of this study

This study is one of the first to demonstrate that better digital competence is associated with a lower risk of gaming addiction, which could potentially lead to better mental wellbeing in children and adolescents.

Implication of all the available evidence

Our study highlighted the importance of digital competence in children and adolescents. We demonstrated that the use of digital device is not 'inherently bad' for children's mental health, digital competence is associated with lower risk of gaming addiction and can promote digital wellness in our younger generation.

and internet addictions and the related physical and mental health risks. According to a recent parent survey in the United Kingdom, 53% of parents were worried about their children's use of technology, which was their greatest concern above drug and alcohol use, school performance, or sexual identity.[2] Problematic internet use is increasingly being recognised as a public health concern.

Mainland China is reported to have one of the highest prevalence rates of internet/gaming addiction among adolescents.[3-5] However, the prevalence of internet/gaming addiction is less clear for younger school-aged children. In addition, studies have shown that children or adolescents with gaming addiction are more likely to develop physical health problems such as obesity and insomnia.[6-7] They are also more likely to exhibit aggression,[8] impulsive behaviours, and psychiatric symptoms such as obsessive-compulsive disorder.[9] Children and adolescents with gaming addiction are prone to risky online behaviours such as cyberbullying, in which the perpetrator causes malicious, repetitive, and hostile harm to individuals or groups via the internet.[10] Cyberbullying can lead to serious mental health consequences such as suicide attempts.[11] There are several intervention programs that target children and adolescents with signs of gaming addiction or risky online behaviours, although their effectiveness can vary.[12,13] Hence, there is a need for effective interventions to prevent gaming addiction and cyberbullying in young children and adolescents. This study investigated whether children with good digital competence can protect against gaming addiction and risky online behaviours such as cyberbullying. Educating future generations with good digital competence could be a relatively easy way to prevent gaming addiction in children and adolescents.

Existing literature often focuses on how the excessive use of digital devices can negatively affect the health and mental wellbeing of children and adolescents. On the other hand, appropriate media use can also be beneficial for school-aged children and adolescents, enabling them to acquire new knowledge and providing opportunities for social interaction and peer support. The American Academy of Paediatrics (AAP) recommends that media use in school-aged children and adolescents should be balanced with other healthy behaviours.[14] Parents can find it very challenging to guide their children on the appropriate use of media. Many parents and educators believe that digital education, the promotion of online safety, and the prevention of online harms should be crucial parts of the school curriculum across all age groups.[15] In the modern digital age, it is impractical and unrealistic to ban the use of media in children and adolescents. Therefore, digital competence is essential for the appropriate use of digital media.

Various labels associated with the term "literacy" have been used in assessment frameworks and studies to describe the knowledge, skills, and attitudes deemed necessary to succeed in the digital era. These labels include "computer literacy", "information literacy", "information and communication technology (ICT) literacy", or "digital literacy", among others.[16-18] Despite these diverse labels, there is a distinct set of competences converging around the retrieval, processing, communication, and production of information and content used in ICT.[17] To avoid confusion, here, we use the more comprehensive term "digital competence", which "can be broadly defined as the confident, critical, and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion, and/or participation in society".[19] Digital competence can be thought of as a multifaceted competence in the use of digital technology involving several aspects, such as an individual's ability to evaluate, integrate, and create digital content (including digital information), solve digital problems, as well as communicate and collaborate with others safely and appropriately.[20] It encompasses knowledge and skills that enable children and adolescents to use technology wisely and safely. In fact, digital competence is essential for participation in society and social life, as technology become integrated into our

daily lives. It is an important facilitator of success in school and in the workplace, as digital technologies permeate all sectors.[21,22] Thus, it is not surprising that several studies have been conducted in the field of education to assess the competent use of digital technologies, including high-profile national and international assessment studies, such as the Australian National Assessment Program for ICT literacy (NAP-ICT)[23] and the International Computer and Information Literacy Study (ICILS).[24] Although most assessments of digital competence have adopted a multidimensional framework, the empirical findings tend to agree that digital competence can be conceived as a unidimensional measure,[25,26] and studies that report different dimensions of digital competence find high correlations among these dimensions.[27,28]

However, many assessment frameworks of digital competence are limited in identifying and evaluating information (i.e., information literacy) and technical skills.[17] Moreover, research has shown that self-reported assessments of digital competence may not be accurate. For example, high school students in Israel and the U. S. were found to have overestimated their digital competence.[29,30] In addition, male students tended to self-report higher levels of digital competence than girls,[31,32] although performance assessments indicated that girls actually show slightly higher performance.[31,33]

Besides gender differences, other factors such as socioeconomic status (SES) and age can affect digital competence. A meta-analysis of empirical studies found a small overall correlation between digital competence and SES.[34] Although only a few studies have examined digital competence across different age cohorts, some empirical studies indicated that older students, on average, are more digitally competent than younger students, but with significant overlaps in performance.[35,36] A range of studies have been conducted to examine the associations between digital competence and the possible outcomes.

Nevertheless, there is little research on whether better digital competence can improve children's health and mental wellbeing by reducing the risk of internet/gaming disorders[37] and preventing poor online behaviour such as cyberbullying. Previous studies have shown that digital competence can have both positive and negative effects on internet-related disorders.[38,39] However, the majority of these studies were performed on secondary school students aged 12 or above. In contrast, research examining the effects of digital competence in younger school-aged children between 6 and 12 is lacking.

In addition, the majority of the digital competence assessment scales are based on self-report questionnaires, which are prone to reporting and recall bias. In order to address these research gaps, our team devised a digital competence assessment scale based on the direct performance of school-aged children and adolescents.[40] Using our newly validated digital competence assessment scale, this study aims to demonstrate how digital competence impacts the mental health of children and adolescents, and to explore whether good digital competence is associated with reducing the harmful effects of media use, while enhancing its positive effects on children's mental development.

Methods

Participants

A total of 18 primary schools and 14 secondary schools were randomly selected from four districts in Hong Kong (out of a total of 18 districts) with different socioeconomic backgrounds. Two classes of students in the selected grade levels were sampled in each participating school, although some schools included more than two classes of students in some grades. The total number of participating classes in the study was 95. Overall, 1956 students (690 in Primary 3 with an age range of 7-11 and 1266 in either Secondary 1 [7th grade equivalent] or Secondary 3 [9th grade equivalent] with an age range of 11-18) participated in this cross-sectional study. Informed consent was obtained from parents and students (assent for primary students) before the start of the study.

All students completed a self-report questionnaire on their psychological health, lifestyle habits, and social experiences. Students also filled in a performance assessment testing their digital competence. Secondary school students further participated in an assessment testing their collaborative problem solving ability. The survey and assessments were delivered to the participating classes through desktop computers, notebooks, or tablets, depending on the schools' preferences.

In total, the student response rate was 79%. Reasons for non-participation were parental refusal to consent, failure to return the consent form, or consenting students absent on the day of data collection. Students who did not complete the relevant instruments or whose responses indicated a lack of validity were also excluded from the analysis.

This study was approved by the Human Research Ethics Committee (HREC approval number: EA1604035) of the University of Hong Kong.

Assessment. The digital competence assessment consisted of a constrained item format with interactive items mimicking realistic everyday scenarios that students might encounter in their daily lives. Age-appropriate items measuring students' competence in computer use in five areas were developed and piloted prior to the data collection.[40] The five computer use areas were based on the Digital Competence Framework (DigComp 2.1) developed by the European Commission: 1) Information and data literacy, 2) Communication and collaboration, 3) Digital content creation, 4) Safety, and

5) Problem solving.[41] The developed items were also mapped onto the assessment framework for computer and information literacy in the ICILS,[42] although the broader DigComp was finally adopted as it allows the capture of digital competence more accurately. Notably, our developed assessment instrument overcomes the limitations of several previous studies that measured only one or a few aspects of digital competence. Details of the test development (including sample items) have been reported elsewhere[40,43] and are only briefly summarized here.

Three different test forms were designed: one for students in Primary 3 containing 45 items and two tests for students in Secondary 1 and Secondary 3 containing 50 items each. All students were required to complete the respective tests within a time limit of 50 minutes. The different test forms included some identical items to allow the placing of students on the same scale so that performances across all students could be compared. Of all test items, six were discarded due to poor discriminating power, and one item was discarded due to differential item functioning (DIF) by gender. The remaining items did not show any gender DIF. A total of 73 items were retained in the final item pool for estimating the students' digital competence (42, 47, and 43 items were retained for Primary 3, Secondary 1, and Secondary 3 test forms, respectively). The root mean square deviation (RMSD) statistic was between 0.007 and 0.077, indicating the high quality of the digital competence tests.[44] The expected a posteriori (EAP) reliability estimates were 0.84, 0.86, and 0.84 for the three cohorts, respectively, indicating good reliability of the digital competence measurements.[45] Competence scores were estimated for all students for further analysis, with a higher score in the digital competence assessment indicating the students were more knowledgeable and skilful at using technology.

Besides digital competence, the secondary school students also participated in a further assessment measuring their collaborative problem solving skills using an instrument developed by the Assessment Research Centre, University of Melbourne.[46] Students were asked to work in pairs on several online collaborative tasks,[47] which assessed their cognitive processing skills (e.g., task regulation and knowledge building) and their social processing skills (e.g., perspective taking and social regulation). Better performances in the two areas indicated a higher proficiency level in collaborative problem solving. As this collaborative problem solving assessment is considered to be valid in students aged 11 or above, only secondary school students were invited to complete this test.

Questionnaire Instruments. The self-report questionnaire covered multiple areas of the students' wellbeing, lifestyle, and social experiences. To measure students' mental health status, the short version of the 4-point General Health Questionnaire (GHQ-12) was adopted, which consists of 12 questions assessing the severity of mental health problems in the past 4 weeks.[48] To measure the level of students' gaming addiction, the Internet Gaming Disorder Scale (IGD) was adopted, which consists of nine items scored on a 5-point Likert scale based on the nine criteria of the Internet Gaming Disorder in DSM-5 (Diagnostic and Statistical Manual of Mental Disorders, 5th Edition).[49] Higher scores in the above two scales indicated worse conditions in terms of the students' mental health and addiction issues.

For the assessment of lifestyle habits, students were asked to estimate the time spent sleeping and using electronic devices for leisure, including smartphones and tablets. For experiences related to cyberbullying, an instrument consisting of 12 questions was used to measure students' experience of cyberbullying as the perpetrator (e.g., sent or forwarded a hurtful message electronically to someone) or as the victim (e.g., had an embarrassing photo or video posted or reposted online). This instrument has been previously validated in other cultural contexts.[50] Participants' overall responses are summarized in Table 1.

Statistical Analysis. Partial correlation was performed to examine the relationship between digital competence and gaming addiction, as well as other variables of interest including mental health status (GHQ score), time spent on electronic devices, cyberbullying, cybervictimization, cognitive CPS score, and social CPS score, controlling for gender and participants' SES. The SES index was estimated from parents' education level using a principal component analysis. The mean SES score of each school was calculated to estimate the SES of participants whose parents' education level was missing. Moderated multiple regression was performed to further explore the relationships between digital competence, gaming addiction, cyberbullying, and cybervictimization. Hierarchical multiple regression was conducted to examine the direct effects (DE), total effect (TE) and indirect effects (mediation) of children's electronic device usage time on gaming addiction and their mental health status. For the regression, the reported mental health status was reverse coded from the GHQ scale. All variables in the moderation and mediation analyses were transformed to z-scores to reduce the multicollinearity between these variables and the interaction variables. Gender and SES were controlled as additional covariates in all models. All statistics were performed by IBM SPSS (Version 27) with 5% alpha levels. Process Macro (v 3.53)[51] for SPSS was used to perform the moderation and mediation analyses.

Role of funding source. The funder (Research Grants Council, HKSAR government) had no role in the

	Primary (n=690) n (%) / Mean (SD)	Secondary (n=1266) n (%) / Mean (SD)	Overall (n=1956) n (%) / Mean (SD)
Basic Demographics			
Gender			
Male	348 (50.4)	596 (47.1)	944 (48.3)
Female	326 (47.2)	661 (52.2)	987 (50.5)
Not stated	16 (2.3)	9 (0.7)	25 (1.5)
Digital Competence			
Unidimensional Digital Competence	-0.759 (0.68)	0.437 (0.78)	0.016 (0.94)
Gaming addiction			
Internet Gaming Disorder Scale	18.683 (8.57)	17.775(8.06)	18.097 (8.25)
Time using electronic devices for leisure	(n=667)	(n=1213)	(n=1880)
Less than 1 hour per day	300 (45.0)	262 (21.6)	562 (29.9)
1-2 hours per day	233 (34.9)	379 (31.2)	612 (32.6)
2-3 hours per day	79 (11.8)	264 (21.8)	343 (18.2)
More than 3 hours per day	55 (8.2)	308 (25.4)	363 (19.3)
General Health Questionnaire (GHQ-12)	□	0.95 (0.48)	□
Collaborative Problem Solving (CPS)			
Cognitive	□	-0.25483 (1.04)	□
Social	□	0.65621 (0.84)	□
Cyberbullying experience	(n=643)	(n=1198)	(n=1841)
As perpetrator only	39 (6.1)	87 (7.3)	126 (6.8)
As victim only	43 (6.7)	160 (13.4)	203 (11.0)
As both perpetrator and victim	118 (18.4)	191 (15.9)	309 (16.8)
Not involved	443 (68.9)	760 (63.4)	1203 (65.3)
Parents' Education Level			
Father	(n=278)	(n=749)	(n=1027)
Below secondary	38 (13.7)	118 (15.8)	156 (15.2)
Secondary	76 (27.3)	378 (50.5)	454 (44.2)
Associate degree	30 (10.8)	38 (5.1)	68 (6.6)
Bachelor's degree	134 (48.2)	215 (28.7)	349 (34.0)
Mother	(n=267)	(n=791)	(n=1058)
Below secondary	65 (24.3)	160 (20.2)	225 (21.3)
Secondary	84 (31.5)	425 (53.7)	509 (48.1)
Associate degree	16 (6.0)	23 (2.9)	39 (3.7)
Bachelor's degree	102 (38.2)	183 (23.1)	285 (26.9)

***Table 1*: Subject characteristics**

design, data collection, data analysis, data interpretation or manuscript preparation.

Results

Table 1 summarizes the demographic characteristics of participants. The overall prevalence of gaming addiction was 7.3% (Primary: 8.0%; Secondary: 6.6%) according to the cut-off score (32) suggested by Qin et al. for the Chinese context.[52] Table 2 illustrates the prevalence of gaming addiction according to digital device usage time. Primary and secondary students who used digital devices for more than 3 hours per day had a significantly higher prevalence of gaming addiction (X^2 [3, 1865] = 19.91, p < 0.001).

The correlation analyses showed that digital competence was negatively associated with gaming addiction and cyberbullying experiences, whereas gaming addiction was positively associated with cyberbullying experiences and the GHQ score, suggesting worse mental health (Table 3). The results of the supplementary sensitivity analysis in secondary school children after controlling for age, cognitive and social CPS (Table S1 & S2) were generally consistent with the primary analysis, suggesting that adding age as a confounder had no major impact on the conclusion.

To explore the role of students' digital competence on gaming addiction and social experiences, we performed a multiple moderated regression analysis, which revealed that digital competence was negatively

Time Using Digital Devices for Leisure.	Prevalence of gaming addiction		
	Secondary school student	Primary School student	Total
Less than 1 hour per day	6.9%	5.7%	6.3%
1-2 hours per day	4%	8.4%	5.6%
2-3 hours per day	4.2%	9.0%	5.3%
More than 3 hours per day	11.7%**	16.4%**	12.4%**

***Table 2*: Prevalence of gaming addiction according to digital device usage time**
** P < .01. Chi-square test was used to Compare digital device usage time in the same age group.

associated with the level of gaming addiction after controlling for gender and SES (β = -0.144, p < 0.0001). There was a significant interaction effect of digital competence with children's education level on gaming addiction (F [1,1802] = 16.42, p < 0.0001). After including the interaction between digital competence and education level, the effect size (R^2) of the regression model changed from 6.7% to 7.5% (R^2 change = 0.8%). Specifically, the association between digital competence and gaming addiction was more pronounced in primary school students (β = -0.368, p < 0.0001) compared with secondary school students (β = -0.117, p = 0.0005) (Figure 1).

Hierarchical multiple regression revealed an association between digital device usage time and mental health status that was mediated by gaming addiction. Digital device usage time was found to be a significant negative predictor of mental health status after controlling for gender and SES (β = -0.24, p < 0.0001; model 1: R^2 = 4.0%). Such effects became non-significant when gaming addiction was included in the model (β = -0.03, p = 0.26; model 2: R^2 = 9.4%; R^2 change = 5.4%, F_{ch} [1,1201] = 71.71, p < 0.0001). The Bootstrap test found a significant indirect effect of digital device usage time on mental health status through gaming addiction (β = 0.05, SE_{boot} = 0.01, 95%CI_{boot} = [0.03, 0.07] after 5000 bootstrap samples).

Moreover, the relationship between digital device usage time and gaming addiction was found to be mediated by digital competence. Digital device usage time was significantly associated with gaming addiction after controlling for gender and SES (β = 0.16, p < 0.0001; model 1: R^2 = 7.3%). Such effects significantly increased when digital competence was included in the model (β = 0.21, p < 0.0001; model 2: R^2 = 10.9%; R^2 change = 3.6%, F_{ch} [1,1811] = 73.49, p < 0.0001). The Bootstrap test found a significant negative indirect effect of digital device usage time on gaming addiction through digital competence (β = - 0.05, SE_{boot} = 0.01, 95%CI_{boot} = [-0.06, -0.03] after 5000 bootstrap samples). Figure 2 shows the relationship between digital device usage time, gaming addiction, digital competence, and mental health status.

On the other hand, digital competence was negatively associated with cyberbullying (β = -0.169, p < 0.0001) and cybervictimization (β = -0.121, p < 0.0001), as shown in a regression model using cyberbullying and cybervictimization as the outcome variables, digital competence as the predictor, gender and SES as covariates, and gaming addiction as the moderator. There was a significant interaction between digital competence and gaming addiction on cyberbullying (F [1,1779] = 19.62, p < 0.0001) and cybervictimization (F [1,1776] = 5.319, p < 0.0001), respectively (Figures 3 & 4). For the

Variables	1	2	3	4	5	6	7
1. Digital Competence	—						
2. Gaming Addiction	-0.148**	—					
3. GHQ score	0.027	0.248**	—				
4. Cybervictimization	-0.119**	0.278**	0.245**	—			
5. Cyberbullying	-0.164**	0.319**	0.180**	0.631**	—		
6. Cognitive CPS	0.400**	-0.083*	-0.012	0.029	-0.012	—	
7. Social CPS	0.259**	-0.095**	-0.043	0.025	-0.006	0.609**	—
8. Time using electronic devices for leisure	0.236**	0.172**	0.088**	0.091**	0.063*	-0.021	-0.036

***Table 3*: Partial Correlation between variables after controlling for gender and socioeconomic status (SES) index**
* p < 0.01
** p < 0.001.Note. Missing values were excluded pairwise. Only secondary school students filled in the GHQ and participated in the CPS assessments (variables 3, 6, and 7).

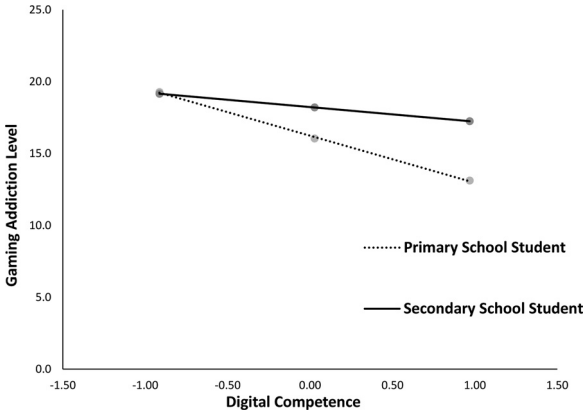

Figure 1. Game addiction as a function of digital competence in primary and secondary school children after controlling for gender and SES.

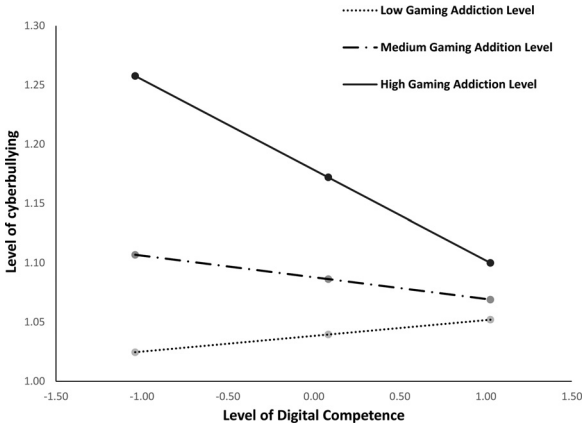

Figure 3. Cyberbullying as a function of digital competence at different levels of game addiction after controlling for gender and SES. Low, medium, and high levels of game addiction defined as 1 S.D. below, equal to, and 1 S.D. above the mean level of game addiction, respectively.

regression model with cyberbullying as the outcome variable, the effect size (R^2) of the regression model changed from 12.0% to 14.6%, with R^2 change = 2.6% after adding the interaction term 'digital competence * gaming addiction'. For the regression model with cybervictimization as the outcome variable, the effect size (R^2) of the regression model changed from 8.0% to 9.4%, with R^2 change = 1.4% after adding the interaction term 'digital competence * gaming addiction'. Nevertheless, the relationship between digital competence and cyberbullying was significant only when gaming addiction was high (β = -0.286, p < 0.0001), but non-significant with medium (β = -0.067, p = 0.0003) and low (β = 0.050, p = 0.121) gaming addiction levels. A similar pattern was also observed for the relationship between digital competence and cybervictimization with high (β = -0.205, p < 0.0001), medium (β = -0.043, p = 0.072), and low (β = -0.04, p = 0.791) gaming addiction.

Discussion

This study is one of the first to demonstrate that higher digital competence is associated with a lower risk of gaming addiction, which could potentially lead to enhanced mental wellbeing in children and adolescents through reducing gaming addiction. Our findings highlight the importance of empowering children and adolescents through digital competence to encourage appropriate media use and reduce the risk of addictive and risky online behaviours.

Prolonged use of digital devices by children or adolescents is a frequent concern of parents. Wong et al.

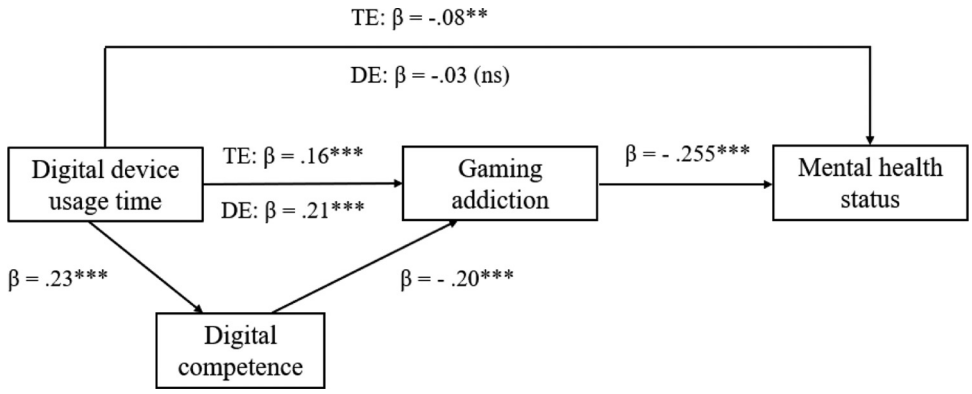

Figure 2. Relationship between digital device usage time, gaming addiction, digital competence, and mental health status after controlling for gender and SES. Mental health status was measured by the GHQ scale (reverse coded). Standardized regression coefficient (beta) was used as the path coefficient. TE: total effect. DE: direct effect. ** p < 0.01, ***p < 0.001, ns: not significant.

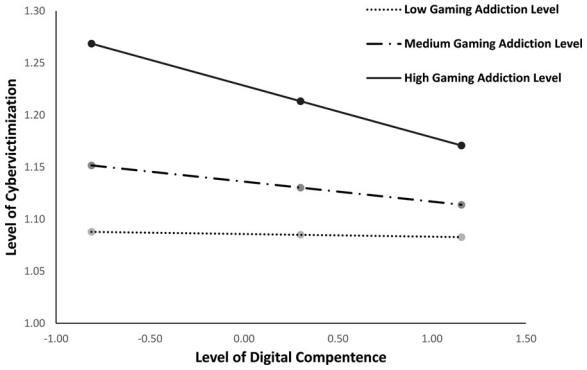

Figure 4. Cybervictimization as a function of digital competence at different levels of game addiction after controlling for gender and SES. Low, medium, and high levels of game addiction defined as 1 S.D. below, equal to, and 1 S.D. above the mean level of game addiction, respectively.

demonstrated that children and adolescents with longer screen time appeared to have a poorer health-related quality of life.[53] Prolonged use of digital devices has also been associated with other adverse health outcomes such as obesity,[54] myopia,[55, 56] inattention,[57] and mental distress.[58] Our study showed that using digital devices for more than 3 hours per day significantly increased the likelihood of gaming addiction. Our finding is consistent with a previous study that showed adolescents who spent more than 3 hours a day on social media had an increased risk of depression[59]. A study in the United States reported that children aged 8-12 averaged 4-6 hours of screen time a day with adolescents spending up to 9 hours.[60] Based on the findings in our study and from other research, limiting media use to 3 hours or less per day is recommended to reduce the adverse effects on mental health and wellbeing. More importantly, our study is one of the first to demonstrate that digital competence might mitigate the harmful effects of excessive digital device usage, especially in young school-aged children. We found that mental health problems caused by prolonged usage of digital devices were mediated by gaming addiction. Our study findings suggest that digital device usage may not be detrimental to mental health if children are equipped with good digital competence, which can empower them to use digital devices safely and appropriately for learning or recreational purposes. We found the association between digital competence and gaming addiction was more pronounced in school-aged children (<12 years old) compared to adolescents (>12 years old). Hence, our study findings highlight the benefit of educating young children on digital competence to reduce the risk of gaming addiction.

Gaming addiction is a global problem that universally affects children and adolescents. A recent study reported the prevalence of gaming addiction was 10.3% in students of different ages,[61] which is broadly in agreement with the prevalence of 7.3% in our cohort. Gaming disorder has now been included in the 11th revision of the International Classification of Disease (ICD-11), and is defined as a gaming behaviour of sufficient severity to result in significant functional impairment. Our study found that gaming addiction was associated with poorer GHQ scores in adolescents, indicating poorer mental health. The existing literature also suggests that young people with gaming addiction are prone to affective symptoms such as anxiety, depression, and negative coping styles.[62] Moreover, functional neuroimaging studies suggest that gaming addiction might lead to over-connectivity of the default mode and executive control networks that may lead to psychiatric comorbidity.[63] Besides affective disorders, gaming addiction was also found to be associated with attention-deficit hyperactivity disorders (ADHD).[64] Excessive internet gaming exposure was found to be associated with reduced striatal dopamine D2 receptors, leading to the dysfunction of the dopaminergic system,[65] which is also believed to underlie the pathogenesis of ADHD.

Unfortunately, gaming addiction/gaming disorder is difficult to treat, as medications might be ineffective in managing the addictions. Patients often refuse to take their medication[62] or have poor compliance with behavioural interventions. With the increasing use of digital technologies for gaming, it is essential to teach children and adolescents digital competence to reduce the risk of gaming addiction.

Cyberbullying, which poses a significant threat to children's mental health and development, can be a result of prolonged internet usage[66] and gaming addiction.[67] Our study findings indicated that digital competence could protect children from cyberbullying behaviours, especially those who are highly addicted to internet gaming. An ecological study involving 24 European countries showed that higher rates of cyberbullying were more likely to lead to a higher incidence of unnatural child deaths.[68] Therefore, teaching digital competence to children and adolescents is critically important and could potentially minimize the long-term adverse physical and mental health outcomes related to prolonged media use.

The majority of the literature on the use of digital devices focuses on the detrimental effects of media use in children and adolescents. However, the appropriate use technology can provide opportunities to learn and to communicate with other children.[69] In addition, our study showed that adolescents with better digital competence had better collaborative problem solving (CPS) skills. Such skills are critical in academic learning and also necessary for daily life. The Programme for International Student Assessment (PISA), which is part of the programme of the Organisation for Economic Co-operation and Development (OECD), defines CPS competency as the capacity of an individual to effectively

engage in a process whereby two or more students attempt to solve a problem by sharing the understanding and effort required to come to a solution.[70] Good CPS skills can, therefore, lead to better problem solving skills, communication skills, leadership skills, as well as enhancing teamwork. Findings from our study showed that good digital competence not only potentially reduced the detrimental effects of media use, but was also associated with better CPS skills, which are important life skills for adolescents.

There is some emerging evidence on the effectiveness of various intervention programs designed to prevent inappropriate media use and gaming addiction. The Wise IT-Use (WIT) programme aims to enhance students' awareness of internet gaming disorder and risky online behaviours. However, the outcome measures mainly focused on gaming addiction risk[71] rather than promoting digital wellness. Bickham et al.[72] evaluated a more comprehensive program called *Screenshots*, which is an in-school curriculum that aims to achieve digital wellness and improve young people's mental health by encouraging positive digital social skills. Despite a relatively small sample size, Bickham et al. demonstrated that the *Screenshots* program led to improvements in the participants' knowledge about key concepts of digital citizenship, while reducing negative online behaviour. Our study found an association between prolonged digital device usage and an elevated risk of gaming addiction in children and adolescents, which could be counteracted by digital competence. Future intervention programs should aim to improve the digital competence of young children as well as emphasize the importance of time limits for digital devices.[73] In addition, digital competence could be an important outcome measure in larger randomized controlled trials for intervention programs that promote digital wellness.

Our study can also inform education ministries on education policy to provide clear guidance for schools on internet/gaming addiction and cyberbullying, as such issues are not only a health risk, but also negatively associated with digital competence. Teacher training programs should raise awareness of the risks associated with increased screen time, and help teachers to identify students with or at risk of developing internet/gaming addiction and to recognize cyberbullying. Schools should also develop explicit guidelines on using digital devices during schooltime and implement strategies to address cyberbullying. In addition, digital competence should be made part of the core curriculum and integrated at all levels of schooling.[43] As the use of digital devices for gaming likely occurs at home and cyberbullying may not be easily detected by teachers at school, education policies should also raise parents' awareness of the detrimental social and health effects of prolonged exposure to digital devices. Strategies linking formal and informal education contexts to support digital competence development should be put into place,[74] and parents, especially those with limited digital competence, should be offered assistance (e.g., workshops offered at universities or events to raise awareness organized by schools).

Our study should be interpreted with the following caveats. This cross-sectional study only reported the associations between digital competence and health outcomes, but did not assess the causal relationships. Longitudinal data are required to further examine these associations over time. Furthermore, there might be recall bias for some variables such as time spent on electronic devices, which were self-reported by the children and adolescents. Finally, we used a new measure of digital competence. Although reliable and without gender DIF, two limitations of the measure are noted and deserve further validation. First, students had the choice of completing the assessment in either Chinese or English. As most students chose the Chinese version, there was an insufficient sample of students completing the English version of the test to examine language DIF. Second, although a comprehensive assessment framework was adopted measuring all five digital competences based on the DigComp,[40] six of 21 *sub*-competences were not covered in our test (e.g., collaboration). Our team is currently amending and further validating an updated digital assessment instrument.

In conclusion, our study provides empirical evidence that better digital competence is associated with less gaming addiction in children and adolescents. In today's modern world, with the increasing use of digital devices permeating every aspect of our lives, promoting digital wellness is essential. Parents, educators, and healthcare professionals should equip future generations with better digital competence to maximize the benefits of media use, while reducing the potential adverse effects from the inappropriate use of digital devices.

Declaration of interests

The authors declare no conflict of interest.

Contributors

Study conceptualization & design: WWYT, FR, NL, KWF, JT, NR, WHSW, PI

Acquisition or interpretation of data: All authors

Statistical analysis: WHSW, LKL, YW

Drafting of the manuscript: WWYT, FR, LKL, YW

Critical revision of the manuscript: All authors

Funding acquisition: NL, NR, JT, KWF, PI

Project supervision: NL, NR, JT, KWF & PI

WWYT, FR, NL, NR, JT, KWF & PI had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Final approval of the version to be published: All authors.

Acknowledgements

This research was supported by the Research Grants Council of the HKSAR Government (#T44-707/16N) under the Theme-based Research Scheme. The funding source does not contribute to the writing of the manuscript or decision to submit it for publication. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lanwpc.2022.100382.

References

1 Reid Chassiakos Y, Radesky J, Christakis D, et al. Aap council on communications and media. Children and Adolescents and Digital Media. *Pediatrics*. 2016;138:(5) e20162593. https://doi.org/10.1542/peds.2016-2593.

2 Throuvala MA, Griffiths MD, Rennoldson M, Kuss DJ. Policy recommendations for preventing problematic internet use in schools: a qualitative study of parental perspectives. *Int J Environ Res Public Health*. 2021;18(9):4522.

3 Cheng C, Li AY. Internet addiction prevalence and quality of (real) life: a meta-analysis of 31 nations across seven world regions. *Cyberpsychol Behav Soc Netw*. 2014;17(12):755–760.

4 Mak KK, Lai CM, Watanabe H, et al. Epidemiology of internet behaviors and addiction among adolescents in six Asian countries. *Cyberpsychol Behav Soc Netw*. 2014;17(11):720–728.

5 Muller KW, Janikian M, Dreier M, et al. Regular gaming behavior and internet gaming disorder in European adolescents: results from a cross-national representative survey of prevalence, predictors, and psychopathological correlates. *Eur Child Adolesc Psychiatry*. 2015;24(5):565–574.

6 Caner N, Evgin D. Digital risks and adolescents: The relationships between digital game addiction, emotional eating, and aggression. *Int J Ment Health Nurs*. 2021. https://doi.org/10.1111/inm.12912.

7 Otsuka Y, Kaneita Y, Itani O, et al. The association between internet usage and sleep problems among Japanese adolescents: three repeated cross-sectional studies. *Sleep*. 2021:zsab175.

8 Gundogdu U, Eroglu M. The relationship between dissociation symptoms, sleep disturbances, problematic internet use and online gaming in adolescents. *Psychol Health Med*. 2021:1984542.

9 Schou Andreassen C, Billieux J, Griffiths MD, et al. The relationship between addictive use of social media and video games and symptoms of psychiatric disorders: A large-scale cross-sectional study. *Psychol Addict Behav*. 2016;30(2):252–262.

10 Huang J, Zhong Z, Zhang H, Li L. Cyberbullying in social media and online games among Chinese college students and its associated factors. *Int J Environ Res Public Health*. 2021;18(9).

11 Dorol-Beauroy-Eustache O, Mishara BL. Systematic review of risk and protective factors for suicidal and self-harm behaviors among children and adolescents involved with cyberbullying. *Prev Med*. 2021;152(Pt 1):106684.

12 Li H, Wang S. The role of cognitive distortion in online game addiction among Chinese adolescents. *Child Youth Serv Rev*. 2013;35(9):1468–1475.

13 Szász-Janocha C, Vonderlin E, Lindenberg K. Treatment outcomes of a CBT-based group intervention for adolescents with Internet use disorders. *J Behav Addict*. 2021;9(4):978–989.

14 AAP COUNCIL ON COMMUNICATIONS AND MEDIA. Media Use in School-Aged Children and Adolescents. *Pediatrics*. 2016;138:(5) e20162592. https://doi.org/10.1542/peds.2016-2592.

15 Moreno MA, Egan KG, Bare K, Young HN, Cox ED. Internet safety education for youth: stakeholder perspectives. *BMC Public Health*. 2013;13(1):543.

16 Bawden D. Origins and concepts of digital literacy. In: Lankshear C, Knobel M, eds. *Digital literacies: Concepts, policies and practices*. New York: Peter Lang; 2008:17–32.

17 Siddiq F, Hatlevik OE, Olsen RV, Throndsen I, Scherer R. Taking a future perspective by learning from the past—A systematic review of assessment instruments that aim to measure primary and secondary school students' ICT literacy. *Educ Res Rev*. 2016;19:58–84.

18 Reichert F, Zhang DJ, Law NW, Wong GK, de la Torre J. Exploring the structure of digital literacy competence assessed using authentic software applications. *Educ Technol Res Dev*. 2020;68(6):2991–3013.

19 Ferrari A, Brecko BN, Punie Y. *DIGCOMP: a framework for developing and understanding digital competence in Europe*. Luxembourg: Publications Office of the European Union; 2013.

20 Law N, Woo D, de la Torre J, Wong G. *A global framework of reference on digital literacy skills for indicator 4.4.2*. Montreal: UNESCO Institute for Statistics; 2018.

21 van Laar E, van Deursen AJ, van Dijk JA, de Haan J. The relation between 21st-century skills and digital skills: A systematic literature review. *Comput Human Behav*. 2017;72:577–588.

22 Rohatgi A, Scherer R, Hatlevik OE. The role of ICT self-efficacy for students' ICT use and their achievement in a computer and information literacy test. *Comput Educ*. 2016;102:103–116.

23 Harrington M. *Australian Curriculum, Assessment and Reporting Authority Bill 2008*. Parliamentary Library; 2008.

24 Fraillon J, Ainley J, Schulz W, Friedman T, Duckworth D. *Preparing for life in a digital world: IEA International computer and information literacy study 2018 international report*. Springer Open; 2020.

25 Aesaert K, Van Nijlen D, Vanderlinde R, van Braak J. Direct measures of digital information processing and communication skills in primary education: Using item response theory for the development and validation of an ICT competence scale. *Comput Educ*. 2014;76:168–181.

26 Gebhardt E, Schulz W. Scaling procedures for ICLS test items. (Eds.). In: Fraillon J, Schulz W, Friedman T, Ainley J, Gebhardt E, eds. *ICILS 2013 technical report*. Amsterdam: IEA Secretariat; 2015:155–175.

27 Ihme JM, Senkbeil M, Goldhammer F, Gerick J. Assessment of computer and information literacy in ICILS 2013: Do different item types measure the same construct? *Eur Educ Res J*. 2017;16(6):716–732.

28 Wilson M, Gochyyev P, Scalise K. Modeling data from collaborative assessments: learning in digital interactive social networks. *J Educ Meas*. 2017;54(1):85–102.

29 Porat E, Blau I, Barak A. Measuring digital literacies: Junior high-school students' perceived competencies versus actual performance. *Comput Educ*. 2018;126:23–36.

30 Spisak JR. *Secondary student information literacy self-efficacy vs. performance*. Virginia Commonwealth University; 2018.

31 Gebhardt E, Thomson S, Ainley J, Hillman K. *Gender differences in computer and information literacy: An in-depth analysis of data from ICILS*. Springer Open; 2019.

32 Lau WW, Yuen AH. Factorial invariance across gender of a perceived ICT literacy scale. *Learn Individ Differ*. 2015;41:79–85.

33 Siddiq F, Scherer R. Is there a gender gap? A meta-analysis of the gender differences in students' ICT literacy. *Educ Res Rev*. 2019;27:205–217.

34 Scherer R, Siddiq F. The relation between students' socioeconomic status and ICT literacy: Findings from a meta-analysis. *Comput Educ*. 2019;138:13–32.

35 Lazonder AW, Walraven A, Gijlers H, Janssen N. Longitudinal assessment of digital literacy in children: Findings from a large Dutch single-school study. *Comput Educ*. 2020;143: 103681.

36 Song L, Zhu L, Liu Y, Zhou X, Shi H. A disposable cobalt-based phosphate sensor based on screen printing technology. *Sci China Chem*. 2014;57(9):1283–1290.

37 Stodt B, Brand M, Sindermann C, et al. Investigating the effect of personality, Iinternet literacy, and use expectancies in Internet-Use disorder: A comparative study between China and Germany. *Int J Environ Res Public Health*. 2018;15(4).

38 Leung L, Lee PS. The influences of information literacy, internet addiction and parenting styles on internet risks. *New Media Soc*. 2012;14(1):117–136.

39 Stodt B, Wegmann E, Brand M. Predicting dysfunctional Internet use: The role of age, conscientiousness, and Internet literacy in

Internet addiction and cyberbullying. *Int J Cyber Behav Psychol*. 2016;6(4):28–43.
40 Jin K-Y, Reichert F, Cagasan LP, de la Torre J, Law N. Measuring digital literacy across three age cohorts: Exploring test dimensionality and performance differences. *Comput Educ*. 2020;157:103968.
41 Carretero S, Vuorikari R, Punie Y. *Digcomp 2.1: The digital competence framework for citizens*. Luxembourg: Publications Office of the European Union; 2017.
42 Fraillon J, Ainley J, Schulz W, Duckworth D, Friedman T. *IEA international computer and information literacy study 2018 assessment framework*. Springer Open; 2019.
43 Reichert F, Lam P, Loh E, Law N. *Hong Kong students' digital citizenship development. Initial findings*. Hong Kong: The University of Hong Kong; 2020.
44 Yamamoto K, Khorramdel L, Von Davier M. Scaling PIAAC cognitive data. *In: Technical Report of the Survey of Adult Skills (PIAAC)*. 2nd ed. Paris: OCED; 2003:408–440.
45 Adams RJ. Reliability as a measurement design effect. *Stud Educ Eval*. 2005;31(2–3):162–172.
46 Hesse F, Care E, Buder J, Sassenberg K, Griffin P. A framework for teachable collaborative problem solving skills. In: Griffin P, Care E, eds. *Assessment and teaching of 21st century skills*. Springer; 2015:37–56.
47 Care E, Griffin P, Scoular C, Awwal N, Zoanetti N. Collaborative problem solving tasks. In: Griffin P, Care E, eds. *Assessment and teaching of 21st century skills. Springer*. 201585–104.
48 Goldberg DP, Williams P. *A User's guide to the General Health Questionnaire*. Windsor: NFER-Nelson; 1988.
49 Lemmens JS, Valkenburg PM, Gentile DA. The Internet gaming disorder scale. *Psychol Assessment*. 2015;27(2):567.
50 Shapka JD, Onditi HZ, Collie RJ, Lapidot-Lefler N. Cyberbullying and cybervictimization within a cross-cultural context: A study of Canadian and Tanzanian adolescents. *Child Dev*. 2018;89(1):89–99.
51 Hayes AF. Introduction to mediation, moderation, and conditional process analysis: a regression-based approach. The Guilford Press; 2017.
52 Qin L, Cheng L, Hu M, et al. Clarification of the cut-off score for nine-item internet gaming disorder scale—short form (IGDS9-SF) in a Chinese context. *Front Psychiatry*. 2020;11(470).
53 Wong CKH, Wong RS, Cheung JPY, et al. Impact of sleep duration, physical activity, and screen time on health-related quality of life in children and adolescents. *Health Qual Life Outcomes*. 2021;19(1):145.
54 Bornhorst C, Wijnhoven TM, Kunesova M, et al. WHO European Childhood Obesity Surveillance Initiative: associations between sleep duration, screen time and food consumption frequencies. *BMC Public Health*. 2015;15:442.
55 Wong CW, Tsai A, Jonas JB, et al. Digital Screen Time During the COVID-19 Pandemic: Risk for a Further Myopia Boom? *Am J Ophthalmol*. 2021;223:333–337.
56 Hansen MH, Laigaard PP, Olsen EM, et al. Low physical activity and higher use of screen devices are associated with myopia at the age of 16-17 years in the CCC2000 Eye Study. *Acta Ophthalmol*. 2020;98(3):315–321.
57 Tamana SK, Ezeugwu V, Chikuma J, et al. Screen-time is associated with inattention problems in preschoolers: Results from the CHILD birth cohort study. *PLoS One*. 2019;14(4):e0213995.
58 Opdal IM, Morseth B, Handegard BH, et al. Is change in mental distress among adolescents predicted by sedentary behaviour or screen time? Results from the longitudinal population study The Tromso Study: Fit Futures. *BMJ Open*. 2020;10(2):e035549.
59 Viner RM, Gireesh A, Stiglic N, et al. Roles of cyberbullying, sleep, and physical activity in mediating the effects of social media use on mental health and wellbeing among young people in England: a secondary analysis of longitudinal data. *Lancet Child Adolesc Health*. 2019;3(10):685–696.
60 Amercian Academy of Child & Adolescent Psychiatry. *Screen Time and Children*. 2021. https://www.aacap.org/AACAP/Families_and_Youth/Facts_for_Families/FFF-Guide/Children-And-Watching-TV-054.aspx.
61 Xiang H, Tian X, Zhou Y, Chen J, Potenza MN, Zhang Q. The relationship between behavioral inhibition and behavioral activation systems, impulsiveness, and internet gaming disorder among students of different ages. *Front Psychiatry*. 2020;11:560142.
62 Gao XJ, Sun JJ, Xiang M. Positive psychological intervention for anxiety, depression and coping in subjects addicted to online games. *World J Clin Cases*. 2021;9(14):3287–3293.
63 Han DH, Kim SM, Bae S, Renshaw PF, Anderson JS. Brain connectivity and psychiatric comorbidity in adolescents with Internet gaming disorder. *Addict Biol*. 2017;22(3):802–812.
64 Weinstein A, Weizman A. Emerging association between addictive gaming and attention-deficit/hyperactivity disorder. *Curr Psychiatry Rep*. 2012;14(5):590–597.
65 Kim SH, Baik S-H, Park CS, Kim SJ, Choi SW, Kim SE. Reduced striatal dopamine D2 receptors in people with Internet addiction. *Neuroreport*. 2011;22(8):407–411.
66 Navarro R, Serna C, Martínez V, Ruiz-Oliva R. The role of internet use and parental mediation on cyberbullying victimization among Spanish children from rural public schools. *Eur J Psychol Educ*. 2013;28(3):725–745.
67 Sureda Garcia I, López Penádes R, Rodríguez Rodríguez R, Sureda Negre J. Cyberbullying and internet addiction in gifted and non-gifted teenagers. *Gift Child Q*. 2020;64(3):192–203.
68 Fu KW, Chan CH, Ip P. Exploring the relationship between cyberbullying and unnatural child death: An ecological study of twenty-four European countries. *BMC Pediatr*. 2014;14:195.
69 Boston Children's Hospital. *Family Digital Wellness Guide*. Boston Children Hospital; 2021. https://digitalwellnesslab.org/parents/family-digital-wellness-guide/.
70 OECD. PISA 2015 collaborative problem-solving framework. *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving*. Paris: OECD Publishing; 2017.
71 Chau CL, Tsui YY, Cheng C. Gamification for internet gaming disorder prevention: Evaluation of a Wise IT-Use (WIT) program for Hong Kong primary students. *Front Psychol*. 2019;10:2468.
72 Bickham DS, Moukalled S, Inyart HK, Zlokower R. Evaluating a middle-school digital citizenship curriculum (Screenshots): Quasi-Experimental study. *JMIR Ment Health*. 2021;8(9):e26197.
73 The Lancet Child Adolescent Health. A balanced online life. *Lancet Child Adolesc Health*. 2019;3(12):835. https://doi.org/10.1016/S2352-4642(19)30354-2.
74 Voogt J, Roblin NP. A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *J Curric Stud*. 2012;44(3):299–321.