



## 2022 Methodology Report

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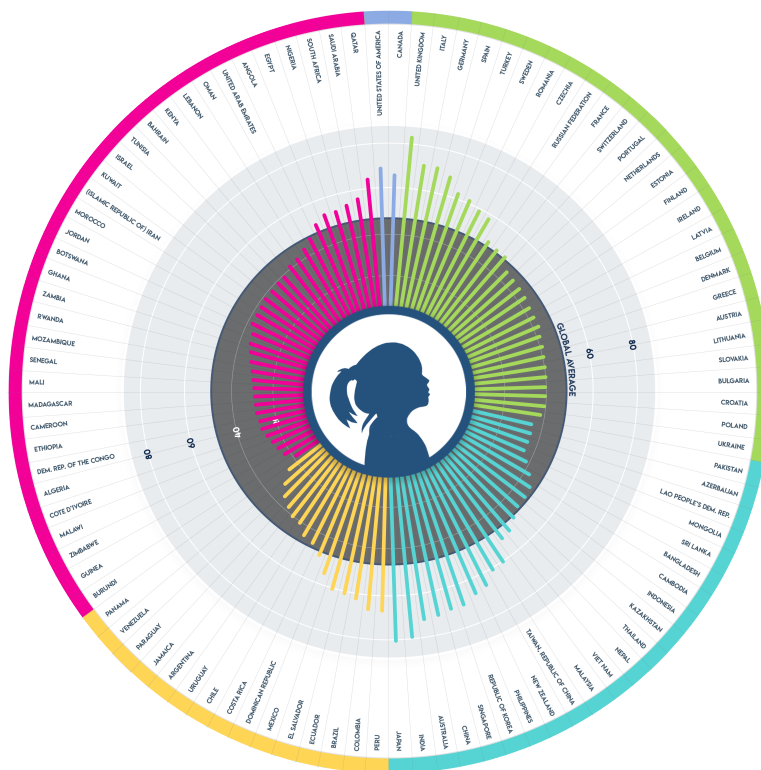
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## ABOUT 2022 COSI

**The Child Online Safety Index (COSI) is a national-level measure to guide child online safety improvement.** Through COSI, nations can identify areas of improvement for their children’s online safety across six stakeholders: children, families, schools, ICT companies, and soft and hard infrastructures of the government. Global benchmarking will make targeting those areas more effective and improve the deployment of relevant programs and initiatives. Actors can then effectively coordinate efforts to enhance child online safety and digital citizenship within their nations, with the ability to measure the national progress.

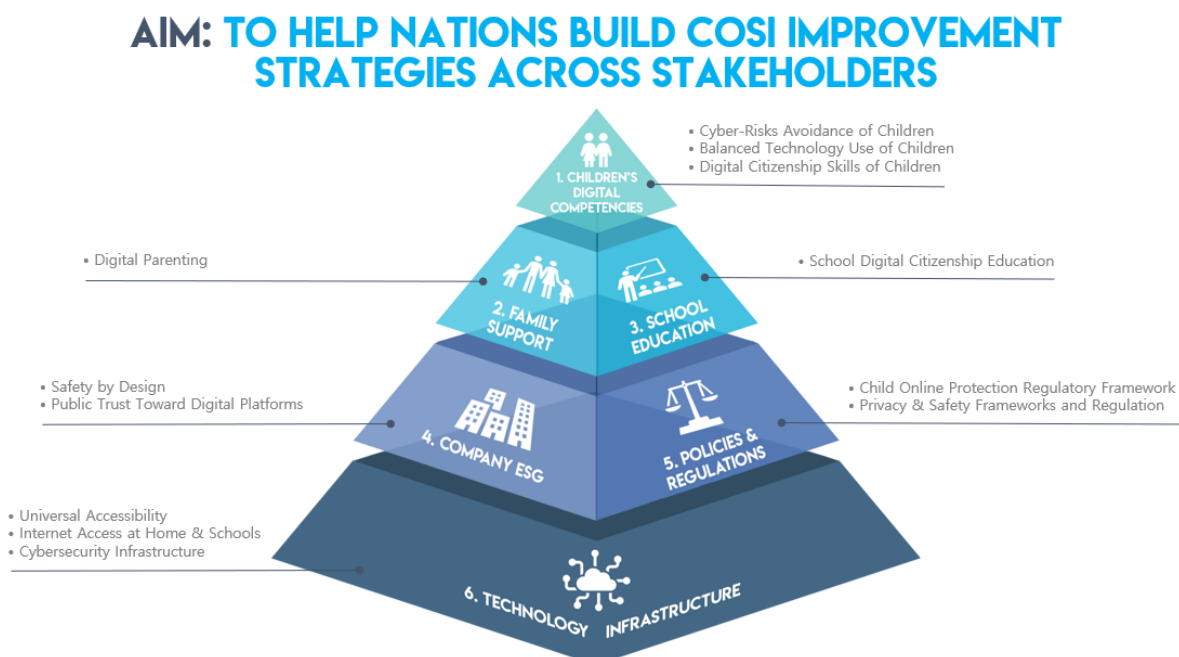
The inaugural COSI was released on Safer Internet Day, February 11, 2020, and the 2022 COSI marks the second publication in the series. The 2022 COSI captures the post-COVID-19 pandemic global status of child online safety based on the DQ Institute’s global databank. This report is developed based on data from 329,142 children and adolescents across 100 countries, collected from the DQ Institute’s impact tracker and publicly available external sources (i.e., international research projects and publications).

The methodology for the index scoring and data collection has been updated from that of the 2020 COSI, based on the feedback received. Thus, the scores in 2022 COSI are not directly comparable to those in the 2020 COSI.

## THE 2022 COSI ASSESSMENT FRAMEWORK

The COSI score represents the overall level of a nation's performance on child online safety measures. The 2022 COSI scoring system is based on 35 indicators related to 12 topics of child online safety across 6 stakeholders—namely, children, families, schools, ICT companies, and soft and hard infrastructures of the government. Each stakeholder score is measured based on the topic scores that belong to each stakeholder, and each topic score is measured based on the indicator scores that belong to each topic, in a hierarchical structure (See Figure 1 and Table 1 for better visualization). Stakeholder scores, rigorously defined by the Performance Level Descriptors (PLDs), are designed to give policymakers and national leaders a better understanding of their countries' performance on child online safety. Topic scores are the indicators of performance in different areas of stakeholders' efforts. The indicator scores can be used to develop assessment instruments, learning curriculum, and/or tasks for relevant groups within each stakeholder.

FIGURE 1. THE 2022 COSI FRAMEWORK



**TABLE 1. THE 2022 COSI FRAMEWORK: INDICATORS, TOPICS, AND STAKEHOLDERS**

6 STAKEHOLDERS					
Stakeholder 1: Children's Digital Competencies for Child Online Safety	Stakeholder 2: Family Support for Child Online Safety	Stakeholder 3: School Education for Child Online Safety	Stakeholder 4: Company Digital-ESG for Child Online Safety	Stakeholder 5: Government Policies and Regulation for Child Online Safety	Stakeholder 6: Technology Infrastructure for Child Online Safety
12 TOPICS					
Cyber-Risks Avoidance of Children  Disciplined Technology Use of Children  Digital Citizenship Skills of Children	Digital Parenting	School Digital Citizenship Education and Policies	Safety by Design  Public Trust Toward Digital Platform	Child Online Protection Regulatory Framework  Privacy & Safety Frameworks and Regulation	Universal Accessibility  Internet Access at Home and Schools  Cybersecurity Infrastructure
35 INDICATORS					
Avoidance of cyber-bullying and -victimization Avoidance of personal data misuse Avoidance of pathological overuse of technology Avoidance of risky contact Avoidance of risky content Avoidance of excessive screen time Avoidance of technology overuse Avoidance of underage social media use Digital citizen identity skills of children Balanced use of technology skills of children Behavioral cyber-risk management skills of children Personal cyber security management skills of children Digital empathy skills of children Digital footprint management skills of children Media and info literacy skills of children Privacy management skills of children	Parental mediation for children and adolescents  Trust networks to support children at cyber-risks	School digital citizenship education  Governmental support for digital literacy	CSAM (Child Sexual Abuse Materials) Reporting  Trust in government websites and apps Trust in ICT sector  Trust in private sector website and apps	Legal framework against CSAM  Legal framework against online grooming  Privacy frameworks and regulation	Internet access  Device access  Internet affordability  Internet quality  Network coverage Device and Internet access - Home  Device and Internet access - School  Global Cybersecurity Index

## COMPUTATION OF SCORES



As mentioned above, the COSI score is calculated by successively combining the scores from each level of the hierarchy. The 6 Stakeholder scores combine the scores of 12 Topics, and the 12 topic scores combine the scores of 35 indicators.

At the lowest level, each score of the 35 Indicators is standardized and measured based on a weighted average of the sub-indicators belonging to each indicator. It is then transformed to a value between 10 and 100, with 10 being the lowest and 100 being the highest possible score.

These indicator scores are combined to create a score for each of the 12 Topics, and eventually a score for each of the 6 Stakeholders. The overall COSI score is then calculated as a weighted average of the 6 Stakeholder scores.

## PERFORMANCE LEVEL DESCRIPTORS (PLDS)

Performance level descriptors are a means of describing performance in terms of levels or categories of performance. For the COSI scores, Stakeholder and Topic outcomes are reported in terms of three levels of performance: Level 1, Level 2, and Level 3.

The PLDs for Stakeholder and Topic scores can be considered policy PLDs designed for policymakers. They are general descriptors that articulate the goals and rigor for the final performance standards. These descriptors set the tone for the subsequent descriptors for Indicator scores, which can be considered as range PLDs. They are content-specific descriptors that may be used by corresponding stakeholders to guide assessment or learning development and/or resource enhancement.



	LEVEL 1	LEVEL 2	LEVEL 3
<b>COSI SCORE</b>	Stakeholders have shown thorough performance on child online safety measures on average	Stakeholders have shown partial performance on child online safety measures on average	Stakeholders have shown minimal performance on child online safety measures on average
<b>STAKEHOLDER 1: CHILDREN DIGITAL USE, BEHAVIORS, COMPETENCIES</b>			
<b>Stakeholder 1:</b> Children's Digital Competencies for Child Online Safety	Level of individual competencies for child online safety is high, compared to the global average	Level of individual competencies for child online safety is the global average	Level of individual competencies for child online safety is low, compared to the global average
<b>Topic 1:</b> Cyber-Risks Avoidance of Children	Avoidance of various cyber-risks among children and adolescents is high, compared to the global average	Avoidance of various cyber-risks among children and adolescents is the global average	Avoidance of various cyber-risks among children and adolescents is low, compared to the global average
<b>Indicator 1:</b> Avoidance of Cyber-Bullying and/or Cyber-Victimization	% of children and adolescents who have been involved with cyber-bullying and/or cyber-victimization is below 40%	% of children and adolescents who have been involved with cyber-bullying and/or cyber-victimization is between 40-55%	% of children and adolescents who have been involved with cyber-bullying and/or cyber-victimization is over 55%
<b>Indicator 2:</b> Avoidance of Misuse of Personal Data	% of children and adolescents who have been exposed to cyber threats is below 30%	% of children and adolescents who have been exposed to cyber threats is between 30-50%	% of children and adolescents who have been exposed to cyber threats is over 50%
<b>Indicator 3:</b> Avoidance of Pathological Overuse of Technology	% of children and adolescents who have been at high risk of technology disorder is below 3%	% of children and adolescents who have been at high risk of technology disorder is between 3-9%	% of children and adolescents who have been at high risk of technology disorder is over 9%
<b>Indicator 4:</b> Avoidance of Risky Contact	% of children and adolescents who have been exposed to risky contact is below 20%	% of children and adolescents who have been exposed to risky contact is between 20-40%	% of children and adolescents who have been exposed to risky contact is over 40%
<b>Indicator 5:</b> Avoidance of Risky Content	% of children (age 8-12) who have been exposed to risky (sexual or violent) content is below 20%	% of children (age 8-12) who have been exposed to risky (sexual or violent) content is between 20-35%	% of children (age 8-12) who have been exposed to risky (sexual or violent) content is over 35%
<b>Topic 2:</b> Disciplined Technology Use of Children	Level of excessive or illegal use of digital technology among children is low, compared to the global average	Level of excessive or illegal use of digital technology among children is the global average	Level of excessive or illegal use of digital technology among children is high, compared to the global average
<b>Indicator 6:</b> Avoidance of Excessive Screen Time	% of children and adolescents who have excessive screen time for entertainment use ( $\geq 30$ hours per week) is below 30%	% of children and adolescents who have excessive screen time for entertainment use ( $\geq 30$ hours per week) is between 30-50%	% of children and adolescents who have excessive screen time for entertainment use ( $\geq 30$ hours per week) is over 50%
<b>Indicator 7:</b> Avoidance of Technology Overuse	% of children and adolescents who show gaming disorder symptoms is below 15%	% of children and adolescents who show gaming disorder symptoms is between 15-25%	% of children and adolescents who show gaming disorder symptoms is over 25%
<b>Indicator 8:</b> Avoidance of Underage Social Media Use	% of children (age 8-12) who have illegally accessed social media is below 40%	% of children (age 8-12) who have illegally accessed social media is between 40-60%	% of children (age 8-12) who have illegally accessed social media is over 60%
<b>Topic 3:</b> Digital Citizenship Skills of Children	DQ digital citizenship scores of children and adolescents is high, compared to the global average	DQ digital citizenship scores of children and adolescents is the global average	DQ digital citizenship scores of children and adolescents is low, compared to the global average

<b>Indicator 9:</b> Digital Citizen Identity Skills of Children	Average DQ score for digital citizen identity skills is higher than 70	Average DQ score for digital citizen identity skills is between 30 and 70	Average DQ score for digital citizen identity skills is lower than 30
<b>Indicator 10:</b> Balanced Use of Technology Skills of Children	Average DQ score for balanced use of technology skills is higher than 70	Average DQ score for balanced use of technology skills is between 30 and 70	Average DQ score for balanced use of technology skills is lower than 30
<b>Indicator 11:</b> Behavioral Cyber-Risk Management Skills of Children	Average DQ score for behavioral cyber-risk management skills is higher than 70	Average DQ score for behavioral cyber-risk management skills is between 30 and 70	Average DQ score for behavioral cyber-risk management skills is lower than 30
<b>Indicator 12:</b> Personal Cyber Security Management Skills of Children	Average DQ score for personal cyber security management skills is higher than 70	Average DQ score for personal cyber security management skills is between 30 and 70	Average DQ score for personal cyber security management skills is lower than 30
<b>Indicator 13:</b> Digital Empathy Skills of Children	Average DQ score for digital empathy skills is higher than 70	Average DQ score for digital empathy skills is between 30 and 70	Average DQ score for digital empathy skills is lower than 30
<b>Indicator 14:</b> Digital Footprint Management Skills of Children	Average DQ score for digital footprint management skills is higher than 70	Average DQ score for digital footprint management skills is between 30 and 70	Average DQ score for digital footprint management skills is lower than 30
<b>Indicator 15:</b> Media and Info Literacy Skills of Children	Average DQ score for media and info literacy skills is higher than 70	Average DQ score for media and info literacy skills is between 30 and 70	Average DQ score for media and info literacy skills is lower than 30
<b>Indicator 16:</b> Privacy Management Skills of Children	Average DQ score for privacy management skills is higher than 70	Average DQ score for privacy management skills is between 30 and 70	Average DQ score for privacy management skills is lower than 30

## STAKEHOLDER 2: FAMILY SUPPORT

<b>Stakeholder 2:</b> Family Support for Child Online Safety	Level of family support for child online safety is high, compared to the global average	Level of family support for child online safety is the global average	Level of family support for child online safety is low, compared to the global average
<b>Topic 4:</b> Digital Parenting	Level of digital parenting and family support for children is high, compared to the global average	Level of digital parenting and family support for children is the global average	Level of digital parenting and family support for children is low, compared to the global average
<b>Indicator 17:</b> Parental Mediation for Children and Adolescents	% of parents who conduct digital parenting for child online safety is over 60%	% of parents who conduct digital parenting for child online safety is between 40-60%	% of parents who conduct digital parenting for child online safety is below 40%
<b>Indicator 18:</b> Trust Networks to Support Children at Cyber-Risks	% of children (age 8-12) who receive support from family in the event of cyber-risk is over 45%	% of children (age 8-12) who receive support from family in the event of cyber-risks is between 30-45%	% of children (age 8-12) who receive support from family in the event of cyber-risks is below 30%

## STAKEHOLDER 3: SCHOOL EDUCATION

<b>Stakeholder 3:</b> School Education for Child Online Safety	Level of education for child online safety is high, compared to the global average	Level of education for child online safety is the global average	Level of education for child online safety is low, compared to the global average
<b>Topic 5:</b> School Digital Citizenship Education	Level of digital literacy/cyber safety education at schools is high, compared to the global average	Level of digital literacy/cyber safety education at schools is the global average	Level of digital literacy/cyber safety education at schools is low, compared to the global average
<b>Indicator 19:</b> School Digital Citizenship Education	% of children and adolescents whose schools teach them about cyber safety is over 90%	% of children and adolescents whose schools teach them about cyber safety is between 70-90%	% of children and adolescents whose schools teach them about cyber safety is below 70%
<b>Indicator 20:</b> Governmental Support for Digital Literacy	There is a current government plan/strategy that addresses digital literacy for students and training for teachers	There is a government plan/strategy that addresses digital literacy for students, but no training for teachers (or the plan is outdated)	There is no current government plan/strategy that addresses digital literacy for students or training for teachers
<b>STAKEHOLDER 4: COMPANY DIGITAL-ESG</b>			
<b>Stakeholder 4:</b> Company Digital-ESG for Child Online Safety	Level of companies' commitment to child online safety through Digital-ESG is high, compared to the global average	Level of companies' commitment to child online safety through Digital-ESG is the global average	Level of companies' commitment to child online safety through Digital-ESG is low, compared to the global average
<b>Topic 6:</b> Safety by Design	Level of CSAM reporting among companies in leading ICT business association is high, compared to the global average	Level of CSAM reporting among companies in leading ICT business association is the global average	Level of CSAM reporting among companies in leading ICT business association is low, compared to the global average
<b>Indicator 21:</b> CSAM (Child Sexual Abuse Materials) Reporting	Both leading national (mobile) telecoms association and national internet industry association report on sexual violence against children in annual reports or codes of conduct	Either leading national (mobile) telecoms association or national internet industry association reports on sexual violence against children in annual reports or codes of conduct	Neither leading national (mobile) telecoms association nor national internet industry association reports on sexual violence against children in annual reports or codes of conduct
<b>Topic 7:</b> Public Trust Toward Digital Platforms	Level of public trust in public and private digital platforms is high, compared to the global average	Level of public trust in public and private digital platforms is the global average	Level of public trust in public and private digital platforms is low, compared to the global average
<b>Indicator 22:</b> Trust in Government Websites and Apps	% of people with trust in government websites and apps is over 60%	% of people with trust in government websites and apps is between 30-60%	% of people with trust in government websites and apps is below 30%
<b>Indicator 23:</b> Trust in ICT Sector	% of people with trust in ICT websites and apps is over 60%	% of people with trust in ICT websites and apps is between 30-60%	% of people with trust in ICT websites and apps is below 30%
<b>Indicator 24:</b> Trust in Private Sector Website and Apps	% of people with trust in private sector websites and apps is over 60%	% of people with trust in private sector websites and apps is between 30-60%	% of people with trust in private sector websites and apps is below 30%
<b>STAKEHOLDER 5: GOVERNMENT POLICIES AND REGULATION</b>			
<b>Stakeholder 5:</b> Government Policies and Regulation for Child Online Safety	Level of regulatory enforcement for child online safety is high, compared to the global average	Level of regulatory enforcement for child online safety is the global average	Level of regulatory enforcement for child online safety is low, compared to the global average
<b>Topic 8:</b> Child Online Protection Regulatory Framework	Level of regulatory enforcement for CSAM and online grooming is high, compared to the global average	Level of regulatory enforcement for CSAM and online grooming is the global average	Level of regulatory enforcement for CSAM and online grooming is low, compared to the global average
<b>Indicator 25:</b> Legal Framework Against CSAM	There are major legislations specific to CSAM	There are some legislations specific to CSAM	There is no legislation specific to CSAM

<b>Indicator 26:</b> Legal Framework Against Online Grooming	There are legislations specific to online grooming (with or without the intent to meet the child)	There are legislations specific to online grooming (with or without the intent to meet the child)	There is no legislation specific to online grooming
<b>Topic 9:</b> Privacy & Safety Frameworks and Regulation	Level of regulatory enforcement for privacy and data protection is high, compared to the global average	Level of regulatory enforcement for privacy and data protection is the global average	Level of regulatory enforcement for privacy and data protection is low, compared to the global average
<b>Indicator 27:</b> Privacy Frameworks and Regulation	Level of legislations specific to privacy regulations and data protection (e.g., e-Commerce legislation and data protection law) is high	Level of legislations specific to privacy regulations and data protection (e.g., e-Commerce legislation and data protection law) is average	Level of legislations specific to privacy regulations and data protection (e.g., e-Commerce legislation and data protection law) is low
<b>STAKEHOLDER 6: TECHNOLOGY INFRASTRUCTURE FOR CHILD ONLINE SAFETY</b>			
<b>Stakeholder 6:</b> Technology Infrastructure for Child Online Safety	Level of technology infrastructure support for child online safety is high, compared to the global average	Level of technology infrastructure support for child online safety is the global average	Level of technology infrastructure support for child online safety is low, compared to the global average
<b>Topic 10:</b> Universal Accessibility	Level of accessibility to internet and digital devices is high, compared to the global average	Level of accessibility to internet and digital devices is the global average	Level of accessibility to internet and digital devices is low, compared to the global average
<b>Indicator 28:</b> Internet Access	Level of Internet access in the nation is high	Level of Internet access in the nation is average	Level of Internet access in the nation is low
<b>Indicator 29:</b> Device Access	% of people own and use a mobile phone is over 90%	% of people own and use a mobile phone is between 60-90%	% of people own and use a mobile phone is below 60%
<b>Indicator 30:</b> Internet Affordability	Level of Internet affordability in the nation is high	Level of Internet affordability in the nation is average	Level of Internet affordability in the nation is low
<b>Indicator 31:</b> Internet Quality	Level of Internet quality in the nation is high	Level of Internet quality in the nation is average	Level of Internet quality in the nation is low
<b>Indicator 32:</b> Network Coverage	Level of network coverage in the nation is high	Level of network coverage in the nation is average	Level of network coverage in the nation is low
<b>Topic 11:</b> Internet Access at Home & Schools	Level of access and connectivity to internet at home and school is high, compared to the global average	Level of access and connectivity to internet at home and school is the global average	Level of access and connectivity to internet at home and school is low, compared to the global average
<b>Indicator 33:</b> Device and Internet Access – School	% of schools with access to computers and to the internet for pedagogical purpose is 100%	% of schools with access to computers for pedagogical purpose is between 50-99%	% of schools with access to computers and to the internet for pedagogical purpose is below 50%
<b>Indicator 34:</b> Device and Internet Access - Home	% of households with access to computers and to the internet for pedagogical purpose is 100%	% of households with access to computers and to the internet for pedagogical purpose is between 50-99%	% of households with access to computers and to the internet for pedagogical purpose is less than 50%
<b>Topic 12:</b> Cybersecurity Infrastructure	Level of cybersecurity infrastructure (legal, technical, organizational, capacity and cooperation) is high, compared to the global average	Level of cybersecurity infrastructure (legal, technical, organizational, capacity and cooperation) is the global average	Level of cybersecurity infrastructure (legal, technical, organizational, capacity and cooperation) is low, compared to the global average
<b>Indicator 35:</b> Global Cybersecurity Index	Level of national cybersecurity commitment is high	Level of national cybersecurity commitment is average	Level of national cybersecurity commitment is low

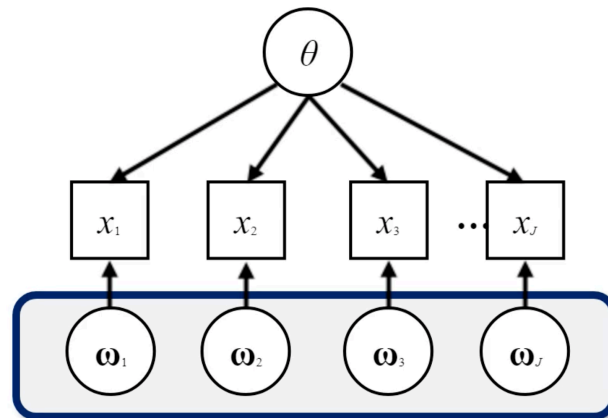
## SCORING METHODOLOGY



### 1. DQ Scoring System for Assessing Individuals' Level of Digital Citizenship using AI Bayesian Modelling

#### 1.1 Reasoning through the Machinery of the Model

In probability models, reasoning through the machinery of the model amounts to deploying the calculus of probabilities. In DQ score, we use the following probability model:

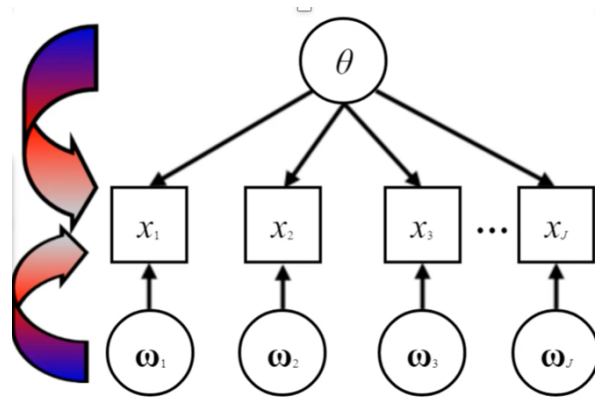


$\theta$  is the parameter for DQ score

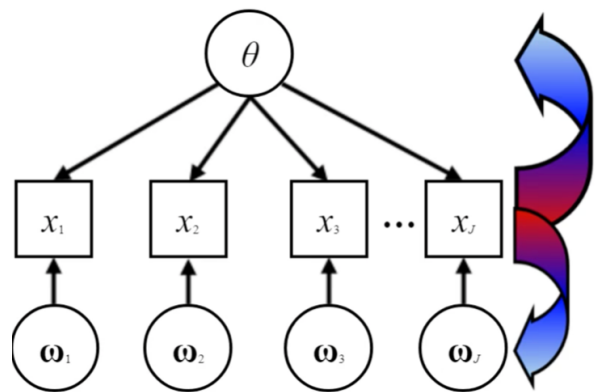
$x_j$  are observable variables summarizing learns performances on assessment  $j$

$\omega_j$  are our model parameters such as estimated difficulty of assessment  $j$  or other parameters

The model is naturally set up in such a way that given the value of  $\theta$ , and model parameters  $\omega_j$  we have (conditional) distributions for the observables  $x_j$  as in the figure below, where the arrows express the flow of reasoning in our model.



This naturally supports probabilistic deductive reasoning from the former to the latter. However, we need to reason inductively to reverse the direction of the flow as shown below, where the arrows express the flow of reasoning in our model.



Thus,

Our goal: reason from  $\mathbf{x}_j$  to make inferences about model parameters  $\theta$  and  $\omega_j$

Our strategy: set up model with a particular flow from  $\theta$  and  $\omega_j$  to  $\mathbf{x}_j$

Our result: accomplish our goal by reversing the flow based on Bayes' theorem

## Bayes' theorem

$$p(\theta|x) = \frac{p(x|\theta)p(\theta)}{p(x)} \approx p(x|\theta)p(\theta)$$

where,

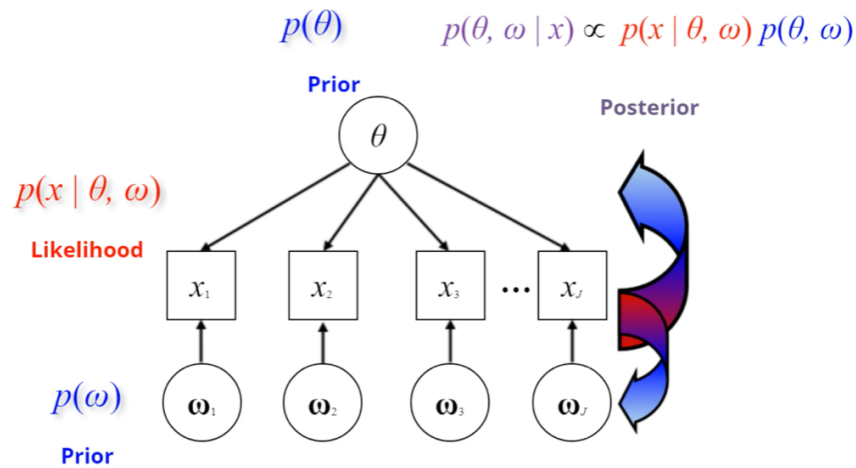
$\theta$ —as above, a parameter (i.e., DQ score)

$p(x|\theta)$ —likelihood of parameter  $\theta$  given data  $x$

$p(\theta)$ —the prior distribution of  $\theta$

$p(\theta|x)$ —posterior distribution of  $\theta$  given  $x$

Therefore, to do the reversal means to obtain  $p(\theta, \omega|x)$  by synthesizing  $p(x|\theta, \omega)$  with the prior distribution  $p(\theta)$ , where  $p(x|\theta, \omega) = \prod_{j=1}^J p(x_j | \theta, \omega_j)$  captures the evidentiary value of our observations.



Via common exchangeability and conditional independence, Bayes' Theorem looks like the following:

$$p(\theta, \omega|x) \sim \prod_{j=1}^J p(x_j | \theta, \omega_j) p(\theta) p(\omega_j)$$

Bringing commonly used probability distribution into Bayes' Theorem, we have

$$x_j | \theta, \omega_j \sim \text{Bernouli}[\psi(\theta, \omega_j)]$$

where  $\psi$  is a cumulative logistic distribution.

$$\theta \sim N(\mu_0, \sigma_\theta^2)$$

where N is normal distribution with mean  $\mu_0$  and standard deviation  $\sigma_\theta^2$ .

$$\omega_i \sim N^+(\mu_0, \sigma_\omega^2)$$

where  $N^+$  is truncated at 0 normal distribution.

## 1.2 Propagating Uncertainty and Missing Data

Conventional approaches to modeling often proceed in stages in such a way that the uncertainty at one stage is ignored at later stages. For example, modeling and inference commonly proceed by first obtaining estimates of parameters of some models, which are then treated as known for estimation. Using Bayesian allows us to incorporate and propagate uncertainty throughout all aspects of our modeling, including parameter estimation and the management of missing data  $\mathbf{x}_j$ . The missing data, for example, can be viewed as a parameter and thus can be learned.

## 1.3 Accumulation of Evidence

Importantly, Bayesian theorem allows us to accumulate evidence. The posterior distribution is a synthesis of the prior and the data. With little data  $\mathbf{x}_j$ , the solution is more heavily influenced by the prior and less so by the data. As more data arrive, they swamp the prior such that the solution becomes increasingly like what the data alone dictate.

As a result, analysts with different prior beliefs (and prior distributions) may have very different conclusions if there is no or little data. When more data are increasingly incorporated, conclusions converge, and posterior distributions resemble each other. A related point concerns the accumulation of evidence as data arrive.

Let  $\mathbf{x}_1$  and  $\mathbf{x}_2$  be data from two tests. Let these data be independent, given DQ score  $\theta$ .

$$p(\theta|\mathbf{x}_1, \mathbf{x}_2) \sim p(\mathbf{x}_1, \mathbf{x}_2|\theta)p(\theta) =$$

using factorization of the conditional probability of the test  $\mathbf{x}_1$  and  $\mathbf{x}_2$  data

$$= p(\mathbf{x}_2|\theta, \mathbf{x}_1)p(\mathbf{x}_1|\theta)p(\theta) =$$



using an assumption that scores of test  $x_1$  and test  $x_2$  are independent given the value  $\theta$  of DQ score

$$\begin{aligned}
 &= p(x_2|\theta)p(x_1|\theta)p(\theta) \sim \\
 &\quad \text{using Bayes' theorem} \\
 &\sim p(x_2|\theta, ) p(\theta|x_1)/p(\theta)]p(\theta) \\
 &= p(x_2|\theta)p(\theta|x_1)
 \end{aligned}$$

Where  $p(x_2|\theta)$  is the conditional probability of the (new) data.  
 $p(\theta|x_1)$  is the prior distribution for the value  $\theta$  of DQ score (prior to having observed  $x_2$ ).  
 It could also be looked at as the posterior distribution for value  $\theta$  of DQ score given  $x_1$ .

Thus, the equation above shows that we begin with a prior distribution for the unknowns,  $p(\theta)$  and by incorporating the first dataset we have the posterior distribution  $p(\theta|x_1)$ , which in turn serves as the prior distribution when incorporating the second dataset,  $x_2$ . At any point, our “current” distribution is both a posterior distribution and a prior distribution: it is posterior to the past data and prior to future data—today’s posterior is just tomorrow’s prior.

## 1.4 Conceptual Simplicity and Missing Data

A fully Bayesian analysis offers considerable simplicity for how to proceed: if  $\theta$  is unknown it gets a prior distribution, and once we condition on what we do know, we have a posterior distribution. More broadly, terminological variations for conveying distinctions among the roles that a latent variable, parameter, or missing data point may play, a fully Bayesian analysis offers considerable simplicity for how to proceed. This conceptual simplicity translates to technical matters. Indeed, estimating posterior distributions remains the same regardless of what we call  $\theta$ , and in Markov chain Monte Carlo (MCMC) strategies, obtaining a posterior distribution for unknown  $x$ , often referred to as missing data, is the same as for unknown  $\theta$  regardless of what we call it.

## 1.5 Linking Methodology

Furthermore, as we have used the two different assessment tools: DQ World and DQ Assessment API, we have used the following linking statistical moderation technique to establish a link between different assessments used in indicator scores. In this approach, assessment I results are expressed in the metric of assessment J.

**Definition:** A score on the assessment I and a score on the assessment J are equivalent in a group of test takers (I and J are linked), if they represent the same relative position in the group.

We can rewrite this definition with an adjustment that defines “relative position” in terms of the mean and the standard deviation. For example, a score on I and a score on J are equivalent in a group of test takers, if they are the same number of standard deviations above or below the mean of the group.

Therefore, the definition can be written as simple mathematical formulas:

$$\frac{I - \text{mean}(I)}{SD(I)} = \frac{J - \text{mean}(J)}{SD(J)}$$

Solving this equation for J gives us a formula for linking I and J:

$$J = \left( \frac{SD(J)}{SD(I)} \right) I + \left[ \text{mean}(J) - \left( \frac{SD(J)}{SD(I)} \right) \text{mean}(I) \right] = \text{adjusted } I$$

The adjusted scores on I have the same mean and the standard deviation as the raw scores on J. That is what it means in statistical moderation to say, “Test I is linked to test J.”

Since the means and the standard deviations for I and J are constants, the linking adjustment consists simply of multiplying the test taker’s score on I by one number and adding another number.

## 2. Development of National-Level Indicator Scores

The national-level scores for sub-indicators are developed based on the calculated DQ scores of individuals. Moreover, we have aggregated other national-level sub-indicators that have been developed from various external data sources. To develop the indicator scores from these sub-indicators collected from various sources, we have used the following standardization methodology:

1. Scaling each sub-indicators into the scale of 0 to 1, using a scaling formula of (the observed value – the minimum value) / (the maximum value – the minimum value)
2. Missing data imputation
3. Normalization of sub-indicators, using a normalization formular of (the scaled value – mean value of the sub-indicator) / standard deviation value of the sub-indicator
4. Scaling to the scale of 10 to 100

### 3. Missing Data Imputation

COSI includes the indicators from multiple internal and external data sources from year 2017 to 2022. Before the normalization of the indicators, the missing country data have been estimated following the two processes below:

1. When some data of a particular country from a particular year are missing (and those of the other years are present), we impute the missing data by the principles of Last Observation Carried Forward (LOCF) and Next Observation Carried Backward (NOCB).
2. For those missing values of country data on the sub-indicator(s), the multiple logistic regression prediction models are used when strong predictors in other indicator values are available with greater than 0.3 R square value. In the absence of such values, a 25-percentile value of the corresponding sub-indicator is imputed.

### 4. Adjustments Based on the Age Group and Data Sources

Due to convenience sampling, the number of participants is not equal across the age groups. Thus, we check for statistically significant differences between the age groups and across four data sources. When statistically significant differences are found, we calculate the measures separately and develop a weighted average based on the sampling size as well as the geographic representation of the data sources.

## DATA

DQ Institute has been serving as a knowledge hub that develops a global databank for aggregated data related to child online safety and digital citizenship education. The DQ databank combines national-level data from external sources with individual-level data from DQ Impact Tracker that is linked to two different mediums—the online platform DQ World and the DQ Assessment API System.

## DQ IMPACT TRACKER

### Data Collection

The DQ Impact Tracker is an assessment tool that is deployed through two programs—the DQ World and the DQ Assessment API system.

DQ World is the main platform to collect children's data. As children participants engage in various "missions" on the platform, they complete surveys and quizzes that reinforce interactive activities. Each child's responses are tracked to measure progress, assess risk, and generate data. Children participants are asked to answer self-reporting survey questions related to social emotional abilities and responsible cyber attitudes/behaviors. They are also tested on technical and critical reasoning abilities through various interactive activities and quizzes.

The DQ Assessment API System provides customized survey questions based on the programs of the DQ World and of other partner organizations. All the questions from the DQ Assessment API System are then matched with those from the DQ World.

Children participants are recruited with the aid of teachers and school administrators who are contacted by our partner organizations in each country. Participation is done either in the classroom or at home, through the DQ World platform. In some countries, paper surveys are used, and the results are coded and shared by the teachers.

The entire participation process is online. However, there are three procedures that need to be completed prior to initiating online participation.

1. Invitation to schools: Interested schools are invited for a briefing session where DQ Institute shares the aims of the study, implementation guidelines, and the role of teachers and key personnel involved.
2. Teachers' briefing and registration: Teachers from the participating schools are informed about the online learning experience and the proposed research aims. The teachers are guided to help with the registration of participating children on the relevant online platform(s).
3. Parental opt-out option: An opt out form is made available to parents to provide an option to opt their children out of the study.

## Sample Size

Through the DQ Impact Tracker, data of a total of 329,241 children and adolescents (aged 8-18) across 100 countries have been collected from March 2017 to September 2022.

COUNTRIES	SAMPLE SIZE
Thailand	81,931
Singapore	40,892
Australia	25,733
Japan	22,567
Turkey	22,240
Indonesia	22,029
Philippines	16,765
Mexico	16,117
Malaysia	7,473
Spain	7,255
Colombia	7,049
Nigeria	6,152
United States of America	5,916
Republic of Korea	4,692
New Zealand	4,651
Peru	4,364
United Kingdom of Great Britain and Northern Ireland	3,382
Ecuador	3,316
Viet Nam	3,201
Oman	2,912
India	2,831
South Africa	2,218
Italy	1,862
China	1,806
Dominican Republic	1,637
Nepal	1,528
Saudi Arabia	1,038
Other countries	7,585
<b>Total</b>	<b>329,142</b>

## LIMITATIONS

This study has been conducted as part of the #DQEveryChild initiative, and the participants of the #DQEveryChild initiative have served as a convenience sample for this study. The number of participants from each country thus varies depending on the extent of the initiative's adoption in the given country, and the sample may not be representative of all children within the country. This is particularly true for countries with a high level of participation from elite private schools in the #DQEveryChild initiative.

## EXTERNAL DATA SOURCES

SUB-INDICATORS	SOURCE REPORT	SOURCE PUBLICATION YEAR	ORGANIZATION
Gender parity index for youth/adults with information and communications technology (ICT) skills (Connecting and installing new devices (e.g., modem, camera, printer))	SDG Tracker	2000 - 2020	Global Change Data Lab
Gender parity index for youth/adults with information and communications technology (ICT) skills (Creating electronic presentations with presentation software (including images, sound, video, or charts))	SDG Tracker	2000 - 2020	Global Change Data Lab
Gender parity index for youth/adults with information and communications technology (ICT) skills (Finding, downloading, installing, and configuring software)	SDG Tracker	2000 - 2020	Global Change Data Lab
Gender parity index for youth/adults with information and communications technology (ICT) skills (Sending e-mails with attached files (e.g., document, picture, video))	SDG Tracker	2000 - 2020	Global Change Data Lab
Gender parity index for youth/adults with information and communications technology (ICT) skills (Transferring files between a computer and other devices)	SDG Tracker	2000 - 2020	Global Change Data Lab
Gender parity index for youth/adults with information and communications technology (ICT) skills (Using basic arithmetic formulas in a spreadsheet)	SDG Tracker	2000 - 2020	Global Change Data Lab

Gender parity index for youth/adults with information and communications technology (ICT) skills (Using copy and paste tools to duplicate or move information within a document)	SDG Tracker	2000 - 2020	Global Change Data Lab
Gender parity index for youth/adults with information and communications technology (ICT) skills (Writing a computer program using a specialized programming language)	SDG Tracker	2000 - 2020	Global Change Data Lab
Gender parity of employed ICT specialists (Broad definition based on the ISCO-08 classification and including jobs) (%)	Women in Digital (WID)	2020	EU Commission
The level of inclusion of the issues of sexual violence against children in leading national (mobile) telecoms association's annual report or code of conduct, or as a clear priority in the scope of work	Out of the Shadows	2020	Economist Intelligence Unit
The level of inclusion of the issues of sexual violence against children in leading national internet industry association's annual report or code of conduct, or as a clear priority in the scope of work	Out of the Shadows	2020	Economist Intelligence Unit
Trust in government websites and apps (To what extent do you trust the information you receive from the following sources online?)	Inclusive Internet Index	2021	Economist Intelligence Unit
Trust in online privacy (To what extent do you feel confident that your activity online is private?)	Inclusive Internet Index	2021	Economist Intelligence Unit
Trust in non-government websites and apps (To what extent do you trust the information you receive from the following sources online?)	Inclusive Internet Index	2021	Economist Intelligence Unit
Trust in information from social media (To what extent do you trust the information you receive from the following sources online?)	Inclusive Internet Index	2021	Economist Intelligence Unit
Trust in e-Commerce safety (To what extent do you think safe and secure to make purchases online?)	Inclusive Internet Index	2021	Economist Intelligence Unit
Law for ISPs to block illegal content (sexual abuse and exploitation)	Out of the Shadows	2020	Economist Intelligence Unit
Law for ISPs to report illegal content (sexual abuse and exploitation)	Out of the Shadows	2020	Economist Intelligence Unit
Law for ISPs: mandatory content blocking and deleting of child pornography	Out of the Shadows	2020	Economist Intelligence Unit

Law for ISPs: mandatory record keeping of illegal content (sexual abuse and exploitation)	Out of the Shadows	2020	Economist Intelligence Unit
Legislation specific to online grooming: intent to meet the child	Out of the Shadows	2020	Economist Intelligence Unit
Legislation specific to online grooming: regardless of intent to meet the child	Out of the Shadows	2020	Economist Intelligence Unit
Privacy regulations (Does the country have data protection law(s) and legal or financial penalties in place for firms that do not follow the law?)	Inclusive Internet Index	2021	Economist Intelligence Unit
Privacy protection by law content	Network Readiness Index	2020	Portulans Institute and World Information Technology and Services Alliance (WITSA)
e-Commerce legislation (whether a country has adopted legislation or has a draft law pending adoption in four areas: electronic transactions, consumer protection, privacy and data protection, and cybercrime.)	Network Readiness Index	2020	Portulans Institute and World Information Technology and Services Alliance (WITSA)
Gender parity of youth not in education, employment, or training	SDG Tracker	2000 - 2020	Global Change Data Lab
Mobile cellular subscriptions (per 100 inhabitants)	Inclusive Internet Index	2021	Economist Intelligence Unit
Mobile broadband subscriptions (per 100 of the population)	Country ICT Data	2010 - 2019	International Telecommunication Union
Fixed broadband subscriptions (per 100 inhabitants)	Country ICT Data	2010 - 2019	International Telecommunication Union
Percentage of the population covered by a mobile-cellular network	Inclusive Internet Index	2021	Economist Intelligence Unit
Percentage of the population covered by at least a 3G mobile network	Inclusive Internet Index	2021	Economist Intelligence Unit
Percentage of the population covered by at least an LTE/WiMAX mobile network	Inclusive Internet Index	2021	Economist Intelligence Unit



Percentage of the population covered by a 5G mobile network	Inclusive Internet Index	2021	Economist Intelligence Unit
Percentage of the population covered by at least a 2G mobile network	SDG Tracker	2000 - 2020	Global Change Data Lab
Proportion of individuals using a mobile phone	Country ICT Data	2010 - 2019	International Telecommunication Union
Proportion of individuals who own a mobile telephone	SDG Tracker	2000 - 2020	Global Change Data Lab
Internet Affordability: Price	Inclusive Internet Index	2021	Economist Intelligence Unit
Internet Affordability: Competitive environment	Inclusive Internet Index	2021	Economist Intelligence Unit
Fixed broadband upload speed (Mbps)	Inclusive Internet Index	2021	Economist Intelligence Unit
Fixed broadband download speed (Mbps)	Inclusive Internet Index	2021	Economist Intelligence Unit
Fixed broadband latency	Inclusive Internet Index	2021	Economist Intelligence Unit
Mobile upload speed (Mbps)	Inclusive Internet Index	2021	Economist Intelligence Unit
Mobile download speed (Mbps)	Inclusive Internet Index	2021	Economist Intelligence Unit
Mobile latency	Inclusive Internet Index	2021	Economist Intelligence Unit
Bandwidth capacity	Inclusive Internet Index	2021	Economist Intelligence Unit
Internet exchange points	Inclusive Internet Index	2021	Economist Intelligence Unit
Proportion of lower secondary schools with access to the internet for pedagogical purposes	SDG Tracker	2000 - 2020	Global Change Data Lab
Proportion of primary schools with access to the internet for pedagogical purposes	SDG Tracker	2000 - 2020	Global Change Data Lab
Proportion of upper secondary schools with access to the internet for pedagogical purposes	SDG Tracker	2000 - 2020	Global Change Data Lab

Proportion of lower secondary schools with access to computers for pedagogical purposes	SDG Tracker	2000 - 2020	Global Change Data Lab
Proportion of primary schools with access to computers for pedagogical purposes	SDG Tracker	2000 - 2020	Global Change Data Lab
Proportion of upper secondary schools with access to computers for pedagogical purposes	SDG Tracker	2000 - 2020	Global Change Data Lab
Percentage difference between male and female access to the Internet	Inclusive Internet Index	2021	Economist Intelligence Unit
Percentage difference between male and female access to mobile phones	Inclusive Internet Index	2021	Economist Intelligence Unit
Percentage difference in access between males and females	Inclusive Internet Index	2021	Economist Intelligence Unit
Percentage difference in the Internet usage between male and female	Network Readiness Index	2020	Portulans Institute and World Information Technology and Services Alliance (WITSA)
Level of country's commitment to cybersecurity	Network Readiness Index	2020	Portulans Institute and World Information Technology and Services Alliance (WITSA)
Secure Internet servers using encryption technology in Internet transactions (per million population)	International Digital Economy and Society (DESI) Index 2020	2015 - 2018	EU Commission
Secure Internet servers using encryption technology in Internet transactions (per million population)	Network Readiness Index	2020	Portulans Institute and World Information Technology and Services Alliance (WITSA)

## REFERENCES

- Anders, D. (2019). What is a Good Internet Speed? Retrieved from <https://www.allconnect.com/blog/internet-speed-classifications-what-is-fast-internet>.
- Anderson, C. A., Berkowitz, L., Donnerstein, E., Huesmann, L. R., Johnson, J. D., Linz, D., Malamuth, N. M., & Wartella, E. (2003). The influence of media violence on youth. *Psychological Science in the Public Interest*, 4(3), 81–110. [https://doi.org/10.1111/j.1529-1006.2003.pspi\\_1433.x](https://doi.org/10.1111/j.1529-1006.2003.pspi_1433.x).
- Anderson, C. A., Shibuya, A., Ihori, N., Swing, E. L., Bushman, B. J., Sakamoto, A., Rothstein, H. R., & Saleem, M. (2010). Violent video game effects on aggression, empathy, and prosocial behavior in Eastern and Western countries: A meta-analytic review. *Psychological Bulletin* 136(2): 151–173. <https://doi.org/10.1037/a0018251>.
- Anderson, C., Gentile, D., & Buckley, K. (2007). *Violent video game effects on children and adolescents: Theory, research, and public policy*. Oxford University Press.
- Ang, R., & Goh, D. (2010). Cyberbullying among adolescents: The role of affective and cognitive empathy, and gender. *Child Psychiatry & Human Development*, 41, 387-397. <https://doi.org/10.1007/s10578-010-0176-3>.
- Broadband Commission for Sustainable Development (2019). Child online safety: Minimizing the risk of violence, abuse, and exploitation online. Retrieved from: [https://www.broadbandcommission.org/Documents/working-groups/ChildOnlineSafety\\_report.pdf](https://www.broadbandcommission.org/Documents/working-groups/ChildOnlineSafety_report.pdf).
- Busching, R., Gentile, D. A., Krahé, B., Möller, I., Khoo, A., Walsh, D. A., & Anderson, C. A. (2015). Testing the reliability and validity of different measures of violent video game use in the USA, Singapore, and Germany. *Psychology of Popular Media Culture*, 4, 97-111.
- DQ Institute (2018). DQ Impact Report. Retrieved from: <https://www.dqinstitute.org/wp-content/uploads/2018/08/2018-DQ-Impact-Report.pdf>.
- Dutta, S., & Lanvin, B. eds. (2020). *Network Readiness Index: Accelerating Digital Transformation in a post-COVID Global Economy*. Portulans Institute and World Information Technology and Services Alliance. Retrieved from: [https://networkreadinessindex.org/wp-content/uploads/2022/09/NRI\\_2020\\_Report.pdf](https://networkreadinessindex.org/wp-content/uploads/2022/09/NRI_2020_Report.pdf).
- Economist Intelligence Unit (2021). The Inclusive Internet Index. Retrieved from: <https://impact.economist.com/projects/inclusive-internet-index/2022>.
- Economist Intelligence Unit (2020). Out of the Shadows Index: Shining light on the response to child sexual abuse exploitation: A 60-Country Benchmarking Index. Retrieved from: <https://outoftheshadows.eiu.com/>.
- Economist Intelligence Unit (2019). Out of the Shadows: Shining light on the response to child sexual abuse exploitation: A 40-Country Benchmarking Index. Retrieved from: <https://outoftheshadows.eiu.com/>.
- European Commission (2020). Women in Digital Scoreboard. Retrieved from: <https://digital-strategy.ec.europa.eu/en/library/women-digital-scoreboard-2020>.
- European Commission (2015-2018). International Digital Economy and Society Index (DESI). Retrieved from: <https://digital-strategy.ec.europa.eu/en/library>.

Gentile, D. A., Bailey, K., Bavelier, D., Funk, J. B., Cash, H., Doan, A., Grant, D. S., Green, C. S., Griffiths, M. D., Markle, T., Petry, N. M., Prot, S., Rae, C. D., Rehbein, F., Rich, M., Sullivan, D., Woolley, E., & Young, K. (2017). Internet Gaming Disorder in children and adolescents. *Pediatrics*, 140, S81–S85.

Gentile, D. A., Lynch, P. J., Linder, J. R., & Walsh, D. A. (2004). The effects of violent video game habits on adolescent hostility, aggressive behaviors, and school performance. *Journal of Adolescence*, 27(1), 5-22.

Global Change Data Lab (2000-2020). Sustainable Development Goal Tracker: Measuring Progress towards the Sustainable Development Goals. Retrieved from: <https://ourworldindata.org>.

Global System for Mobile Communications (2019). GSMA Mobile Connectivity Index. Retrieved from <https://www.mobileconnectivityindex.com/#year=2018&secondaryMenu=about-the-index>.

International Centre for Missing & Exploited Children (2018). Child Sexual Abuse Material: Model Legislation & Global Review. Retrieved from: <https://www.icmec.org/child-pornography-model-legislation-report/>.

International Telecommunication Union (2010-2019). Statistics and Indicators: Country ICT Data. Retrieved from: <https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>.

International Telecommunication Union (2019). ITU Committed to connecting the world. Retrieved from <https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>.

International Telecommunication Union (2018). Global Cybersecurity Index. Retrieved from: <https://www.itu.int/en/ITU-D/Cybersecurity/Pages/global-cybersecurity-index.aspx>.

Lemmens, J., Valkenberg, P., & Gentile, D. (2015). The Internet Gaming Disorder Scale. *Psychological Assessment*, 27(2), 567.

Livingstone, S., & Bober, M. (2004). Taking up online opportunities? Children's uses of the Internet for education, communication, and participation. *E-Learning and Digital Media*, 1(3), 395-419.

Livingstone, S., & Haddon, L. (2009). EU Kids Online. *Zeitschrift Für Psychologie/Journal of Psychology*, 217(4), 236.

Patchin, J. (2019). Summary of Our Cyberbullying Research (2007-2019). Cyberbullying Research Center. Retrieved from: <https://cyberbullying.org/summary-of-our-cyberbullying-research>.

Speedtest (2019). Internet speed glossary. Retrieved from: <https://www.speedtest.net/about/knowledge/glossary>.

Speedtest (2019). Speedtest Global Index. Retrieved from: <https://www.speedtest.net/global-index>.

van den Eijnden, R. J. J. M., Lemmens, J. S., & Valkenburg, P. M. (2016). The Social Media Disorder Scale. *Computers in Human Behavior*, 61, 478–487. <https://doi.org/10.1016/j.chb.2016.03.038>.