Education and Information Technologies (2024) 29:655–693
https://doi.org/10.1007/s10639-023-12272-9

Digital gender gaps in Students' knowledge, attitudes and skills: an integrative data analysis across 32 Countries

Diego G. Campos[1,2] · Ronny Scherer[1,2]

Received: 28 July 2023 / Accepted: 9 October 2023 / Published online: 13 November 2023

Abstract
The digital gender divide is one of the most critical issues in education today. Digital gender gaps can exist in students' access to and use of ICT, attitudes toward technology, and digital knowledge and skills. However, previous research has primarily examined these divides in isolation and largely ignored their interdependencies. Using student data from the 2013 and 2018 International Computer and Information Literacy Study (ICILS), this study examines how these gaps are related. Specifically, we synthesize evidence on gender gaps in digital knowledge and skills, controlling for differences in ICT access and technology attitudes. In addition, we examine the role that technology attitudes play in the gender gap in digital knowledge and skills. Our findings suggest that (a) girls outperform boys in digital knowledge and skills (β = -0.11 to -0.29); (b) gender differences in attitudes toward technology partially explain gender differences in digital knowledge and skills; (c) the variability within and between countries in the gender gap in students' digital skills is partly explained by the type of digital skill and the country's socio-economic development and gender inequality. Overall, this research shows a relationship between the gender gaps in students' digital knowledge and skills and the gender gaps in students' attitudes toward technology. We conclude that the first- and second-level gender digital divides are connected.

Keywords Gender differences · Digital divides · Digital literacy · Attitudes toward technology · Integrative Data Analysis

Students' access, attitudes, knowledge, and skills are critical for 21st-century education. Critical reviews and meta-analyses on the use of ICT in education suggest

✉ Diego G. Campos
d.g.campos@cemo.uio.no

1 Centre for Educational Measurement at the University of Oslo (CEMO), Faculty of Educational Sciences, University of Oslo, Forskningsparken, Postbox 1161, 0318 Oslo, Norway

2 Centre for Research on Equality in Education (CREATE), Faculty of Educational Sciences, University of Oslo, Oslo, Norway

that ICT facilitates students' access to digital information, supports self-directed and student-centered learning, promotes collaborative learning, and has positive effects on student outcomes (Fu, 2013; Jeong & Hmelo-Silver, 2016; Kim et al., 2018; Vogel et al., 2017; Wang, 2020). To a large extent, employment, social, economic, and political participation in contemporary societies also depend on using information and communication technologies (OECD, 2018; Siddiq et al., 2016). Thus, disparities in opportunities to access ICT resources and develop digital skills can negatively impact students' learning and amplify social inequalities.

Prior studies have identified disparities in digital access and usage among students of different genders, known as digital gender divides (Cai et al., 2017; Cooper, 2006; OECD, 2018; Scheerder et al., 2017; Siddiq & Scherer, 2019; van Deursen & van Dijk, 2014). These divides have three core dimensions: differences in (a) the access to ICT resources; (b) the attitudes toward technology and digital knowledge and skills; and (c) the usage of ICT and tangible outcomes (Van Dijk, 2020). Despite research that analyzes these gaps separately (Cai et al., 2017; Scheerder et al., 2017; Siddiq & Scherer, 2019), the relations between the various digital divides are still unclear. Van Dijk (2020) argues that knowledge about these relations is crucial to understanding the mechanisms or possible causes of digital gender divides. However, empirical evidence that connects the different gender divides is scarce for student populations (Tyers-Chowdhury & Binder, 2021), especially for drawing inferences across countries, over time, and for performance-based rather than self-reported measures of digital skills.

The present study aims to close these research gaps by investigating the relations between digital gender divides in students' ICT access, attitudes toward technology, and digital knowledge and skills and by examining the development of these relations across countries and over time. Using large-scale international assessment data from the *International Computer and Information Literacy Study* (ICILS) 2013 and 2018, we synthesize information about gender differences in digital knowledge and skills after controlling for ICT access and attitudes toward technology and investigate the mediating role of students' attitudes toward technology. Overall, we aim to contribute to the digital divide research by (a) providing large-scale evidence on the extent, direction, and connection of digital gender divides; and (b) identifying areas for action in the formulation of educational policies that help to bridge the digital gender divides.

1 Digital knowledge and skills

Various terms and concepts are used to describe students' knowledge and skills in using ICT (Ferrari, 2012; Hatlevik & Christophersen, 2013; Siddiq et al., 2016). The most commonly used concepts in national and international frameworks and educational research describe this knowledge and these skills as digital competence (Ferrari & Punnie, 2013), Internet skills (van Deursen & van Diepen, 2013), computer and information literacy (Fraillon et al., 2013a), or ICT competence (Aesaert & van Braak, 2015). Although these terms refer to different sets of ICT-related skills, in most cases, they are used interchangeably (Aesaert & van Braak, 2018) and emphasize learners' ability to safely and responsibly gather, understand, produce, and communicate digital information (Gallardo-Echenique et al., 2015; Siddiq et al., 2016; Zhao et al., 2021).

Reflective, evaluative, and critical approaches to computers, the Internet, and digital information are central to current conceptualizations of digital knowledge and skills (Hatlevik et al., 2018). As such, descriptions of digital literacy include fundamental abilities for participation in life, work, and education, such as problem-solving, information processing, creativity, innovation, critical thinking, digital citizenship, communication, collaboration, and technology operations and concepts (Aesaert et al., 2014; Ferrari & Punnie, 2013; Voogt & Roblin, 2012). Thus, the definition and construct of digital literacy are derived from the literature on the broader set of 21st-century skills, focusing on one of its dimensions (van Laar et al., 2017). In this sense, digital literacy is a collection of multiple forms of literacy rather than a single, independent literacy.

According to Fraillon et al., (2019a, 2019b), computer and information literacy enables digital literacy and represents aspects of broader 21st-century skills. This study focuses on the functional aspects of digital literacy that support the use of digital devices and the problem-solving and algorithmic thinking aspects of computer literacy (see Fraillon et al., 2013a, 2013b, 2019a, 2019b). Moreover, we differentiate digital knowledge and skills from attitudes toward technology, as they refer to different yet related concepts. Digital knowledge and skills refer to what learners can do with ICT (Hatlevik & Christophersen, 2013), while attitudes toward technology refer to learners' global evaluation—cognitive, emotional, social, and behavioral—of ICT technologies (Cai et al., 2017).

2 Digital gender divides

Gender differences in ICT access, attitudes toward technology, knowledge and skills, and use and participation are often called "digital gender divides" (Van Dijk, 2020). In general, digital divides can be categorized into three different levels. The first level refers to disparities in access to ICT resources and attitudes toward technology. The second level describes gender gaps in ICT usage, knowledge, and skills. Finally, the third level refers to gaps in outcomes of ICT use, such as learning or educational achievement. These divides are linked to cultural, social, and economic inequalities in education (Goudeau et al., 2021), and they may reinforce and amplify other societal inequalities (van Deursen et al., 2021).

The extant body of research has documented mainly first- and second-level gender digital divides. For instance, in the PISA study, the OECD mapped the unequal distribution of the material resources that enable students' physical access to ICT (OECD, 2015). Regarding the attitudes dimension, several research syntheses and meta-analyses found a gender gap in students' attitudes toward technology (Cai et al., 2017; Vekiri & Chronaki, 2008). Finally, gender differences in digital knowledge and skills have also been documented (Gebhardt et al., 2019a; Siddiq & Scherer, 2019). While many empirical studies exist, the directions of the gender divide vary considerably. For example, research on the gender differences in attitudes toward technology reported effect sizes in favor of boys in self-efficacy ($g = +0.18$) and positive attitudes ($g = +0.27$) (Cai et al., 2017), while research on digital knowledge and skills reported effect sizes in favor of girls ($g = +0.12$) (Siddiq & Scherer, 2019). As Scherer and Siddiq (2019) noted, examining different digital divides in isolation—that is, focusing on one level without considering the other—may be an explanation for this variation. Van Dijk (2020) also encouraged researchers to study digital divides jointly rather than separately. However, in their recent review of digital divides, Lythreatis et al. (2022) found that researchers have focused on specific aspects rather than examining how these dimensions interact to affect students' digital knowledge and skills. To our knowledge, there is indeed limited information on the links between the different levels of the digital gender divide and their interactions. This information is needed to understand possible mechanisms driving the digital gender divide.

2.1 Gender and ICT access

The first-level digital gender divide highlights different opportunities for boys and girls to access ICT and technology resources. A systematic review showed that boys are more likely than girls to have access to a computer at home from their primary school years onwards (Samuelsson & Olsson, 2014). This pattern persisted in secondary schools across educational systems (OECD, 2015). More recent evidence, however, suggested that the first-level digital gender divide has begun to close (OECD, 2018). Despite this closing divide, tracking remaining differences is essential for organizing the necessary school resources, for supporting children with school-related activities and tasks at home, and for facilitating schools' role in compensating for potential lack of access to ICT resources at home (e.g., González-Betancor et al., 2021). Such out-of-school computer activities and experiences can foster students' computer use (Becker, 2007), attitudes toward technology (Meelissen & Drent, 2008), and digital skills (Claro et al., 2012).

The first-level gender digital divide also presents notable regional differences. For instance, in 2017, the average percentage of households with computer access at home was 51% in the Latin American and Caribbean regions and 81% in the European region (OECD, 2022). It is also estimated that 60% of young people in Africa are not connected to the Internet, compared to 4% in Europe (UNICEF, 2017). According to Pick and Nishida (2015), the mechanisms affecting technology availability differ between developed and developing regions. Thus, it is crucial to uncover how the first-level gender digital divide varies across regions.

2.2 Gender and attitudes toward technology

A second aspect of the first-level gender digital divide is attitudes toward technology. Attitudes have been conceptualized in many ways. For example, Ajzen and Fishbein (1977) considered them as an "evaluation of [an] […] entity in question" which represents "some aspect[s] of the individual's world, such as another person, a physical object, a behavior, or a policy" (p. 889). In the context of ICT, Zhang et al. (2008) identified two fundamental entities: behaviors and objects. While *behavior*-oriented attitudes toward technology are based on a person's evaluation of the performance of a specific action (e.g., using ICT for schoolwork or leisure), *object*-oriented attitudes toward technology are based on a person's favorable or unfavorable evaluation of ICT objects (e.g., specific software or applications; see also Scherer et al. (2018) and Tate et al. (2015). These attitudes are multidimensional and include affect, belief, and self-efficacy (Cai et al., 2017; Kemp et al., 2019; Whitley, 1997). Research syntheses on the relation between gender and attitudes toward technology suggested that boys hold more positive attitudes toward technology than girls. However, the sizes of this gap vary across the attitudinal dimensions and geographical regions (Cai et al., 2017; Whitley, 1997). For example, girls in South American regions tend to exhibit higher self-efficacy and the same positive beliefs than boys (Gebhardt et al., 2019b; Hatlevik et al., 2018), while boys in North America tend to exhibit higher self-efficacy (g = 0.34) and positive beliefs (g = 0.43) than girls (Cai et al., 2017). Understanding the gender gaps in affect, belief, and self-efficacy dimensions and how they vary across geographical regions is important to achieve gender digital equity.

The affective dimension encompasses emotions, moods, and feelings when performing technology-related tasks (Cai et al., 2017). Previous research on gender differences among adults in the affect dimension suggested that girls have higher computer anxiety than boys (Broos, 2005; Durndell & Haag, 2002). In addition, boys seem to show more interest in and enjoy technology-related tasks than girls (Colley & Comber, 2003). Students' anxiety, interest, enjoyment, fear, and liking of technology are critical predictors of digital skills (Fraillon et al., 2015; Gebhardt et al., 2019c), and they emerge through processes by which children are socialized into gender roles in their cultures (Wigfield & Eccles, 2000). Borokhovski et al., (2018) found that girls in non-commonwealth countries have a lower interest in ICT than boys (g = 0.15); however, girls in the USA have a higher interest in ICT than boys (g = -0.12). Further research is needed to understand how social, cultural, and economic contexts are related to gender differences in students' affect and their relationship to digital knowledge and skills.

The second dimension represents students' technology beliefs. It includes, among others, technology acceptance and satisfaction, positive and negative views on technology, and perceptions of the effects of technology on society (Cai et al., 2017; Kemp et al., 2019). The *International Computer and Information Literacy Study* (ICILS) and the *Programme for International Student Assessment* (PISA) reported that boys have more positive attitudes towards ICT than girls (Fraillon et al., 2014; OECD, 2011). Gender differences in students' beliefs about technology are essential contributors to students' achievement in mathematics, reading, and science (Petko et al., 2017). However, there is limited evidence on the interplay between gender, students' beliefs about technology, and their digital skills.

Finally, self-efficacy refers to students' beliefs in their capabilities to learn and use technology effectively (Bandura et al., 1999; Hatlevik et al., 2018). Students who underestimate their abilities can easily be discouraged when something goes wrong. At the same time, those who believe in their capabilities may persist, even when the desired result is not achieved (Broos & Roe, 2006). Gender differences in students' self-efficacy are essential, as previous research found a positive relationship between self-efficacy and digital skills in secondary school students (Rohatgi et al., 2016). Meta-analyses on gender differences in students' self-efficacy suggested that boys exhibit higher self-efficacy beliefs than girls (g = 0.18; Cai et al., 2017). However, the magnitude of the differences varied across geographical regions (g = -0.01 to 0.34). Potential factors explaining variation in the magnitude of gender gaps in self-efficacy between regions were not explored. Therefore, it remains unclear whether cultural, economic, and social factors are associated with the magnitude of gender self-efficacy gaps between regions and their connection to students' digital skills.

2.3 Gender and digital skills

The second level of the digital divide focuses primarily on inequalities in digital knowledge and skills. Several studies have reported gender gaps in digital skills. For instance, Gnambs (2021) used longitudinal data from a sample of 15-year-old students to investigate the effects of gender on ICT literacy and its evolution over time. Though no significant gender differences were found at the beginning of the study (d = -0.03), boys had a higher ICT literacy than girls after three years (d = -0.15; Gnambs, 2021). Kaarakainen et al.'s (2018) study corroborated this finding in an earlier study of ICT skills in upper-secondary school students from Finland. While these studies seemed to substantiate the general direction of gender difference, several other studies found the opposite. For instance, Aesaert and van Braak (2015) reported that primary-school girls in Belgium outperformed boys in a test of ICT skills (d = 0.37). Moreover, Kim et al. (2014) found that girls had higher scores than boys in the average and lower levels of a Korean national ICT literacy test. A recent meta-analysis of the second-level gender digital divide suggested that girls outperform boys in performance-based assessments of digital skills in K-12 education (g = 0.12; Siddiq & Scherer, 2019). Gender differences tended to vary across geographical regions and sample ages. The magnitude of the differences was larger in American (g = 0.18) than in Asian (g = 0.14), European (g = 0.11), and Australian (g = 0.09) countries, although regional differences were not statistically significant. Task mode and types of skills assessed were not associated with variation in the magnitude of the gender gaps. However, Kaarakainen et al. (2017) found that boys scored significantly higher than girls on more technical-oriented items, while girls outperformed boys on schoolwork-oriented and social interaction-related items. An examination of ICILS 2013 items supported the findings (Gebhardt et al., 2019a; Punter et al., 2017). Hence, further information is necessary to understand whether types of digital skills may explain variation in the second-level gender divide in digital skills.

2.4 The present study

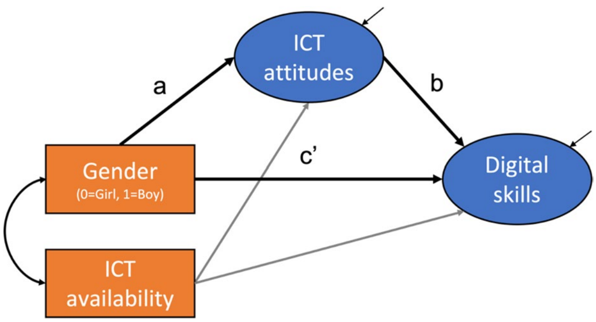
The extant literature exhibits significant variation in the first- and second-level gender digital divides. Sample age, geographical region, type of attitudes toward technology, and type of digital skill are related to variations in the magnitude of the gender digital divides. A rich body of research indicated gender differences in favor of boys in access to physical ICT resources and attitudes toward technology, yet differences in favor of girls in digital skills. We noted that research on the different levels of the digital gender divide has been conducted in isolation, so it is unclear how the first- and second-level gender digital divides relate to each other. Further research is needed to understand whether gender differences in digital skills are consistent across domains, over time, and between geographical regions after controlling for access to ICT resources.

The present study addresses these gaps by employing an integrative data analysis (IDA) approach using individual participant data (IPD) from the 2013 and 2018 International Computer and Information Literacy Study (ICILS). IDA has several advantages, such as the possibility to control for individual variation, including individual-level covariates and confounders, and the model-based generation of effect sizes (e.g., see Campos et al., 2023; Curran & Hussong, 2009; Riley et al., 2010). These benefits are crucial to the present study, as the gender digital divide is not only a societal phenomenon but is largely based on individual differences in students' opportunities to use, access, and own digital technology at home and school (Van Dijk, 2020). Furthermore, as we aim to describe digital gender differences in students' attitudes and skills after controlling for other possible differences, we needed to generate effect sizes from the raw data using the same analytical model across primary studies (Campos et al., 2023).

In the present study, we synthesize the evidence on the gender differences in digital skills after controlling for ICT access and attitudes toward technology. Moreover, we examine the mediating role of students' attitudes toward technology (see Fig. 1). In this study, we address the following research questions:

1. To what extent are gender differences in digital skills mediated by attitudes toward technology?
2. To what extent do the direct and indirect effects of gender on digital skills via attitudes toward technology vary across primary studies, countries, and types of attitudes toward technology?
3. To what extent do study, country, and measurement characteristics explain this heterogeneity?

Fig. 1 Effect size generating model of the direct and indirect effects of gender on digital skills via ICT attitudes



3 Method

3.1 Search for IPD

The data search for this integrative data analysis was conducted following a two-step procedure. First, we conducted a computerized database search in the databases ERIC and PsycINFO using the following search terms: (International large-scale assessment) AND (gender OR sex) AND (attitudes OR attitudes toward technology OR Affect OR belief* OR self-efficacy) AND (Internet skills OR digital skills OR online skills OR digital competence OR digital literacy OR Information literacy). Second, we manually searched the international data repositories of the OECD and the IEA (ILSA-Gateway, OECD, and IEA).

3.2 Eligibility criteria

The selection criteria that guided the inclusion of IPD in our integrative data analyses were as follows: the IPD (a) was based on K-12 student populations; (b) contained information on gender; (c) included at least one measure of attitudes toward ICT; (d) contained a performance-based measure of digital competence; (e) contained a measure of students' ICT access (f) included representative and random student samples; and (g) comprised samples of students from different countries. A total of 165 studies were identified and screened for inclusion in the review, with two studies meeting the inclusion criteria and being included in the final analysis (see Supplementary material S0).

3.3 Included IPD

We used student data from the *International Computer and Information Literacy Study* (ICILS) (Fraillon et al., 2014, 2020b). ICILS is a large-scale international assessment conducted every five years, with the first cycle in 2013 and the second in 2018. The assessment aims to provide international information about eighth-grade students' digital skills—computer and information literacy and computational thinking—. ICILS data can shed light on the relationships between digital literacy, student characteristics, and school contexts within and between countries (Fraillon et al., 2014, 2020b).

ICILS followed a stratified two-stage cluster sample design to achieve representative probability samples of students in grade eight (Fraillon et al., 2013b). In the first stage, schools are randomly selected with probabilities proportional to size, as measured by the number of students enrolled. In the second stage, twenty students are randomly sampled from all students enrolled in the target grade in each sampled school. The effective sample size of this study consisted of 32 countries and 105,981 students, with 52,096 (49.2%) girls and 53,885 (50.8%) boys (see Table 1). No countries or students were excluded from the final analyses, as we were interested

Table 1 Description of the study samples and available effect sizes

Characteristics	*m*	*k*	Proportion of samples	Proportion of effect sizes
Assessment cycle				
2013	21	126	60.0%	35.4%
2018	14	230	40.0%	64.6%
Types of digital skills				
Computer and information literacy	31	266	88.6%	74.7%
Computational thinking	9	90	25.7%	25.3%
Attitudes toward technology				
ICT affect				
Interest	21	42	60.0%	11.8%
ICT belief				
Positive attitudes	14	46	40.0%	12.9%
Negative attitudes	14	46	40.0%	12.9%
Future expectations	14	46	40.0%	12.9%
ICT self-efficacy				
Basic	31	88	88.6%	24.7%
Advanced	31	88	88.6%	24.7%
World region				
Asia and the Pacific	4	48	12.9%	13.5%
Europe and North America	24	276	77.4%	77.5%
Latin America and the Caribbean	3	32	9.7%	9.0%

Note. m = Number of independent country samples, *k* = Number of direct and indirect effect sizes

in quantifying the heterogeneity in the digital gender divide across educational systems. Supplementary Material S1 contains additional information about country-specific sample sizes.

3.4 Measures

3.4.1 Digital skills

ICILS performance assessments covered two outcomes—Computational and Information Literacy (CIL) in 2013 and 2018, and Computational Thinking (CT) in 2018. The CIL construct represents students' knowledge and skills in understanding computer use, gathering information, producing information, and communicating digitally (Fraillon et al., 2019b; Fraillon et al., 2013b). Conversely, the CT construct represented students' abilities to conceptualize problems and operationalize computational solutions (Fraillon et al., 2019b). In ICILS 2018, CIL and CT items were organized into seven modules randomly assigned to each student. Every student completed two test modules for the CIL assessment and two for the CT assessment (Fraillon et al., 2019b). ICILS 2013 did not assess students' CT, so students only completed two CIL modules (Fraillon et al., 2013a). One-parameter and partial credit IRT models were used to scale the test items. Students' CIL and CT scores were generated with a mean of 500 and a standard deviation of 100 (see Fraillon et al., 2020a; Fraillon et al., 2013a). In the present study, we used the plausible values provided by the study designers for CIL and CT as the observed estimates of students' digital skills.

3.4.2 Attitudes toward technology

The ICILS student questionnaires contained scales assessing students' affect, belief, and self-efficacy as parts of their attitudes toward technology. The *Affect* dimension was measured in ICILS 2013 but was not administered in ICILS 2018. The scale aimed to capture students' interest and enjoyment in using computers and computing (see Supplementary Material S1.0.1). This scale included Likert-type items in which students indicated their agreement with seven statements using four response categories (*0 = strongly disagree, 1 = disagree, 2 = agree, 3 = strongly agree*). Cronbach's alpha average reliability estimate was 0.81 across national samples (Fraillon et al., 2013b). We used students' item responses to create the latent variable *ICT affect*.

ICILS 2018 included measures of *ICT beliefs*, a construct not assessed in ICILS 2013. Students' responses to three scales captured their perceptions of the positive (4 items) and negative (4 items) views of ICT for society, and expectations of future use of ICT (3 items) for work and study (see Supplementary Material S1.0.2). These scales were based on the same response scale as the ICILS 2013 affect dimension. We used students' item responses to create the latent variables *Positive Attitudes, Negative Attitudes,* and *Future Expectations,* respectively. On average and across national samples, internal consistencies (Cronbach's alpha) were 0.75 for positive attitudes, 0.66 for negative attitudes, and 0.80 for future expectations (Fraillon et al., 2020a).

Finally, ICILS 2013 and ICILS 2018 measured *ICT self-efficacy* via two scales, basic and advanced self-efficacy in ICT (see Supplementary Material S1.0.3). Students indicated how well they could do a series of tasks when using ICT on a three-point scale (*1 = I know how to do this, 2 = I could work out how to do this, 3 = I do not think I can do this*). We used students' item responses as indicators of the latent variables *ICT self-efficacy basic* and *ICT self-efficacy advanced*. Cronbach's alpha reliability estimates for the ICT self-efficacy basic and advanced scales were 0.76 and 0.80 in ICILS 2013 (Fraillon et al., 2013b), and 0.83 and 0.74 in ICILS 2018, respectively (Fraillon et al., 2020a).

3.4.3 Background variables

The student questionnaire collected information about students' gender and the availability of ICT resources at home. Students' gender was recoded as 0 (*girls*) and 1 (*boys*). Students' responses on the number of desktop computers (0, 1, 2, three or more), number of laptops, tablets, or digital readers (0, 1, 2, three or more), and the availability of an Internet connection at home (*0 = No, 1 = Yes*) were used to create an ICT availability index. This index was a composite sum score of all ICT availability items and represents students' ICT access at home.

3.4.4 Socio-economic development

The Human Development Index (HDI) from the United Nations Development Program indicates a country's socio-economic development (UNDP, 2022). The HDI combines information about health, education, and living standards, and the respective scores are aggregated into a composite index using a geometric mean. High HDI scores indicate a high socio-economic development, while low HDI scores indicate low socio-economic development. For this study, we used the HDIs from 2013 and 2018 [https://hdr.undp.org/data-center], the years of the ICILS assessment.

3.4.5 Gender inequality

The gender inequality index (GII) from the World Health Organization Country indicates a country's gender inequality (UNDP, 2022). The GII is a composite measure of inequality between women and men in three dimensions: reproductive health, empowerment, and the labor market. The GII varies between 0 and 1, and values close to 0 indicate high levels of gender equality, while values close to 1 reflect high country gender inequality. In the present study, we used the GIIs from 2013 and 2018 [https://hdr.undp.org/data-center/composite-indices].

3.4.6 Country innovation

The Global Innovation Index developed by the World Intellectual Property Organization (WIPO) indicates a country's innovation potential (Dutta & Lanvin, 2013; Dutta et al., 2018). Economies worldwide are scored on seven inputs (i.e., institutions, human and capital research, infrastructure, market sophistication, and business sophistication) and two outputs (i.e., knowledge and technology output and creative output). We used the global innovation indices from 2013 and 2018 [https://www.globalinnovationindex.org/analysis-indicator].

3.4.7 Gender gaps in ICT use

The ICT use index created by the International indicated gender gaps in ICT use in a country (ITU, 2014, 2020). Fifteen-year-old and older women and men were asked if they had Internet access for personal use in a typical week and if they had fixed (wired) and wireless broadband subscriptions. Gender differences in use percentage formed the indicator of ICT use country gender gaps. A positive coefficient indicates that the ICT use gender gaps are in favor of men, and a negative coefficient indicates that the ICT use gender gaps are in favor of women, respectively. We utilized the indices from 2013 and 2018 [https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx].

3.4.8 World region

Participating countries in ICILS 2013 and 2018 were geographically classified using the UNESCO classification of world regions. The UNESCO classification includes five regions: Africa, Arab States, Asia and the Pacific, Europe and North America, and Latin America and the Caribbean (UNESCO, 2021). The classification helps to understand the regional patterns that may arise due to geographical, cultural, and economic factors.

3.5 Data analysis

We adopted a two-stage integrative data analysis approach to synthesize the student data from ICILS 2013 and 2018. This approach generates the effect sizes of interest from each country independently using the same analysis protocol and then combines the resultant effect size estimates using random-effects meta-analytic models (Campos et al., 2023; Scherer et al., 2021).

3.5.1 Stage 1: effect size generation

In this stage, we estimated the direct and indirect effects of attitudes toward ICT on digital skills by implementing our effect size-generating model (see Fig. 1) via multigroup structural equation models (SEMs) with complex sampling survey characteristics. First, we imputed missing data via a two-level predictive mean matching and a passive imputation approach using the R package *mice* (Buuren & Groothuis-Oudshoorn, 2011). The multiple imputation procedure was conducted in each country independently and based on the information available on students' backgrounds, ICT use, and attitudes toward technology. The passive imputation technique first imputed the ICT availability items and then derived the ICT availability index (Desai et al., 2016). We generated 20 complete data sets for each plausible value, yielding 100 complete data sets for each ICILS cycle. Subsequent analyses were performed using all 100 imputations, and the resulting model parameters were combined using Rubin's (1987) rules.

Second, we examined the gender differences in digital skills both directly and indirectly via attitudes toward technology, controlling for the availability of ICT at home (see Fig. 1). We specified separate multigroup SEMs for each attitude dimension (i.e., affect, beliefs, and self-efficacy) and digital skill (computational and information literacy and computational thinking). The models accounted for the hierarchical and complex survey structure of ICILS data, incorporating sampling weights, jackknife/balance repeated replication procedures, and plausible values. To construct measures of attitudes toward ICT that satisfied approximate measurement invariance across countries, we performed the alignment optimization method within the SEMs. This method estimates a set of measurement model parameters with minimal differences between countries and ensures a maximal level of comparability across countries (Asparouhov & Muthén, 2014). Measurement invariance is needed to establish the validity of cross-country comparisons of structural relations among constructs (Millsap, 2011). From this model, we derived partially standardized parameter estimates of the direct and indirect effects of the attitudes toward technology dimensions on digital skills. The statistical software M*plus* 8.8 (Muthén & Muthén, 1998–2022) via the R package *MplusAutomation* (Hallquist & Wiley, 2018) was used to perform stage one analysis.

3.5.2 Stage 2: synthesis of effect sizes

In the second stage, we submitted the model-based effect sizes and their sampling variances to random- and mixed-effects meta-analysis to obtain the average direct ($c\prime_{ps}$) and indirect effects (ab_{ps}) and to explore their heterogeneity. Given that each country sample provided at least two effect sizes per ICILS cycle, and some countries participated in multiple ICILS cycles, we considered the nature of the meta-analytic dataset to be both hierarchical and correlational (Pustejovsky & Tipton, 2022). Three baseline models were tested to examine heterogeneity across countries and effect sizes. Model 1 represented a multivariate random-effects model that modeled the within-country correlation of the direct and indirect effect sizes (Cheung, 2013). Model 2 represented a multilevel multivariate random-effects model that modeled the average effect size for the direct and indirect effects, their variance at the effect size level, and a single random effect at the country level (Pustejovsky & Tipton, 2022). Finally, Model 3 specified a full multilevel and full multivariate random-effects model that modeled the average effect size for the direct and indirect effect and their variance and correlation at the different levels of the nesting structure (McShane & Böckenholt, 2022). To compare the sensitivity of our results to the choices made in our baseline model, we compared several competing models. Cluster-robust standard errors and confidence intervals for each model were obtained using robust variance estimation procedures (Tanner-Smith & Tipton, 2014).

Finally, we investigated whether heterogeneity in the direct and indirect effects can be accounted for by country-level variables, that is, socio-economic development, gender inequality, country innovation, Gender gaps in ICT use, and world region, by extending the random-effects model to a mixed-effects meta-regression model. We used the R package *metafor* for the stage-2 analyses (Viechtbauer, 2010).

3.6 Data availability

This study was pre-registered in the Open Science Framework (OSF) at https://osf.io/z9uba. To fully replicate the findings of the present study, we provide the datasets analyzed, the analytic code, and the respective output in the OSF at https://osf.io/6um4t/?view_only=1ff8ba652cc646d1b90930b2a8fbee57.

4 Results

4.1 Data description

The MG-ASEMs showed acceptable fit and supported approximate measurement invariance across countries (see Appendix Table 3). From these models, we derived the partially standardized parameter estimates of the direct and indirect effects for each participating country (see Fig. 1). The direct effect represented the estimated differences in digital skills between boys and girls, controlling for ICT access at home, attitudes toward technology, and possible gender differences within them; respectively, the indirect effect captured the mediating effect of students' attitudes toward technology.

The meta-analytic sample contained information from 31 countries, two ICILS assessments, and 356 direct and indirect effect sizes. Most effect sizes were based on measures of computer and information literacy (74.7%) and the ICT self-efficacy attitude dimension (49.4%). Additionally, 77.5% of the effect sizes were from European and North American samples, 13.5% from Asia and the Pacific, and 9% from Latin America and the Caribbean. Supplementary Material S1 contains the descriptive statistics of the student's scores on the scales measuring digital skills and attitudes toward technology. Table 1 describes the distribution of these effect sizes by study and sample characteristics. The complete meta-analytic data set can be accessed at https://osf.io/6um4t/?view_only=1ff8ba652cc646d1b90930b2a8fbee57.

4.2 Gender gaps in digital skills mediated by attitudes toward technology and their heterogeneity

We specified four meta-analytic models with multiple random effects to aggregate the direct and indirect effect sizes across primary studies (see Supplementary Material S2). The information criteria and likelihood-ratio tests showed that a multivariate random-effects meta-analysis model (Model 1) represented the data for the ICT affect dimension. The single multilevel multivariate random-effects model (Model 2) was the baseline model for negative attitudes, future expectations, and the basic self-efficacy attitudes dimensions. Finally, Model 3, the full multilevel multivariate random-effects meta-analysis model, served as the baseline model for the positive attitudes and self-efficacy advanced dimensions. In the following, we report the results from these baseline models for each attitude dimension.

4.2.1 Gender differences in digital skills via ICT affect

The multivariate random-effects model indicated that the weighted average indirect effect was close to zero ($\overline{ab}_{ps}$ = 0.04, 95% CI [0.03, 0.06]), whereas the direct effect was moderate (c'_{ps} = -0.29, 95% CI [-0.35, -0.23]; see Table 2). Heterogeneity in the indirect effects (τ^2 = 0.001, 95% CI [0.001, 0.002], I^2 = 83.5%) and the direct effects (τ^2 = 0.016, 95% CI [0.008, 0.034], I^2 = 98.7%) was substantial between

Table 2 Results of the multivariate random-effects meta-analyses of the direct and indirect effects of gender on digital skills via attitudes toward technology

	ICT affect	ICT beliefs: Positive attitudes	ICT beliefs: Negative attitudes	ICT beliefs: Future expectations	ICT self-efficacy: basic	ICT self-efficacy: advanced
Weighted average effect size						
Direct effect ($\bar{c'}_{ps}$) [95% CI]	-.29 [-.35, -.23]	-.13 [-.20, -.07]	-.11 [-.16, -.05]	-.12 [-.19, -.04]	-.11 [-.15, -.06]	-.17 [-.22, -.12]
Indirect effect ($\overline{ab}_{ps}$) [95% CI]	.04 [.03, .06]	.04 [.02, .05]	.01 [.00, .01]	.01 [-.01, .04]	-.05 [-.07, -.03]	.00 [-.02, .01]
m	21	23	23	23	44	44
k	42	46	46	46	88	88
Heterogeneity						
τ^2_{dir} [95% CI]	.016 [.008, .034]	.027 [.015, .053]	.027 [.015, .054]	.039 [.022, .076]	.026 [.017, .042]	.027 [.017, .045]
τ^2_{ind} [95% CI]	.001 [.000, .002]	.000 [.000, .000]	.000 [.000, .000]	.000 [.000, .001]	.001 [.000, .002]	.000 [.000, .001]
γ^2 [95% CI]	-	-	.000 [.000, .001]	.002 [.001, .004]	.001 [.001, .003]	-
γ^2_{dir} [95% CI]	-	.007 [.000, .035]	-	-	-	.004 [.000, .016]
γ^2_{ind} [95% CI]	-	.001 [.000, .002]	-	-	-	.001 [.000, .002]

m = Number of country samples, *k* = Number of effect sizes, $\bar{c'}_{ps}$ = Weighted average of the partially standardized direct effect, $\overline{ab}_{ps}$ = Weighted average of the partially standardized indirect effect samples. All effect sizes and the results of the multivariate random-effects modeling are presented in Fig. 2. These findings showed that girls outperformed boys in digital skills, even after controlling for ICT access and affect. As the indirect effect of gender on digital skills via ICT affect was positive and different from zero, there was evidence for at least partial mediation of gender differences.

Subsequent mixed-effect meta-regression models showed that countries' socio-economic development explained some between-effect heterogeneity in the indirect effect (β = 0.28, 95% CI [0.05, 0.52], R^2 = 23.9%) and direct effect (β = -1.32, 95% CI [-2.20, -0.45], R^2 = 38.2%; see Appendix Table 4). Hence, for countries with higher socio-economic development, indirect effects tended to be larger, and direct effects tended to be more negative (i.e., larger gender gaps in favor of girls) than for countries with lower socio-economic development. Gender inequality also explained some between-effect heterogeneity in the direct effect (β = 0.80, 95% CI [0.18, 1.41], R^2 = 36.8%), suggesting that the gender differences may decrease or be reversed (i.e., in favor of boys) with increasing gender inequality country scores.

4.2.2 Gender differences in digital skills via ICT beliefs

The weighted average indirect effect was almost zero across the beliefs sub-dimensions (Positive attitudes: $\overline{ab}_{ps}$ = 0.04, 95% CI [0.02, 0.05]; Negative attitudes: $\overline{ab}_{ps}$ = 0.01, 95% CI [0.00, 0.01]; Future expectations: $\overline{ab}_{ps}$ = 0.01, 95% CI [-0.01, 0.04]). The direct effects were moderate and favored girls (Positive attitudes: c'_{ps} = -0.13, 95% CI [-0.20, -0.07]; Negative attitudes: c'_{ps} = -0.11, 95% CI [-0.16, -0.05]; Future expectations: c'_{ps} = -0.12, 95% CI [-0.19, -0.04]). Figure 3 displays

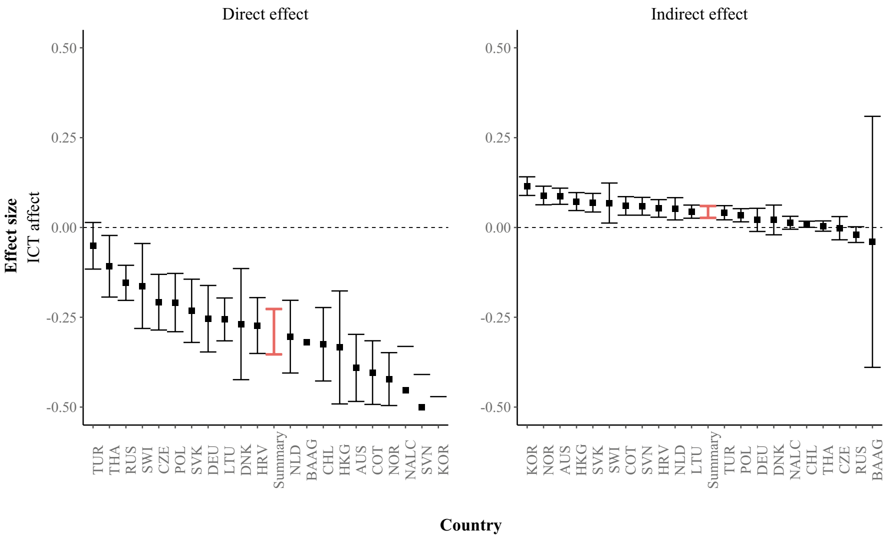


Fig. 2 Forest Plot of the Direct and Indirect Effects of Gender on Computer and Information Literacy via ICT Affect. *Note.* Effect sizes represent the partially standardized direct and indirect effect of gender on digital skills via ICT affect. Participating countries are represented by their ISO-3 letter codes

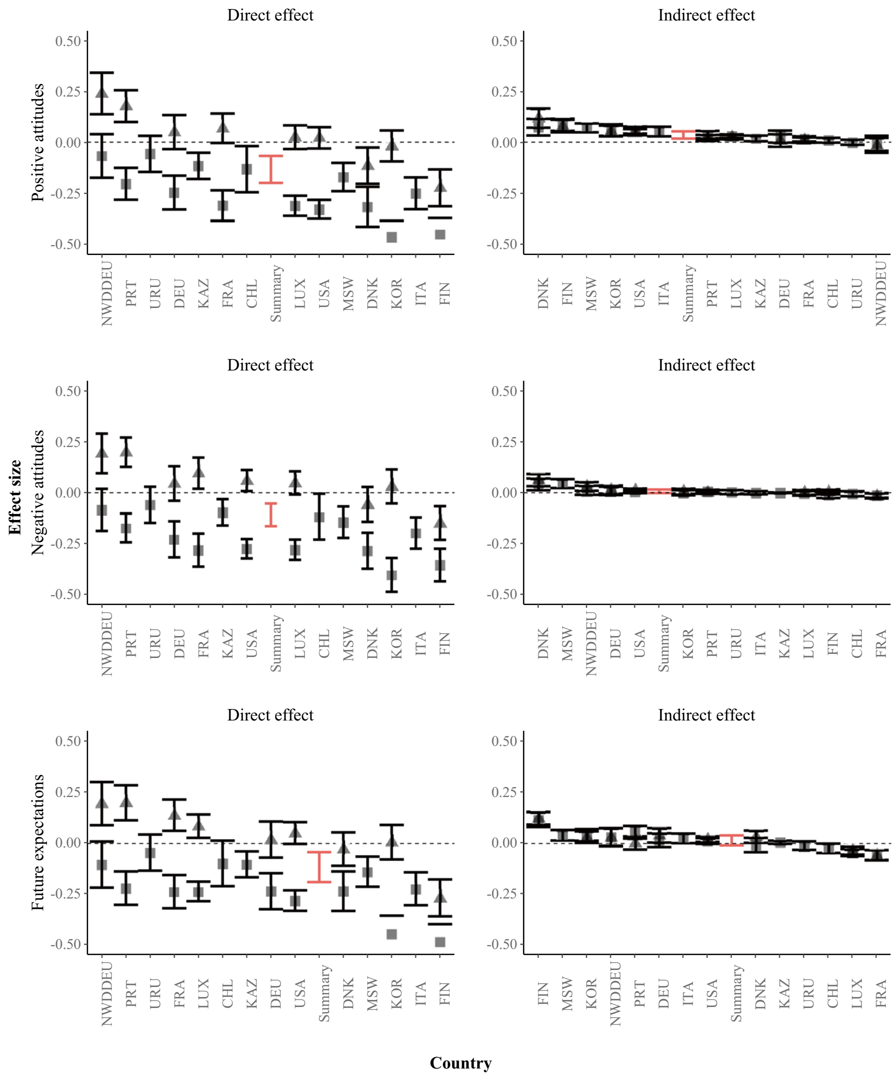


Fig. 3 Forest plot of the direct and indirect effects of gender on digital skills via ICT beliefs. *Note.* Effect sizes represent the partially standardized direct and indirect effect of gender on digital skills via ICT beliefs constructs. Participating countries are represented by their ISO-3 letter codes. ■ = Computer and information literacy, ▲ = Computational thinking

the country-specific direct and indirect effects of gender on students' digital skills via ICT belief constructs. Overall, we found evidence for a (partial) mediating role of ICT beliefs only for positive attitudes, with consistent direct effects favoring girls for all belief subdimensions.

Socio-economic development, gender inequality, country innovation, gender gaps in ICT use, and world region did not predict the direct and indirect effects of gender on digital skills via the ICT affect sub-dimensions (see Appendix Table 5). The only significant moderator of the between-effect heterogeneity in the direct effects was the type of digital skill (CIL vs. CT) with estimated slopes of the direct effects were 0.32 (95% CI [0.26, 0.37], R^2 = 94.9%) for positive attitudes, 0.27 (95% CI [0.19, 0.34], R^2 = 65.0%) for negative attitudes, and 0.27 (95% CI [0.19, 0.35], R^2 = 60.8%) for future expectations in favor of CT.

4.2.3 *Gender differences in digital skills* via *ICT self-efficacy*

The multilevel multivariate random-effects models showed that the mean indirect effect was near zero for both self-efficacy sub-dimensions (Basic: $\overline{ab}_{ps}$ = -0.05, 95% CI [-0.07, -0.03]; Advanced: $\overline{ab}_{ps}$ = 0.00, 95% CI [-0.02,0.01]), whereas the direct effect was moderate and statistically significant (Basic: $\overline{c'}_{ps}$ = -0.11, 95% CI [-0.15, -0.06]; Advanced: $\overline{c'}_{ps}$ = -0.17, 95% CI [-0.22, -0.12]; see Table 2). The between-effect heterogeneity in the indirect and direct effects was substantial. Figure 4 shows the direct and indirect effects of gender on students' digital skills via ICT self-efficacy.

Type of digital skills (CIL vs. CT) and assessment cycle (ICILS 2013 vs. 2018) moderated the direct effects of gender on digital skills via both self-efficacy dimensions (see Appendix Table 6). Digital skills explained some of the between-effect heterogeneity in the self-efficacy basic and advanced models, and assessment cycle was related to between-effect heterogeneity in the self-efficacy basic models, and with between-effect and between-country heterogeneity in the self-efficacy advanced model. Specifically, after accounting for ICT self-efficacy and ICT access, the reported gender differences in digital skills favored girls for the CIL skill (Basic: c'_{ps} = -0.17, 95% CI [-0.21, -0.13], R^2 = 70.1%; Advanced: c'_{ps} = -0.22, 95% CI [-0.27, -0.18], R^2 = 88.0%); however, they favored boys for the CT skill (Basic: c'_{ps} = 0.31, 95% CI [0.23, -0.39], R^2 = 70.1%; Advanced: c'_{ps} = 0.35, 95% CI [0.27, 0.42], R^2 = 88.0%). Similarly, gender differences favored girls in the ICILS 2013 assessment (Basic: c'_{ps} = -0.19, 95% CI [-0.23, -0.14], R^2 = 19.7%; Advanced: c'_{ps} = -0.25, 95% CI [-0.31, -0.19], R^2 = 17.4%//64.7%), yet not in the ICILS 2018 assessment (Basic: c'_{ps} = 0.14, 95% CI [0.08, 0.21], R^2 = 19.7%; Advanced: $\overline{c'}_{ps}$ = 0.16, 95% CI [0.09, 0.24], R^2 = 17.4%//64.7%). Neither ICT self-efficacy's direct nor indirect effects on digital skills were moderated by countries' socio-economic and gender inequality indicators (see Appendix Table 6).

5 Discussion

5.1 Linking digital divides

Calls by researchers to investigate how different gender digital divides relate to each other remained largely unanswered (Lythreatis et al., 2022; Van Dijk, 2020). Empirical evidence linking the first- and second-level of the gender digital divide in the school contexts was missing. This study addressed this gap by directly linking digital gender divides in digital knowledge and skills and attitudes toward technology,

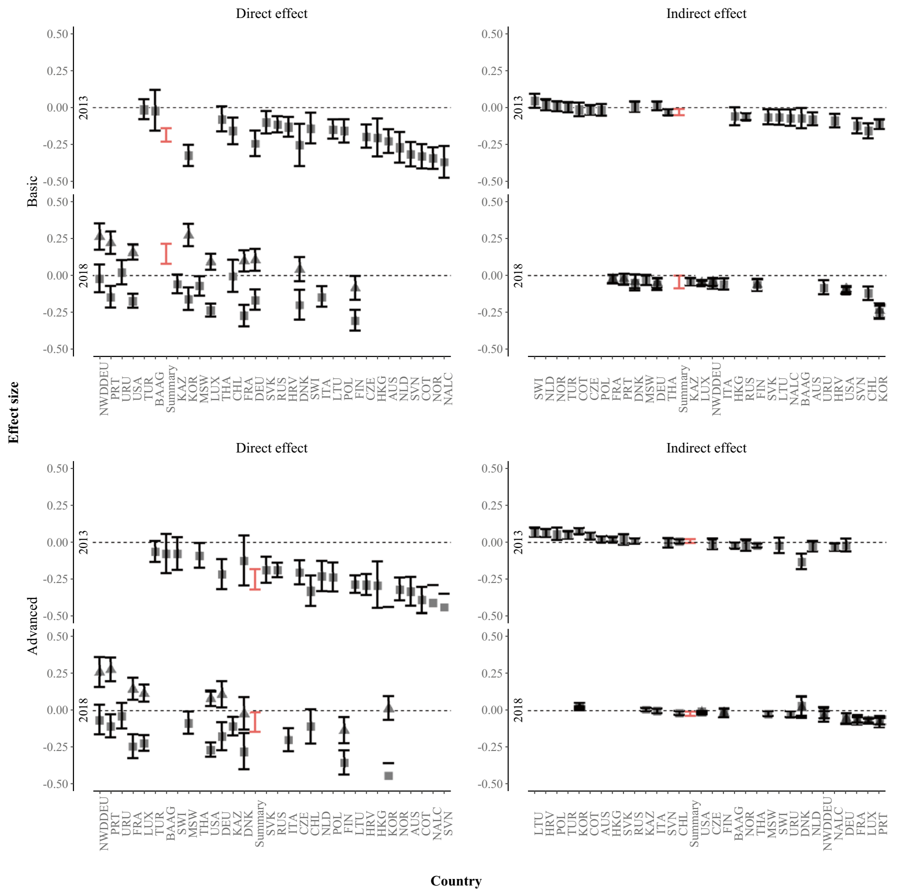


Fig. 4 Forest plot direct and indirect effects of gender on digital skills via ICT self-efficacy. *Note.* Effect sizes represent the partially standardized direct and indirect effect of gender on digital skills via ICT self-efficacy. Participating countries are represented by their ISO-3 letter codes. ■ = Computer and information literacy, ▲ = Computational thinking

after controlling for access to ICT resources. Studying the relations between different gender digital divides can help understand how inequalities occur in the digital domain and will help those trying to bridge the divide to achieve equal societal benefits from digitalization. The evidence backing the connections between several gender digital divides also suggests that they are complex, intertwined, and may impact one another. Hence, we argue that educational policies addressing only one level of the gender digital divides may not effectively close other divides.

5.2 Gender divides in digital skills mediated by attitudes (RQ1)

In the present study, we first set to investigate the extent to which gender differences in digital skills are mediated by attitudes toward technology. This integrative data analysis suggests that attitudes toward technology partially mediate the gender gaps in digital skills. Previous studies found that students with higher ICT self-efficacy tended to achieve better results in assessments of digital skills (Rohatgi et al., 2016; Tømte & Hatlevik, 2011), even after controlling for background and contextual characteristics (Hatlevik et al., 2018). This study found that girls with equal ICT access to boys performed better in digital skills, partly due to differences in ICT self-efficacy in basic computer skills. However, we did not find the same association in items assessing students' ICT self-efficacy in advanced computer skills. The ICILS digital literacy assessments included only a limited number of advanced ICT tasks that required higher-order thinking and problem-solving skills. As a result, the alignment with the measure of advanced ICT self-efficacy was low (Rohatgi et al., 2016). Self-efficacy evaluations should be aligned with performance measures to draw meaningful conclusions about their relationships (Bandura, 1997). Thus, further analysis of the alignment between ICT self-efficacy measures and other digital skills is necessary to test the transferability of the relationship reported in this study.

The ICT attitudes dimension of affect and beliefs also partially mediated the relation between gender and digital skills. Students' positive attitudes and interest in ICT are determinants of students' digital skills development (Erdogdu & Erdogdu, 2022). However, gender gaps in favor of boys in the dimensions of affect and attitudes toward ICT have been reported in the literature (Cai et al., 2017). This integrative data analysis found a gender gap favoring boys in the ICT affect and beliefs dimensions. Furthermore, we found that boys with equal ICT access than girls performed better in digital skills partly due to differences in interest and positive attitudes toward ICT. Prior research on gender differences in digital skills showed that girls had a higher performance than boys (Siddiq & Scherer, 2019), however, our findings indicate that the magnitude of the gender gaps in digital skills seems to reverse once interest and positive attitudes are considered. These results confirm the link between the first- and second-level gender digital divide and emphasize the need to address gender differences in attitudes toward technology to achieve digital equity. Colley and Comber (2003) state that cultural gender stereotypes impact attitudes toward technology. Gnambs (2021) suggested that gender differences in digital skills may result from different experiences of boys and girls with ICTs, which are influenced by gendered interests. Thus, cultural norms and socialization patterns at home and school should be studied to understand how girls and boys develop their attitudes and interests towards technology, as well as how they use ICT. The second gender digital divide could be addressed by educational interventions aiming to address gender stereotypical socialization patterns.

Taken together, the results of this research point to the link between the first- and second-level gender digital divide. The gender gaps in digital knowledge and skills could be partly explained by gender differences in attitudes toward technology. This attitude-skills link is by no means unique to the digital domain. Previous research indicates that students who express greater interest or enjoyment in subjects like science, reading, or mathematics typically perform better on assessments than their peers (Gebhardt et al., 2019a). Hence, our study extends the existing body of research by providing evidence of this relation in the context of ICT-related skills.

5.3 Heterogeneity in digital gender divides (RQ2)

As a second research question, we investigated the extent to which the direct and indirect effects of gender on digital skills vary across samples, countries, and types of attitudes toward technology. Results from the meta-analysis models indicated considerable between-effect, between-sample, and between-country heterogeneity in the direct and indirect effects of gender on digital skills across all attitudes toward technology dimensions. The results align with previous research on the first-level gender digital divide, showing between-country variation in gender gaps in attitudes toward technology (Borokhovski et al., 2018), and contrast findings from previous meta-analyses on the second-level gender digital divide by showing that the magnitude of the gender gaps in digital skills is related to the countries' geographical region (Siddiq & Scherer, 2019). Variance in the direct and indirect effects may indicate the presence of different mechanisms through which gender digital divides are established across countries. First, cultural response bias—which refers to the preferences of students from different cultural backgrounds when responding to scales about their abilities—could explain the between-country variation of the direct and indirect effects of gender on digital skills (Lu & Bolt, 2015). Evidence from international large-scale assessments indicates a positive association between students' attitudes and achievement in mathematics, science, and reading (Gebhardt et al., 2019a). However, countries situated among the top performers in mathematics and science scored among the lowest on attitudinal measures (Min et al., 2016; Van de gaer et al., 2012). Students from various cultural backgrounds may respond to ICT attitude scales differently, which can result in significant between-country variation in the relationship between digital abilities and attitudes toward technology. Second, between-country and between-effect heterogeneity can be partly attributed to differences in distribution and access to digital resources. Access to ICTs is a determining factor in developing students' digital competencies (Ferro et al., 2011). However, gaps in ICT access between developing and developed countries have been reported in the literature (OECD, 2022). The disparity in ICT resources between countries and geographical regions may significantly explain variation in the gender digital divide. Overall, our findings indicate that the digital divide is not uniform across countries and samples, providing evidence about the variability of gender gaps in digital skills and attitudes toward technology, as reported in previous meta-analyses (Cai et al., 2017; Scherer et al., 2021).

5.4 Moderators of digital gender divides (RQ3)

The final research question addressed in this study was the extent to which study, country, and measurement characteristics explain heterogeneity in the direct and indirect effects of gender in digital skills via attitudes toward technology. As noted in the previous section, we found significant variations in the direct and indirect effects of gender on digital skills. This variation was partly explained by study, sample, and measurement characteristics. First, the type of digital skills moderated the gender digital divide. Specifically, boys performed higher in computational thinking and girls in computer and information literacy. The findings are consistent with previous research indicating that boys outperform girls on computer literacy tasks, while girls exhibit higher levels of performance on information literacy tasks (Punter et al., 2017). Gender differences in ICT use may explain the observed gender differences in digital skills. According to Lim and Meier (2011), female students in South Korea are likelier to use computers for social networking and e-mail communication than their male counterparts, while boys are likelier to use computers for gaming. Boys also use more digital platforms and services than girls and are more likely to use the Internet for learning (Tyers-Chowdhury & Binder, 2021). A positive association between ICT use and students' self-reported perceived ability in digital skills has been reported in the literature (Hargittai, 2010; Tømte & Hatlevik, 2011). However, an analysis of ICILS 2013 data reported no significant correlations between ICT use and students' computer and information literacy (Gebhardt et al., 2019a). There is still a need for more comprehensive research to explore the relationship between ICT use and performance-based assessments of digital skills. Future research should examine whether ICT use patterns may explain differences in students' digital knowledge and skills.

Second, country socio-economic development and country gender inequality moderated the direct effect of gender on digital skills after controlling for ICT affect and ICT availability. A comprehensive understanding of regional differences in gender gaps in digital literacy and attitudes toward technology was lacking (Cai et al., 2017; Gebhardt et al., 2019b). The findings from this study suggest that in countries with higher levels of socio-economic development, girls tend to obtain higher scores in digital skills than boys after controlling for ICT affect and ICT access. However, gender gaps in digital skills could be reduced or reversed in countries with higher levels of gender inequality, thus favoring boys over girls. The higher performance of girls in digital skills related to communication and collaboration and boys in digital skills related to abstract and algorithmic thinking may reflect the presence of gender stereotypes in the digital domain. Western countries with larger gender gaps tend to socialize boys in ways that emphasize the development of autonomy and abstract thinking and girls in ways that promote the development of affiliation and consideration for others (Butler, 2014). Cooper (2006) found that countries with larger gender gaps have stronger social stereotypes linking gender and technology, creating an environment where computers are not for girls. Considering that students will not receive enough returns from developing counter-stereotypical skills, boys and girls are less motivated to spend time and effort developing talents that challenge gender norms in the digital domain (Borgonovi & Greiff, 2020). Thus, country gender stereotypes may be underlying the gender digital divides in knowledge and digital skills.

The gender digital divides in countries with higher levels of gender inequality may also be the product of offline gender inequalities (Andrieu et al., 2019; Antonio & Tuffley, 2014; Burns & Gottschalk, 2019; van Deursen et al., 2021). For example, in Turkey, only 27% of women use the Internet regularly compared to 46% of men, and they are less likely to own a phone than their male counterparts, particularly in poor or rural areas (Polat, 2012; Santosham & Lindsey, 2015). Previous research indicates that access to education can help bridge the gender gap in internet access and usage (Scheerder et al., 2017). However, 12% of adult women in Turkey are illiterate, with women making up 80% of illiterate individuals (Polat, 2012). Furthermore, only 33% of the country's women have jobs compared to 76% of men, and only 10% work in the technology industry (Schwab et al., 2017). The lack of access to education, ICT resources, and positive role models may explain why the gender digital divides in digital skills tend to reverse in countries with high levels of gender inequality.

Educational policies from higher socio-economic development countries could help overcome offline inequalities. For example, Norway, Denmark, and Finland have developed policies to increase digital inclusion and gender equality in ICT (Borokhovski et al., 2018). These policies involve gender-sensitive curriculum design, teacher training, or funding for programs that promote the inclusion of both genders in non-traditional gender careers, and they promote inclusive and supportive learning environments, warranty access to ICT resources, and encourage girls to participate actively in ICT education (Borokhovski et al., 2018). Thus, these policies could be linked to the smaller gender gaps in digital skills observed in this study among Scandinavian student populations. Further research is needed to fully understand how a country's socio-economic development and gender inequality may be related to the gender digital divides and their implications for educational policies and gender equality efforts in different regions.

5.5 Practical implications

Ensuring digital equity requires multiple efforts to bridge the first- and second-gender digital divides. First, providing access to ICT resources is essential to achieve gender digital equity. In South Asian and African economies, girls are nearly 23% and 13% less likely to own a mobile phone than boys within the same household, thus limiting their ability to participate in the digital world (Tyers-Chowdhury & Binder, 2021). Ensuring ICT access is central to providing opportunities for children to develop positive attitudes toward ICT (Erdogdu & Erdogdu, 2022) and the necessary digital skills to thrive in contemporary economies (Hurwitz & Schmitt, 2020). Countries with developing economies should strengthen their investment in ICT infrastructure and provide opportunities for all children to access and interact with ICT technologies.

Second, teachers, parents, and peers should support and encourage girls and boys to engage in diverse digital environments and help them avoid negative attribution patterns in ICT tasks (Koch et al., 2008). Early experiences and cultural gender stereotypes may influence gender differences in attitudes toward ICT and digital skills. Studies have shown that girls tend to prefer collaborative work, while boys show greater interest in abstract tasks (Su et al., 2009). Encouraging girls to engage in programming and boys in communication tasks may help bridge the gap in digital skills (Gnambs, 2021). Promoting healthy gender roles for boys and girls in homes and schools is crucial for tackling the negative gender stereotypes contributing to barriers to technology access, positive attitudes toward technology, and digital skills development (United Nations Children's Fund, 2023).

Finally, digital skills should be integrated into formal education programs to ensure the digital inclusion of girls and boys (Hatlevik & Christophersen, 2013). Teachers and schools must be mindful of gender-based differences in digital skills and work towards eliminating any possible barriers. By involving both girls and boys in developing technology-based learning experiences, educators can ensure that the learning experiences meet their needs and reflect their digital realities, while encouraging positive attitudes toward technology (Tyers-Chowdhury & Binder, 2021). New technological solutions, such as artificial intelligence and machine learning, can be used to create personalized learning experiences that serve students' diverse needs and promote positive attitudes toward technology (Bhutoria, 2022).

5.6 Limitations and future directions

The present study has some limitations that point to future research directions. First, geographic regions were not equally represented in this integrative data analysis. The sample of primary studies was limited to 32 independent country samples that were retrieved from two ICILS cycles and yielded 356 effect sizes. An estimated 77.4% of the independent country samples were from Europe and North America, with the remaining 12.9% and 9.7% coming from Asia–Pacific, Latin America, and the Caribbean. Future ICILS studies should expand the sample of participating countries in Africa, Asia–Pacific, Latin America, and the Caribbean to understand whether the patterns observed in this study can be generalized across regions.

A second limitation of this study is the representation of different skills in the ICILS assessments. Siddiq et al. (2016) found that most digital skill tests focused on students' assessments of digital information search, retrieval, evaluation, and technical skills, while ICT problem-solving, digital communication, and online collaboration were not equally assessed. In this study, computer and information literacy—a construct focused on the ability to use computers to investigate, create, and communicate (Fraillon et al., 2019b)—was the key outcome in 88.6% of the effect sizes, while 25.7% came from assessments of students' computational thinking—a construct reflecting the ability to use computational formulation for real-world problems and to evaluate and develop algorithmic solutions to those problems (Fraillon et al., 2019b). Covering content in a more balanced and comprehensive way could help to identify the specific areas where digital divides emerge. This could be achieved by extending our integrative data analysis to a meta-analysis combining ICILS data with aggregated data from published primary studies (Campos et al., 2023).

6 Conclusion

Studying the relations between the first- and second-level gender digital divide is a promising field for achieving digital gender equity. There was a lack of information on how the material, attitudinal, knowledge, and skills dimensions of the gender digital divide are related to each other (Lythreatis et al., 2022; Van Dijk, 2020). Our integrative analysis examined how attitudes toward technology mediated the gender differences in digital skills after accounting for ICT access at home. Our findings indicate that students' attitudes toward technology can account for gender differences in digital skills. Moreover, we highlight the importance of investigating specific digital skills and attitudes toward technology when developing interventions to address the relationship between first- and second-level gender digital divides. The variance in the direction and nature of the gender digital divides suggests that there is no single solution to bridge the gender digital divide that can be applied in all contexts. Girls living in countries with high gender gaps may benefit from programs encouraging their algorithmic and computational thinking, while boys may gain from developing their digital communication abilities. Overall, we provided evidence on the relationship between first- and second-level gender digital divides and outlined future research paths that may help to achieve digital gender equity.

Appendix

Please see Tables 3, 4, 5 and 6.

Table 3 Fit Statistics of the multi-group alignment structural equation models

Student skill (Study and year)	Motivational construct	RMSEA	CFI	TLI	R^2
Computer and information literacy (ICILS 2013)	ICT affect	0.079	0.932	0.904	0.54
	ICT self-efficacy: basic	0.044	0.975	0.962	0.55
	ICT self-efficacy: advanced	0.061	0.949	0.928	0.34
Computer and information literacy (ICILS 2018)	ICT beliefs: Positive attitudes	0.055	0.978	0.957	0.58
	ICT beliefs: Negative attitudes	0.047	0.961	0.926	0.33
	ICT beliefs: Future expectations	0.050	0.992	0.980	0.51
	ICT self-efficacy: basic	0.040	0.980	0.973	0.30
	ICT self-efficacy: advanced	0.972	0.05	0.947	0.36
Computational thinking (ICILS 2018)	ICT beliefs: Positive attitudes	0.055	0.979	0.960	0.64
	ICT beliefs: Negative attitudes	0.046	0.965	0.932	0.32
	ICT beliefs: Future expectations	0.047	0.994	0.985	0.42
	ICT self-efficacy: basic	0.043	0.976	0.967	0.41
	ICT self-efficacy: advanced	0.054	0.974	0.951	0.27

R^2= Average invariance index (Asparouhov & Muthén, 2014)

Table 4 Moderation analysis of the direct and indirect effects of gender on digital skills via ICT affect by study and sample characteristics

Moderator variable	m	k	Intercept ($\bar{c'}_{ps}$) [95% CI]	Intercept ($\overline{ab}_{ps}$) [95% CI]	$\beta_{\bar{c'}_{ps}}$ [95% CI]	$\beta_{\overline{ab}_{ps}}$ [95% CI]	Q_M (df)	Q_E (df)	$R^2_{\bar{c'}_{ps}}$	$R^2_{\overline{ab}_{ps}}$
Socioeconomic development	21	42	.87 [.11, 1.63]	-.20 [-.41, .00]	-1.32 [-2.20, -.45]	.28 [.05, .52]	155.29 (4)*	231.54 (38)*	38.2%	23.9%
Gender inequality	20	40	-.41 [-.52, -.30]	.07 [.04, .10]	.80 [.18, 1.41]	-.17 [-.34, .00]	144.90 (4)*	209.58 (36)*	36.8%	24.1%
Country innovation	21	42	.04 [-.34, .41]	-.03 [-.11, .04]	-.01 [-.01, .00]	.00 [.00, .00]	122.54 (4)*	265.38 (38)*	22%	14.5%
Gender gaps in ICT use	19	38	-.32 [-.42,-0.22]	.05 [.02, .07]	.02 [-.01, .05]	.00 [-.01, .00]	90.46 (4)*	307.16 (34)*	12.5%	0%
World region[#]	21	42					88.66 (6)*	334.94 (36)*	0%	0%
Asia and the Pacific					-.33 [-.92, .26]	.06 [-.08, .20]				
Latin America and the Caribbean					.01 [-.68, .70]	-.05 [-.22, .11]				
Europe and North America					.05 [-.42, .52]	-.02 [-.13, .09]				

m = Number of country samples, k = Number of direct and indirect effect sizes, $\bar{c'}_{ps}$ = Partially standardized direct effect, $\overline{ab}_{ps}$ = Partially standardized indirect effect, $\beta_{\bar{c'}_{ps}}$ = Regression slope direct effect, $\beta_{\overline{ab}_{ps}}$ = Regression slope indirect effect, $R^2_{\bar{c'}_{ps}}$ = R-squared value direct effect, $R^2_{\bar{c'}_{ps}}$ = R-squared value indirect effect, * $p < .001$. [#] We report the effect sizes for each category of this categorical moderator without an intercept

Table 5 Moderation analysis of the direct and indirect effects of gender on digital skills via ICT beliefs by study and sample characteristics

Belief dimension	Moderator variable	m	k	Intercept ($\underline{c'}_{ps}$) [95% CI]	Intercept ($\overline{ab}_{ps}$) [95% CI]	$\beta_{\overline{c'}_{ps}}$ [95% CI]	$\beta_{\overline{ab}_{ps}}$ [95% CI]	Q_M (df)	Q_E (df)	$R^2_{\overline{c'}_{ps}}$	$R^2_{\overline{ab}_{ps}}$	R^2_{σ}
Positive attitudes	Socioeconomic development	23	46	.26 [-1.19, 1.72]	-.11 [-.54, .31]	-.45 [-2.10, 1.21]	.17 [-.31, .65]	20.79 (4)**	9078.68 (42)**	0%//0%	0%//0.4%	-
	Gender inequality	23	46	-.18 [-.30, -.05]	.05 [.01, .08]	.34 [-.27, .94]	-.11 [-.34, .13]	21.20 (4)**	5638.31 (42)**	0%//3.6%	0%//1.1%	-
	Country innovation	23	46	-.01 [-.32, .30]	-.01 [-.11, .08]	.00 [-.01, .00]	.00 [.00, .00]	22.46 (4)**	6923.29 (42)**	0%//4.0%	0%//6.2%	-
	Gender gaps in ICT use	21	42	-.18 [-.31, -.05]	.04 [.00, .08]	.02 [-.03, .07]	.00 [.00, .01]	25.481 (4)**	68,441.28 (38)**	0%//100%	0%//6.1%	-
	World region#	23	46					24.63 (6)**	68,695,745.31 (40)**	0%//0%	0%//8.3%	-
	Asia and the Pacific					-.18 [-1.01, .65]	.04 [-.21, .29]					
	Latin America and the Caribbean					.08 [-.25, .42]	-.03 [-.12, .05]					
	Europe and North America					.04 [-.48, .55]	.00 [-.13, .14]					
	Digital skill#	23	46					211.19 (4)*	1319.32 (42)*	94.9%//0%	89.7%//1.3%	-
	Computer and information literacy					-.25 [-.32, -.17]	.04 [.02, .05]					
	Computational thinking					.32 [.26, .37]	-.01 [-.01, .00]					

Table 5 (continued)

Belief dimension	Moderator variable	*m*	*k*	Intercept ($\overline{c\prime_{ps}}$) [95% CI]	Intercept ($\overline{ab_{ps}}$) [95% CI]	$\beta_{\overline{c\prime_{ps}}}$ [95% CI]	$\beta_{\overline{ab_{ps}}}$ [95% CI]	Q_M (*df*)	Q_E (*df*)	$R^2_{\overline{c\prime_{ps}}}$	$R^2_{\overline{ab_{ps}}}$	R^2_{σ}
Negative attitudes	Socioeconomic development	23	46	.20 [-1.01, 1.42]	-.04 [-.25, .18]	-.34 [-1.71, 1.02]	.05 [-.19, .28]	14.65 (4)*	1989.64 (42)**	0%//-	0%//-	0%
	Gender inequality	23	46	-.13 [-.23, -.03]	.01 [-.01, .03]	.19 [-.30, .69]	.00 [-.13, .14]	14.09 (4)*	7030.03 (42)**	0%//-	0%//-	0%
	Country innovation	23	46	-.01 [-.28, .25]	.00 [-.05, .05]	.00 [-.01, .00]	.00 [.00, .00]	14.54 (4)*	1813.07 (42)**	0%//-	0%//-	0%
	Gender gaps in ICT use	21	42	-.14 [-.23, -.05]	.00 [-.01, .02]	.01 [-.03, .05]	.00 [.00, .00]	12.44 (4)*	2875.87 (38)**	0%//-	54.8%//-	0%
	World region[#]	23	46					14.74 (6)*	821.60 (40)**	0%//-	0%//-	0%
	Asia and the Pacific					-.16 [-.70, .38]	.00 [-.02, .02]					
	Latin America and the Caribbean					.07 [-.16, .30]	.00 [-.02, .02]					
	Europe and North America					.06 [-.31, .43]	.01 [-.03, .04]					
	Digital skill[#]	23	46					91.59 (4)**	17,958.86 (42)**	65.0%//-	0%//-	0%
	Computer and information literacy					-.21 [-.28, -.15]	.00 [.00, .01]					
	Computational thinking					.27 [.19, .34]	.01 [.00, .01]					

Table 5 (continued)

Belief dimension	Moderator variable	m	k	Intercept ($\bar{c'}_{ps}$) [95% CI]	Intercept ($\overline{ab}_{ps}$) [95% CI]	$\beta_{\bar{c'}_{ps}}$ [95% CI]	$\beta_{\overline{ab}_{ps}}$ [95% CI]	Q_M (df)	Q_E (df)	$R^2_{\bar{c'}_{ps}}$	$R^2_{\overline{ab}_{ps}}$	R^2_{σ}
Future expectations	Socioeconomic development	23	46	.41 [-1.00, 1.82]	-.20 [-.61, .21]	-.58 [-2.19, 1.02]	.24 [-.23, .71]	12.89 (4)*	9094.50 (42)**	0%//-	90.2%//-	0%
	Gender inequality	23	46	-.14 [-.29, .00]	.03 [-.03, .09]	.25 [-.50, 1.01]	-.11 [-.41, .19]	12.04 (4)*	8169.23 (42)**	0%//-	59.5%//-	0%
	Country innovation	23	46	.04 [-.30, .38]	-.04 [-.14, .07]	.00 [-.01, .00]	.00 [.00, .00]	12.78 (4)*	15,523.73 (42)**	0%//-	92.5%//-	0%
	Gender gaps in ICT use	21	42	-.14 [-.28, .01]	.01 [-.04, .06]	.01 [-.04, .05]	.00 [-.01, .01]	9.20 (4)	1057.21 (38)**	0%//-	0%//-	0%
	World region[#]	23	46					12.63 (6)*	13,069.19 (40)**	0%//-	89.0%//-	0%
	Asia and the Pacific					-.18 [-.86, .49]	.02 [-.17, .22]					
	Latin America and the Caribbean					.11 [-.15, .38]	-.04 [-.11, .03]					
	Europe and North America					.07 [-.39, .54]	.00 [-.14, .14]					
	Digital skill[#]	23	46					324.61 (4)**	1263.98 (42)**	60.8%//-	0%//-	49.8%
	Computer and information literacy					-.22 [-.29, -.15]	.01 [-.01, .04]					
	Computational thinking					.27 [.19, .35]	.02 [.00, .04]					

m = Number of country samples, k = Number of direct and indirect effect sizes, $\bar{c'}_{ps}$ = Partially standardized direct effect, $\overline{ab}_{ps}$ = Partially standardized indirect effect, $\beta_{\bar{c'}_{ps}}$ = Regression slope direct effect, $\beta_{\overline{ab}_{ps}}$ = Regression slope indirect effect, $R^2_{\bar{c'}_{ps}}$ = R-squared value direct effect, $R^2_{\bar{c'}_{ps}}$ = R-squared value indirect effect, * $p < .05$, ** $p < 0.001$. [#] We report the effect sizes for each category of this categorical moderator without an intercept

Table 6 Moderation analysis of the direct and indirect effects of gender on digital skills via ICT self-efficacy by study and sample characteristics

Self-efficacy dimension	Moderator variable	m	k	Intercept ($\overline{c'}_{ps}$) [95% CI]	Intercept ($\overline{ab}_{ps}$) [95% CI]	$\beta_{\overline{c'}_{ps}}$ [95% CI]	$\beta_{\overline{ab}_{ps}}$ [95% CI]	Q_M (df)	Q_E (df)	$R^2_{\overline{c'}_{ps}}$	$R^2_{\overline{ab}_{ps}}$	R^2_{γ}
Basic	Socioeconomic development	44	88	.26 [–.35, .87]	–.07 [–.36, .22]	–.41 [–1.12, .30]	.02 [–.31, .35]	51.78 (4)**	1411.75 (84)**	0%//-	0%//-	0%
	Gender inequality	43	86	–.14 [–.22, –.07]	–.04 [–.09, .00]	.30 [–.01, .61]	–.05 [–.29, .20]	49.49 (4)**	1336.45 (82)**	0%//-	0%//-	0%
	Country innovation	44	88	.01 [–.15, .18]	–.07 [–.16, .03]	.00 [–.01, .00]	.00 [.00, .00]	51.94 (4)**	1431.92 (84)**	0%//-	0%//-	0%
	Gender gaps in ICT use	40	80	–.12 [–.17, –.07]	–.06 [–.09, –.03]	.01 [–.01, .02]	.00 [.00, .01]	46.62 (4)**	981.40 (76)**	7.3%//-	0%//-	0%
	World region#	44	88					69.33 (6)**	1444.91 (82)**	1.3%//-	0.8%//-	22.2%
	Asia and the Pacific					–.07 [–.18, .05]	–.09 [–.25, .06]					
	Latin America and the Caribbean					.03 [–.09, .16]	–.01 [–.16, .13]					
	Europe and North America					–.05 [–.17, .06]	.05 [–.08, .18]					
	Digital skill#	44	88					243.46 (4)**	702.36 (84)**	70.1%//-	0%//-	0%
	Computer and information literacy					–.17 [–.21, –.13]	–.05 [–.07, –.03]					
	Computational thinking					.31 [.23, .39]	.00 [–.02, .02]					
Basic	*Assessment cycle*#	44	88					70.62 (4)**	1397.19 (84)**	19.7%//-	83.8%//-	0%
	2013					–.19 [–.23, –.14]	–.03 [–.05, –.01]					
	2018					.14 [.08, .21]	–.04 [–.09, .00]					

Table 6 (continued)

Self-efficacy dimension	Moderator variable	m	k	Intercept ($\overline{c'}_{ps}$) [95% CI]	Intercept ($\overline{ab}_{ps}$) [95% CI]	$\beta_{\overline{c'}_{ps}}$ [95% CI]	$\beta_{\overline{ab}_{ps}}$ [95% CI]	Q_M (df)	Q_E (df)	$R^2_{\overline{c'}_{ps}}$	$R^2_{\overline{ab}_{ps}}$	R^2_{γ}
Advanced	Socioeconomic development	44	88	.02 [–.76, .80]	.17 [–.05, .40]	–.21 [–1.11, .69]	–.20 [–.45, .05]	69.05 (4)**	9850.82 (84)**	1.0%//0%	26.9%//0%	-
	Gender inequality	43	86	–.19 [–.28, –.10]	–.02 [–.04, .00]	.19 [–.24, .62]	.10 [–.02, .23]	67.82 (4)**	26055.59 (82)**	1.0%//0%	25.0%//0%	-
	Country innovation	44	88	–.11 [–.32, .10]	.05 [–.01, .11]	.00 [.00, .00]	.00 [.00, .00]	68.76 (4)**	10005.15 (84)**	0.1%//0%	18.3%//0%	-
	Gender gaps in ICT use	40	80	–.20 [–.26, –.13]	–.01 [–.03, .02]	.01 [–.01, .03]	.00 [–.01, .01]	60.96 (4)**	9527.06 (76)**	8.2%//0%	0%//0%	-
	World region[#]	44	88					58.40 (6)**	27603.17 (82)**	0%//8.3%	0%//1.0%	-
	Asia and the Pacific					–.22 [–.47, .02]	.02 [–.03, .06]					
	Latin America and the Caribbean					.09 [–.17, .36]	–.03 [–.07, .01]					
	Europe and North America					.06 [–.16, .28]	–.02 [–.07, .02]					

Table 6 (continued)

Self-efficacy dimension	Moderator variable	m	k	Intercept ($\overline{c'}_{ps}$) [95% CI]	Intercept ($\overline{ab}_{ps}$) [95% CI]	$\beta_{\overline{c'}_{ps}}$ [95% CI]	$\beta_{\overline{ab}_{ps}}$ [95% CI]	Q_M (df)	Q_E (df)	$R^2_{\overline{c'}_{ps}}$	$R^2_{\overline{ab}_{ps}}$	R^2_{γ}
Advanced	*Digital skill*#	44	88					253.22 (4)**	1725.19 (84)**	88.0%//0%	0%//14.4%	-
	Computer and information literacy					–.22 [–.27, –.18]	.00 [–.01, .01]					
	Computational thinking					.35 [.27, .42]	–.02 [–.03, .00]					
	Assessment cycle#	44	88					87.49 (4)**	127146671 (84)**	17.4%//64.7%	95.0%//14.5%	-
	2013					–.25 [–.31, –.19]	.01 [–.01, .03]					
	2018					.16 [.09, .24]	–.03 [–.06, .00]					

m = Number of country samples, k = Number of direct and indirect effect sizes, $\bar{c'}_{ps}$ = Partially standardized direct effect, $\overline{ab}_{ps}$ = Partially standardized indirect effect, $\beta_{\bar{c'}_{ps}}$ = Regression slope direct effect, $\beta_{\overline{ab}_{ps}}$ = Regression slope indirect effect, $R^2_{\bar{c'}_{ps}}$ = R-squared value direct effect, $R^2_{\bar{c'}_{ps}}$ = R-squared value indirect effect, * $p < .05$, ** $p < .001$. # We report the effect sizes for each category of this categorical moderator without an intercept

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10639-023-12272-9.

Funding Open access funding provided by University of Oslo (incl Oslo University Hospital) This work was partially supported by the Research Council of Norway through its Centres of Excellence scheme, project number 331640.

Declarations

Conflict of interest We have no known conflict of interest to disclose.

References

Aesaert, K., & van Braak, J. (2015). Gender and socioeconomic related differences in performance based ICT competences. *Computers & Education, 84*, 8–25. https://doi.org/10.1016/j.compedu.2014.12.017

Aesaert, K., & van Braak, J. (2018). Information and communication competences for students. In J. Voogt, G. Knezek, R. Christensen, & K.-W. Lai (Eds.), *Second Handbook of Information Technology in Primary and Secondary Education* (pp. 255–269). Springer International Publishing. https://doi.org/10.1007/978-3-319-71054-9_22

Aesaert, K., van Nijlen, D., Vanderlinde, R., & van Braak, J. (2014). 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. *Computers & Education, 76*, 168–181. https://doi.org/10.1016/j.compedu.2014.03.013

Ajzen, I., & Fishbein, M. (1977). Attitude-behavior relations: a theoretical analysis and review of empirical research. *Psychological Bulletin, 84*(5), 888. https://doi.org/10.1037/0033-2909.84.5.888

Andrieu, E., Borgonovi, F., & Liebender, A.-S. (2019). *The role of education and skills in* bridging *the digital gender divide: Evidence from APEC economies*.

Antonio, A., & Tuffley, D. (2014). The gender digital divide in developing countries. *Future Internet, 6*(4), 673–687. https://doi.org/10.3390/fi6040673

Asparouhov, T., & Muthén, B. (2014). Multiple-group factor analysis alignment. *Structural Equation Modeling: A Multidisciplinary Journal, 21*(4), 495–508. https://doi.org/10.1080/10705511.2014.919210

Bandura, A., Freeman, W. H., & Lightsey, R. (1999). Self-efficacy: the exercise of control. *Journal of Cognitive Psychotherapy, 13*(2), 158–166. https://doi.org/10.1891/0889-8391.13.2.158

Bandura, A. (1997). *Self-efficacy: The exercise of control* (pp. ix, 604). W H Freeman/Times Books/Henry Holt & Co.

Becker, J. D. (2007). Digital equity in education: a multilevel examination of differences in and relationships between computer access, computer use and state-level technology policies. *Education Policy Analysis Archives, 15*, 3. https://doi.org/10.14507/epaa.v15n3.2007

Bhutoria, A. (2022). Personalized education and artificial intelligence in the United States, China, and India: a systematic review using a human-in-the-loop model. *Computers and Education: Artificial Intelligence, 3*, 100068. https://doi.org/10.1016/j.caeai.2022.100068

Borgonovi, F., & Greiff, S. (2020). Societal level gender inequalities amplify gender gaps in problem solving more than in academic disciplines. *Intelligence, 79*, 101422. https://doi.org/10.1016/j.intell.2019.101422

Borokhovski, E., Pickup, D., El Saadi, L., Rabah, J., & Tamim, R. M. (2018). *Gender and ICT: meta-analysis and systematic review*. Commonwealth of Learning. 4710 Kingsway Suite 2500, Burnaby, BC V5H 4M2 Canada. Tel: 604–775–8200; Fax: 604–775–8210; e-mail: info@col.org; Web site: http://www.col.org

Broos, A. (2005). Gender and information and communication technologies (ICT) anxiety: male self-assurance and female hesitation. *CyberPsychology & Behavior, 8*(1), 21–31. https://doi.org/10.1089/cpb.2005.8.21

Broos, A., & Roe, K. (2006). The digital divide in the playstation generation: self-efficacy, locus of control and ICT adoption among adolescents. *Poetics, 34*(4), 306–317. https://doi.org/10.1016/j.poetic.2006.05.002

Burns, T., & Gottschalk, F. (Eds.). (2019). *Educating 21st Century Children: Emotional Well-being in the Digital Age*. Educational Research and Innovation; OECD Publishing. https://doi.org/10.1787/b7f33425-en

Butler, R. (2014). Chapter one - motivation in educational contexts: does gender matter? In L. S. Liben & R. S. Bigler (Eds.), *Advances in Child Development and Behavior* (Vol. 47, pp. 1–41). JAI. https://doi.org/10.1016/bs.acdb.2014.05.001

Cai, Z., Fan, X., & Du, J. (2017). Gender and attitudes toward technology use: a meta-analysis. *Computers & Education, 105*, 1–13. https://doi.org/10.1016/j.compedu.2016.11.003

Campos, D. G., Cheung, M.W.-L., & Scherer, R. (2023). A primer on synthesizing individual participant data obtained from complex sampling surveys: a two-stage IPD meta-analysis approach. *Psychological Methods*. https://doi.org/10.1037/met0000539

Cheung, M.W.-L. (2013). Multivariate meta-analysis as structural equation models. *Structural Equation Modeling: A Multidisciplinary Journal, 20*(3), 429–454. https://doi.org/10.1080/10705511.2013.797827

Claro, M., Preiss, D. D., San Martín, E., Jara, I., Hinostroza, J. E., Valenzuela, S., Cortes, F., & Nussbaum, M. (2012). Assessment of 21st century ICT skills in Chile: test design and results from high school level students. *Computers & Education, 59*(3), 1042–1053. https://doi.org/10.1016/j.compedu.2012.04.004

Colley, A., & Comber, C. (2003). Age and gender differences in computer use and attitudes among secondary school students: what has changed? *Educational Research, 45*(2), 155–165. https://doi.org/10.1080/0013188032000103235

Cooper, J. (2006). The digital divide: the special case of gender. *Journal of Computer Assisted Learning, 22*(5), 320–334. https://doi.org/10.1111/j.1365-2729.2006.00185.x

Curran, P. J., & Hussong, A. M. (2009). Integrative data analysis: the simultaneous analysis of multiple data sets. *Psychological Methods, 14*(2), 81. https://doi.org/10.1037/a0015914

Desai, M., Mitani, A. A., Bryson, S. W., & Robinson, T. (2016). Multiple imputation when rate of change is the outcome of interest. *Journal of Modern Applied Statistical Methods: JMASM, 15*(1), 160–192. https://doi.org/10.22237/jmasm/1462075740

Durndell, A., & Haag, Z. (2002). Computer self efficacy, computer anxiety, attitudes towards the internet and reported experience with the internet, by gender, in an east european sample. *Computers in Human Behavior, 18*(5), 521–535. https://doi.org/10.1016/S0747-5632(02)00006-7

Dutta, S., Lanvin, B., & Wunsch-Vincent, S. (2018). *Global Innovation Index 2018: Energizing the World with Innovation*. World Intellectual Property Organization. https://doi.org/10.34667/tind.28174

Dutta, S., & Lanvin, B. (Eds.). (2013). *The global innovation index 2013: The local dynamics of innovation*. World Intellectual Property Organization. https://www.wipo.int/edocs/pubdocs/en/economics/gii/gii_2013.pdf.

Erdogdu, F., & Erdogdu, E. (2022). Understanding students' attitudes towards ICT. *Interactive Learning Environments*, 1–19. https://doi.org/10.1080/10494820.2022.2073455

Ferrari, A., & Punnie, Y. (2013). *DIGCOMP: A framework for developing and understanding digital competence in Europe*. Publications Office of the European Union. https://data.europa.eu/doi/https://doi.org/10.2788/52966

Ferrari, A. (2012). *Digital competence in practice: An analysis of frameworks*. Publications Office of the European Union. https://data.europa.eu/doi/10.2791/82116.

Ferro, E., Helbig, N. C., & Gil-Garcia, J. R. (2011). The role of IT literacy in defining digital divide policy needs. *Government Information Quarterly, 28*(1), 3–10. https://doi.org/10.1016/j.giq.2010.05.007

Fraillon, J., Schulz, W., & Ainley, J. (2013a). *International computer and information literacy study: Assessment framework*. IEA Secretariat.

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Gebhardt, E. (2014). Preparing for life in a digital age: the IEA international computer and information literacy study international report. *Springer International Publishing*. https://doi.org/10.1007/978-3-319-14222-7

Fraillon, J., Ainley, J., Schulz, W., Duckworth, D., & Friedman, T. (2019b). IEA international computer and information literacy study 2018 assessment framework. *Springer International Publishing*. https://doi.org/10.1007/978-3-030-19389-8

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Duckworth, D. (2020b). Preparing for life in a digital world: IEA international computer and information literacy study 2018 international report. *Springer International Publishing*. https://doi.org/10.1007/978-3-030-38781-5

Fraillon, J., Schulz, W., Friedman, T., Ainley, J., & Gebhardt, E. (Eds.). (2013b). *IEA International Computer and Information Literacy Study 2013: Technical report*. International Association for the Evaluation of Educational Achievement (IEA). https://www.iea.nl/sites/default/files/2019-04/ICILS_2013_Technical_Report.pdf

Fraillon, J., Schulz, W., Gebhardt, E., & Ainley, J. (2015). *National Assessment Program : ICT Literacy Years 6 & 10 Report 2014*. Australian Curriculum, Assessment and Reporting Authority (ACARA). https://research.acer.edu.au/ict_literacy/11

Fraillon, J., Ainley, J., Schulz, W., Duckworth, D., & Friedman, T. (2019a). *IEA international computer and information literacy study 2018 Assessment Framework*. Springer Open; International Association for the Evaluation of Educational Achievement (IEA). https://doi.org/10.1007/978-3-030-19389-8

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Duckworth, D. (Eds.). (2020a). *IEA International Computer and Information Literacy Study 2018: Technical report*. International Association for the Evaluation of Educational Achievement (IEA. https://files.eric.ed.gov/fulltext/ED610699.pdf.

Fu, J. S. (2013). ICT in education: a critical literature review and its implications. *International Journal of Education and Development Using Information and Communication Technology, 9*(1), 112–125. Publicly Available Content Database; Social Science Premium Collection.

Gallardo-Echenique, E. E., de Oliveira, J. M., Marqués-Molias, L., & Esteve-Mon, F. (2015). Digital competence in the knowledge. *Society, 11*(1), 16.

Gebhardt, E., Thomson, S., Ainley, J., & Hillman, K. (2019). *Gender Differences in Computer and Information Literacy: An In-depth Analysis of Data from ICILS* (Vol. 8). Springer International Publishing. https://doi.org/10.1007/978-3-030-26203-7

Gebhardt, E., Thomson, S., Ainley, J., & Hillman, K. (2019). Student achievement and beliefs related to computer and information literacy. In E. Gebhardt, S. Thomson, J. Ainley, & K. Hillman (Eds.), *Gender Differences in Computer and Information Literacy: An In-depth Analysis of Data from ICILS* (pp. 21–31). Springer International Publishing. https://doi.org/10.1007/978-3-030-26203-7_3

Gebhardt, E., Thomson, S., Ainley, J., & Hillman, K. (2019). Students' interest and enjoyment in, and patterns of use of ICT. In E. Gebhardt, S. Thomson, J. Ainley, & K. Hillman (Eds.), *Gender Differences in Computer and Information Literacy* (Vol. 8, pp. 33–52). Springer International Publishing. https://doi.org/10.1007/978-3-030-26203-7_4

Gnambs, T. (2021). The development of gender differences in information and communication technology (ICT) literacy in middle adolescence. *Computers in Human Behavior, 114*, 106533. https://doi.org/10.1016/j.chb.2020.106533

González-Betancor, S. M., López-Puig, A. J., & Cardenal, M. E. (2021). Digital inequality at home. the school as compensatory agent. *Computers & Education, 168*, 104195. https://doi.org/10.1016/j.compedu.2021.104195

Goudeau, S., Sanrey, C., Stanczak, A., Manstead, A., & Darnon, C. (2021). Why lockdown and distance learning during the COVID-19 pandemic are likely to increase the social class achievement gap. *Nature Human Behaviour, 5*(10), 10. https://doi.org/10.1038/s41562-021-01212-7

Hallquist, M. N., & Wiley, J. F. (2018). *MplusAutomation*: an R package for facilitating large-scale latent variable analyses in *Mplus*. *Structural Equation Modeling: A Multidisciplinary Journal, 25*(4), 621–638. https://doi.org/10.1080/10705511.2017.1402334

Hargittai, E. (2010). Digital Na(t)ives? variation in internet skills and uses among members of the "net Generation"*. *Sociological Inquiry, 80*(1), 92–113. https://doi.org/10.1111/j.1475-682X.2009.00317.x

Hatlevik, O. E., & Christophersen, K.-A. (2013). Digital competence at the beginning of upper secondary school: identifying factors explaining digital inclusion. *Computers & Education, 63*, 240–247. https://doi.org/10.1016/j.compedu.2012.11.015

Hatlevik, O. E., Throndsen, I., Loi, M., & Gudmundsdottir, G. B. (2018). Students' ICT self-efficacy and computer and information literacy: determinants and relationships. *Computers & Education, 118*, 107–119. https://doi.org/10.1016/j.compedu.2017.11.011

Hurwitz, L. B., & Schmitt, K. L. (2020). Can children benefit from early internet exposure? short- and long-term links between internet use, digital skill, and academic performance. *Computers & Education, 146*, 103750. https://doi.org/10.1016/j.compedu.2019.103750

ITU. (2020). *Manual for measuring ICT access and use by households and individuals* (2020th ed.). International Telecommunication Union.

ITU. (2014). *Manual for measuring ICT access and use by households and individuals*. International Telecommunication Union. https://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-ITCMEAS-2014-PDF-E.pdf.

Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of computer-supported collaborative learning: how to support collaborative learning? how can technologies help? *Educational Psychologist, 51*(2), 247–265. https://doi.org/10.1080/00461520.2016.1158654

Kaarakainen, M.-T., Kivinen, A., & Kaarakainen, S.-S. (2017). Differences between the genders in ICT skills for Finnish upper comprehensive school students: Does gender matter? *Seminar Net*, *13*(2). https://doi.org/10.7577/seminar.2304

Kaarakainen, M.-T., Kivinen, O., & Vainio, T. (2018). Performance-based testing for ICT skills assessing: A case study of students and teachers' ICT skills in Finnish schools. *Universal Access in the Information Society, 17*(2), 349–360. https://doi.org/10.1007/s10209-017-0553-9

Kemp, A., Palmer, E., & Strelan, P. (2019). A taxonomy of factors affecting attitudes towards educational technologies for use with technology acceptance models. *British Journal of Educational Technology, 50*(5), 2394–2413. https://doi.org/10.1111/bjet.12833

Kim, H.-S., Kil, H.-J., & Shin, A. (2014). An analysis of variables affecting the ICT literacy level of korean elementary school students. *Computers & Education, 77*, 29–38. https://doi.org/10.1016/j.compedu.2014.04.009

Kim, N. J., Belland, B. R., & Walker, A. E. (2018). Effectiveness of computer-based scaffolding in the context of problem-based learning for stem education: bayesian meta-analysis. *Educational Psychology Review, 30*(2), 397–429. https://doi.org/10.1007/s10648-017-9419-1

Koch, S. C., Müller, S. M., & Sieverding, M. (2008). Women and computers. effects of stereotype threat on attribution of failure. *Computers & Education, 51*(4), 1795–1803. https://doi.org/10.1016/j.compedu.2008.05.007

Lim, K., & Meier, E. B. (2011). Different but similar: computer use patterns between young korean males and females. *Educational Technology Research and Development, 59*(4), 575–592. https://doi.org/10.1007/s11423-011-9206-5

Lu, Y., & Bolt, D. M. (2015). Examining the attitude-achievement paradox in PISA using a multilevel multidimensional IRT model for extreme response style. *Large-Scale Assessments in Education, 3*(1), 2. https://doi.org/10.1186/s40536-015-0012-0

Lythreatis, S., Singh, S. K., & El-Kassar, A.-N. (2022). The digital divide: a review and future research agenda. *Technological Forecasting and Social Change, 175*, 121359. https://doi.org/10.1016/j.techfore.2021.121359

McShane, B. B., & Böckenholt, U. (2022). Multilevel multivariate meta-analysis made easy: an introduction to MLMVmeta. *Behavior Research Methods*. https://doi.org/10.3758/s13428-022-01892-7

Meelissen, M. R. M., & Drent, M. (2008). Gender differences in computer attitudes: does the school matter? *Computers in Human Behavior, 24*(3), 969–985. https://doi.org/10.1016/j.chb.2007.03.001

Millsap, R. E. (2011). Statistical approaches to measurement invariance. *Routledge*. https://doi.org/10.4324/9780203821961

Min, I., Cortina, K. S., & Miller, K. F. (2016). Modesty bias and the attitude-achievement paradox across nations: a reanalysis of TIMSS. *Learning and Individual Differences, 51*, 359–366. https://doi.org/10.1016/j.lindif.2016.09.008

Muthén, L. K., & Muthén, B. O. (1998-2017). *Mplus User's Guide* (8th ed.). Los Angeles, CA: Muthén & Muthén.

OECD. (2011). *PISA 2009 Results: Students On Line: Digital Technologies and Performance (Volume VI)*. PISA, OECD Publishing. https://doi.org/10.1787/9789264112995-en.
OECD. (2015). *Students, Computers and Learning: Making the Connection*. PISA, OECD Publishing. https://doi.org/10.1787/9789264239555-en
OECD. (2018). *Bridging the digital gender divide: Include, upskill, innovate*. PISA, OECD Publishing. https://www.oecd.org/digital/bridging-the-digital-gender-divide.pdf
OECD. (2022). Access to computers from home (indicator) [Data repository]. OECD Data. https://data.oecd.org/ict/accessto-computers-from-home.htm#indicator-chart
Petko, D., Cantieni, A., & Prasse, D. (2017). Perceived quality of educational technology matters: a secondary analysis of students' ICT use, ICT-related attitudes, and PISA 2012 test scores. *Journal of Educational Computing Research, 54*(8), 1070–1091. https://doi.org/10.1177/0735633116649373
Pick, J. B., & Nishida, T. (2015). Digital divides in the world and its regions: a spatial and multivariate analysis of technological utilization. *Technological Forecasting and Social Change, 91*, 1–17. https://doi.org/10.1016/j.techfore.2013.12.026
Polat, R. K. (2012). Digital exclusion in Turkey: a policy perspective. *Government Information Quarterly, 29*(4), 589–596. https://doi.org/10.1016/j.giq.2012.03.002
Punter, R. A., Meelissen, M. R., & Glas, C. A. (2017). Gender differences in computer and information literacy: an exploration of the performances of girls and boys in ICILS 2013. *European Educational Research Journal, 16*(6), 762–780. https://doi.org/10.1177/1474904116672468
Pustejovsky, J. E., & Tipton, E. (2022). Meta-analysis with robust variance estimation: expanding the range of working models. *Prevention Science, 23*, 425–438. https://doi.org/10.1007/s11121-021-01246-3
Riley, R. D., Lambert, P. C., & Abo-Zaid, G. (2010). Meta-analysis of individual participant data: rationale, conduct, and reporting. *BMJ, 340*, c221–c221. https://doi.org/10.1136/bmj.c221
Rohatgi, A., Scherer, R., & Hatlevik, O. E. (2016). The role of ICT self-efficacy for students' ICT use and their achievement in a computer and information literacy test. *Computers & Education, 102*, 103–116. https://doi.org/10.1016/j.compedu.2016.08.001
Rubin, D. (1987). *Multiple Imputation for Nonresponse in Surveys*. Wiley Series in Probability and Statistics.
Samuelsson, U., & Olsson, T. (2014). Digital inequality in primary and secondary education: findings from a systematic literature review. In M. Stocchetti (Ed.), *Media and education in the digital age: Concepts, assessments, subversions* (pp. 41–62). Peter Lang.
Santosham, S., & Lindsey, D. (2015). *Connected women 2015-bridging the gender gap: Mobile access and usage in low and middle income countries*. Groupe Speciale Mobile Association.
Scheerder, A., van Deursen, A., & van Dijk, J. (2017). Determinants of internet skills, uses and outcomes. a systematic review of the second- and third-level digital divide. *Telematics and Informatics, 34*(8), 1607–1624. https://doi.org/10.1016/j.tele.2017.07.007
Scherer, R., Tondeur, J., Siddiq, F., & Baran, E. (2018). The importance of attitudes toward technology for pre-service teachers' technological, pedagogical, and content knowledge: comparing structural equation modeling approaches. *Computers in Human Behavior, 80*, 67–80. https://doi.org/10.1016/j.chb.2017.11.003
Scherer, R., & Siddiq, F. (2019). The relation between students' socioeconomic status and ICT literacy: Findings from a meta-analysis. *Computers & Education, 138*, 13–32. https://doi.org/10.1016/j.compedu.2019.04.011
Scherer, R., Siddiq, F., & Nilsen, T. (2021). *The potential of international large-scale assessments for meta-analyses in education*. PsyArXiv. https://doi.org/10.31234/osf.io/bucf9
Schwab, K., Samans, R., Zahidi, S., Leopold, T. A., Ratcheva, V., Hausmann, R., & Tyson, L. D. (2017). *The global gender gap report 2017*. World Economic Forum.
Siddiq, F., & Scherer, R. (2019). Is there a gender gap? a meta-analysis of the gender differences in students' ICT literacy. *Educational Research Review, 27*(June 2018), 205–217. https://doi.org/10.1016/j.edurev.2019.03.007
Siddiq, F., Hatlevik, O. E., Olsen, R. V., Throndsen, I., & Scherer, R. (2016). 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. *Educational Research Review, 19*, 58–84. https://doi.org/10.1016/j.edurev.2016.05.002
Su, R., Rounds, J., & Armstrong, P. I. (2009). Men and things, women and people: a meta-analysis of sex differences in interests. *Psychological Bulletin, 135*(6), 859–884. https://doi.org/10.1037/a0017364

Tanner-Smith, E. E., & Tipton, E. (2014). Robust variance estimation with dependent effect sizes: practical considerations including a software tutorial in stata and SPSS: robust variance estimation. *Research Synthesis Methods, 5*(1), 13–30. https://doi.org/10.1002/jrsm.1091

Tate, M., Evermann, J., & Gable, G. (2015). An integrated framework for theories of individual attitudes toward technology. *Information & Management, 52*(6), 710–727. https://doi.org/10.1016/j.im.2015.06.005

Tømte, C., & Hatlevik, O. E. (2011). Gender-differences in self-efficacy ICT related to various ICT-user profiles in Finland and Norway. how do self-efficacy, gender and ICT-user profiles relate to findings from PISA 2006. *Computers & Education, 57*(1), 1416–1424. https://doi.org/10.1016/j.compedu.2010.12.011

Tyers-Chowdhury, A., & Binder, G. (2021). *What we know about the gender digital divide for girls*. UNICEF.

UNDP. (2022). *Human Development Report 2021-22*. United Nations Development Programme. http://report.hdr.undp.org.

UNESCO. (2021). *UNESCO Science Report 2021: The Race Against Time for Smarter Development* (S. Schneegans; T. Straza; J. Lewis). UNESCO Publishing. https://doi.org/10.18356/9789210058575

UNICEF. (2017). The State of the World's Children 2017: Children in a Digital World. UNICEF. https://www.unicef.org/media/48601/file/SOWC_2017_Summary_ENG.pdf

United Nations Children's Fund. (2023). *Bridging the Gender Digital Divide: Challenges and an Urgent Call for Action for Equitable Digital Skills Development*. UNICEF.

van Buuren, S., & Groothuis-Oudshoorn, K. (2011). Mice: multivariate imputation by chained equations in R. *Journal of Statistical Software, 45*, 1–67. https://doi.org/10.18637/jss.v045.i03

van Deursen, A. J. A. M., & van Diepen, S. (2013). Information and strategic internet skills of secondary students: a performance test. *Computers & Education, 63*, 218–226. https://doi.org/10.1016/j.compedu.2012.12.007

van Deursen, A. J., & van Dijk, J. A. (2014). The digital divide shifts to differences in usage. *New Media & Society, 16*(3), 507–526. https://doi.org/10.1177/1461444813487959

van Deursen, A. J. A. M., van der Zeeuw, A., de Boer, P., Jansen, G., & van Rompay, T. (2021). Digital inequalities in the internet of things: differences in attitudes, material access, skills, and usage. *Information, Communication & Society, 24*(2), 258–276. https://doi.org/10.1080/1369118X.2019.1646777

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: a systematic literature review. *Computers in Human Behavior, 72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Van de gaer, E., Grisay, A., Schulz, W., & Gebhardt, E. (2012). The reference group effect: an explanation of the paradoxical relationship between academic achievement and self-confidence across countries. *Journal of Cross-Cultural Psychology, 43*, 1205–1228. https://doi.org/10.1177/0022022111428083

Van Dijk, J. (2020). *The Digital Divide*. John Wiley & Sons.

Vekiri, I., & Chronaki, A. (2008). Gender issues in technology use: perceived social support, computer self-efficacy and value beliefs, and computer use beyond school. *Computers & Education, 51*(3), 1392–1404. https://doi.org/10.1016/j.compedu.2008.01.003

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software, 36*(1), 1. https://doi.org/10.18637/jss.v036.i03

Vogel, F., Wecker, C., Kollar, I., & Fischer, F. (2017). Socio-cognitive scaffolding with computer-supported collaboration scripts: a meta-analysis. *Educational Psychology Review, 29*(3), 477–511. https://doi.org/10.1007/s10648-016-9361-7

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: implications for national curriculum policies. *Journal of Curriculum Studies*. https://doi.org/10.1080/00220272.2012.668938

Wang, Z. (2020). When large-scale assessments meet data science: the big-fish-little-pond effect in fourth- and eighth-grade mathematics across nations. *Frontiers in Psychology, 11*(579545), 1–17. https://doi.org/10.3389/fpsyg.2020.579545

Whitley, B. E. (1997). Gender differences in computer-related attitudes and behavior: a meta-analysis. *Computers in Human Behavior, 13*(1), 1–22. https://doi.org/10.1016/S0747-5632(96)00026-X

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25*(1), 68–81. https://doi.org/10.1006/ceps.1999.1015

Zhang, P., Aikman, S. N., & Sun, H. (2008). Two types of attitudes in ICT acceptance and use. *International Journal of Human-Computer Interaction, 24*(7), 628–648. https://doi.org/10.1080/10447310802335482

Zhao, Y., Pinto Llorente, A. M., & Sánchez Gómez, M. C. (2021). Digital competence in higher education research: a systematic literature review. *Computers & Education, 168*, 104212. https://doi.org/10.1016/j.compedu.2021.104212

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.