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Article

School or home: Exploring the impact of digital infrastructure on digital literacy of school-age young people in a developing economy

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Abstract: Digital literacy plays a very important role for a developing innovative economy, since one of the global trends significantly affecting the dynamics of open innovation is strengthening of the influence of digital technologies on all spheres of society. This paper seeks to study the impact of digital infrastructure on digital literacy of school-age young people, which starts and develops both at school and/or at home. This paper uses a balanced panel of statistical data that includes 18 regions of Kazakhstan surveyed for the period between 2016 and 2022 on four indicators: the level of digital literacy in Kazakhstan, the share of households with Internet access, the share of Internet users aged 6-15, and the number of students per PC in public schools. Methods of correlation, variance, and structural model analysis proposed hereby consist of successive stages and include five hypotheses for verification. The results have shown that (a) the literature has not accumulated a unified methodology for assessing digital literacy yet; (b) digital infrastructure in Kazakhstan's public schools has been found to have a negligible impact on formation of digital literacy, as well as on the increase in the number of school-age Internet users; (c) the number of young school-age Internet users have been found to have a positive effect on formation of digital literacy in Kazakhstan; (d) access to the Internet at home has been found to have a significant stable impact on digital literacy in Kazakhstan and an increase in the share of young school-age Internet users. This paper is intended for decision makers, researchers, education and open innovation experts interested in opportunities for the development of citizens' digital skills and competencies and the implementation of an open innovation economy strategy.

Keywords: digital literacy; school digital infrastructure; school-age young people; digital skills; education; households; developing economy
JEL classification: A21; D83; I24; O14

1. Introduction

Most modern world professions require employees to be proficient in digital technologies. Educating school-aged young people in Kazakhstan ensures their future competitiveness in the labor market. Digital literacy of Kazakhstan's youth is also important for maintaining and developing the country's innovative economy that is in desperate need of creative and innovative experts. All the while Kazakhstan

youth's knowledge of online security principles and personal data protection is an integral part of digital literacy.

In the context of Kazakhstan striving to develop a digital economy, digital literacy of school-age young people appears to be a key factor in ensuring sustainable development and progress.

Currently, basic problems of Kazakhstan's education system directly affecting the level of digital literacy include the following: digital inequality and uneven access to digital resources in a number of regions, the shortage of teachers qualified in digital technologies. In some cases, curricula do not meet modern digital era requirements. There is also insufficient funding for digital infrastructure in schools.

According to the OECD's (Organization for Economic Cooperation and Development) approach, in a digital economy, the management of digital security and privacy risks is necessary for economic and social prosperity (OECD, 2017). An increase in the share of digital economy, a transition of entire industries with their employees into it have resulted in the emergence of new "digital users."

Today, one of the global trends with a significant impact on the dynamics of open innovation is the increasing influence of digital technologies on all social spheres (Mubarak and Petraite, 2020; Skare and Soriano, 2021; Usai et al., 2021; Urbinati et al., 2020). In these conditions, skills and abilities of interaction with the digital environment required both for work and for everyday household activities are in demand. Accordingly, digital literacy, as a complex of specific knowledge and skills, becomes an integral element of not just professional, but also general cultural competence of any person. In this regard, the study of the digital literacy formation peculiarities remains an urgent task. Such studies are of particular importance in the light of heterogeneity of the population in terms of digital literacy's maturity and level, which means inequality of opportunities for self-realization, meeting diverse needs, ensuring security, and, in general, addressing all kinds of tasks within the expanding digital environment.

Like "conventional" literacy, digital one is an important factor in achieving life goals and improving quality of life (Cetindamar Kozanoglu and Abedin, 2021; Park et al., 2020; Reddy et al., 2020; Tejedor et al., 2020). Proper measurement of digital literacy and appropriate adjustment of support measures and programs increase productivity, strengthen the competitiveness of both individuals and businesses, and, ultimately, drive national economies up. The measurement of digital literacy and its various components allows for more accurate building of programs to support digital transformation (Jin et al., 2020; Maureen et al., 2020). However, at present, a unified methodology for assessing digital literacy is not yet been formed in the literature (Bejaković et al., 2020; Liu et al., 2020; Prete, 2022; Widana et al., 2020). Different countries and regions worldwide use different indicators to assess digital literacy.

The modern scientific literature (Bergson-Shilcock, 2020; Bejinaru, 2019; Carlisle et al., 2023; Kateryna et al., 2020; Van Deursen and Van Dijk, 2014; Zain, 2021) offers a wide range of studies of professional and user skills in information and communication technologies. However, the number of studies of the formation and development of user skills or basic elements of school-age young people's digital literacy is limited; especially that for developing countries. The study of the level of formation and application of the basic elements of school-age young

people's digital literacy appears difficult due to their wide range. This means that its assessment requires identification of individual, the most common and important aspects from the point of view of the object under study.

In this paper, the research focuses on studying the impact of school and home digital infrastructure on digital literacy of school-age young people in a developing economy. Other previously conducted studies have made a certain contribution to understanding the features of processes of formation and development of digital literacy's basic elements. To name a few, Kateryna et al., 2020 conclude that poor Internet proficiency is one of the frequent reasons for refusing to use the global network for information and communication technologies. Daoud et al., 2020 explore the Internet's role in homeschooling.

This paper contributes to the study of key indicators of improving the basic elements of digital literacy in a developing economy through their formation and development among young people of school age. In this respect, firstly, the basic elements of digital literacy have been described: working with information (digital content), working with a computer as a tool. Secondly, statistical data is proposed for the analysis on the following indicators: the level of digital literacy in Kazakhstan, the share of households with Internet access, the share of Internet users aged 6-15, and the number of students per PC in public schools. Thirdly, the methods of correlation, variance, and structural model analysis proposed for analysis consist of successive stages and include five research questions (hypotheses) for verification. This discussion is followed by the results and analysis of the data and ends with conclusions and practical recommendations.

This study has been conducted due to the existing gaps in methodology for assessing digital literacy, limited research on formation and development of the basic elements of school-age young people's digital literacy in a developing economy and the issues the education system of Kazakhstan is now facing.

2. Literature review and hypotheses

2.1. Digital literacy

Online payments, electronic services, blogging: all of these are becoming part of the daily routine for a modern person. Digitalization, which has intensively entered into the life of every person, creates new business models (i.e., the economy of shared consumption and the economy of free earnings), in which not only basic industries and businesses are digitized, but also the whole social life. In these conditions, open innovations in the process of creating and distributing information and knowledge are becoming more and more relevant. A traditional model of business processes assumes betting on internal human capital, whereas the concept of "open innovation" is targeting transparency of innovation activities for specialists in other areas. In this context, adaptation of people to the culture of open innovation and open business models through increasing their digital literacy is of paramount importance.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) defines digital literacy as a set of basic skills required for working with

digital media, with the search and processing of data. This concept also implies the use of social networks to create and disseminate knowledge.

A unified methodology for assessing the digital literacy is yet to be formed in the scientific literature (Bejaković et al., 2020; Liu et al., 2020; Prete, 2022; Widana et al., 2020). Internationally, various indicators are used to determine the level of digital literacy. Some countries monitor implementation of their digital development programs through supranational indices, such as the European Union's Digital Economy and Society Index (DESI), others use aggregate digitization indices.

Aggregate digitalization indices are a popular approach among many countries and organizations to assess and track digital literacy and digital inclusion. The following are some examples of such indices:

1) The European Union's Digital Economy and Society Index (DESI, 2024). A study by Başol and Yalçın, 2021 specifies the impact of DESI (connectivity, digital skills, human capital, use of internet services, integration of digital technologies and digital government services) on labor market indicators (long-term unemployment rate, employment rate, salaries, labor market insecurity). Bruno et al., 2022 focus on the DESI to assess digital divide between countries and, above all, within countries, to identify subnational differences.

2) The World Economic Forum's Network Readiness Index (NRI, 2024). This index assesses a country's readiness to use ICT for development and competitiveness. It addresses a wide range of factors, including the level of digital skills of the population, technological infrastructure, and the use of digital technologies in business and public administration. Silva et al., 2022 identify indicators with the most significant influence on main components of the Network Readiness Index's economic and social impact. Tokmergenova and Dobos, 2024 determine the relationship between twelve components of the Network Readiness Index.

3) ICT Development Index (IDI, 2024) developed by the International Telecommunication Union (ITU). This index measures the overall level of ICT development in countries, including ICT access, use, and skills. Afshar et al., 2020 argue that the ICT Development Index and related indicators of a country's ICT development maturity suffer from a number of limitations, including subjective assessment of the weights of individual sub-indices, the use of inappropriate quantitative models, and specification bias. To overcome these challenges and provide a more reliable assessment of ICT development, the study develops a modified ICT maturity index using 2015 data collected in 166 countries.

These indices are used to measure various aspects of digitalization and provide valuable data for governments, businesses, and researchers seeking to understand and improve digital inclusion and literacy in different countries.

Recent research by Cone et al., 2022 shows how pandemic has accelerated the shift to digital technologies, especially that in the educational sector. Using the examples of Italy, Germany, Belgium, and the Nordic countries, the study provides insight into how restrictions due to COVID-19, as well as the various processes of emergency digitalization that followed them, simultaneously accelerated and consolidated participation of various commercial and non-commercial entities in public education infrastructures. A study by Karagul et al., 2021, which assessed the current state of digital literacy based on a survey of 510 school students in Turkey,

found a statistically significant relationship between students' digital literacy, their gender and school education, while age was found to be a not statistically significant variable. Kaeophanuek and Chaisriya (2022) Alt and Raichel (2020) explore the impact of gaming technologies and gamification on digital literacy learning and provide new approaches to education. Using the survey of 186 New Zealand students aged 9 to 12, McNaughton et al., 2022, explore the benefits and risks for youth interpersonal and intrapersonal skill development in ubiquitous digital environments both at school and at home. Researchers conclude that self-regulation and social skills are sensitive to digital context during primary school years.

In our study, we adhere to the approach developed during the G20 Summit back in 2017, where the following was proposed (Chetty, 2017). Digital literacy consists of five elements, the aggregate assessment of which shows the objective level of a person's digital literacy.

1) Working with data (digital content), i.e., the ability to create and find data, work with it competently, combine and analyze it,

2) Working with a computer as a tool, i.e., knowing technical procedures, understanding hardware and software,

3) Working with media material (texts, sounds, pictures, videos, etc.), i.e., the ability to evaluate media, navigate the media environment, create media content,

4) Communication, i.e., communication skills in the digital sphere and social networks, and

5) Attitude towards technological innovations, i.e., the use of various technologies in life, tools for working in the digital space (gadgets, applications).

Our research focuses on the study of the basic elements No. 1 and 2 of digital literacy of school-age young people, as we believe that at this level, the state, the education system, and the home environment must actively influence the formation of digital skills of schoolchildren.

2.2. Digital literacy of school-age young people

Back in 2017, the G20 Digital Economy Ministerial Conference noted that digital skills progressively become a condition for participation in the modern economy (including digital one), social, cultural, and political life. All generations and social groups should equally benefit and adapt to the new digital environment, i.e., have the necessary skills and knowledge (G20, 2017).

Depending on goals of application of information and communication technologies, Carlisle et al., 2023; Bergson-Shilcock, 2020; Bejinaru, 2019; Kateryna et al., 2020; Van Deursen and Van Dijk, 2014; Zain, 2021 divide them into professional and user ones. An important place within is occupied by PC and Internet skills, a digital content experience. Studying the level of formation and application of all the knowledge, skills, and abilities included in the concept of digital literacy of school-age young people is difficult due to their wide range. Accordingly, its assessment requires identification of individual, the most common and important aspects from the point of view of the object under study. For young people of school age, these are user digital skills.

Case in point, Kateryna et al., 2020 conclude that poor Internet proficiency is one of the frequent reasons for refusing to use the global network for information and communication technologies.

According to Hassan and Mirza, 2021, Liu et al., 2020, Quaicoe and Pata, 2020, a successful formation of Internet skills at school contributes to the digital literacy for a fairly simple reason: students with the necessary skills gain access to more and more information more easily as the volume of digital storage databases grows. This simplifies access greatly compared to working with traditional, paper-based learning resources. In addition, integration and evaluation of data become part of the skills mastered as part of the formation of digital literacy when a teacher shows students the differences between reliable and useless digital resources, acting at this moment as an expert in evaluating data.

Considering the above, in our study, we state the following:

H1. An increase in the number of young school-age Internet users positively affects formation of digital literacy's basic elements.

2.3. Internet access

The mass digitalization has resulted in the fact that an increasing number of young people worldwide spend their time online and use Internet opportunities for a variety of purposes.

Due to the COVID-19 pandemic restrictions and the mass transition of institutions and organizations to distance forms of work, Internet access has become practically a necessity for increasing the level of digital literacy of school-age young people (Lai and Widmar, 2021; Mahmood, 2021; Qazi et al., 2020; Tadesse and Muluye, 2020). However, studies of the COVID-19 impact have shown that despite the presence of positive aspects, distance education using Internet entails the so-called online risk for users, primarily children. One of the main disadvantages of distance education is social isolation combined with a lack of interaction between teachers and peers, which contributes to the development of inadequate communicative behavior (Bokayev et al., 2021; LeMay, 2021; Purnama et al., 2021). Gómez-Galán et al., 2021 have found that in an educational environment, knowledge of the interests of students with Internet access is vital for guiding teaching methodologies, facilitating communication processes, developing digital literacy practices, etc.

Currently, the issue of Internet access is very relevant for developing countries, especially for Kazakhstan. Some of these countries face certain barriers in improving digital literacy:

- Poor Internet access,
- Low level of information infrastructure,
- Low level of digital security,
- Personnel constraints,
- Lack of financial capital.

In this regard, we put the following study hypotheses:

H2. Access to the Internet at home significantly affects digital literacy.

H3. The share of school-age users increases with the expansion of Internet accessibility at home.

2.4. School digital infrastructure

Today, leaders of many countries are making significant efforts to modernize education systems based on the use of the latest computer technologies. Gradually, there was a need to adapt educational institutions to new operating conditions. All the while, computer technologies are either used during implementation of educational process in classrooms, or education is implemented remotely. Introduction of information and communication technologies into educational process is not so much an urgent necessity as automating routine processes in order to release the individual's creative energy in modern society.

Numerous studies (Li, 2021; Reimer et al., 2021; Inan Karagul et al., 2021; Sánchez-Cruzado et al., 2021) both during the pandemic and in the post-COVID period have shown how formation of digital literacy of school-age young people occurs in distance education, self-education, and school's influence on this process.

It stands to mention that the use of computer technologies in educational process contributes to improving the quality of student training, the development of digital literacy of school-age young people as it significantly expands access to open educational resources worldwide. In the context of "open innovation" concept, we see growth in cooperation between educational institutions, exchange of experience, and creation of a single information space.

As Schleicher, 2019 notes, the level of school provision with digital resources correlates with the level of digital literacy: to a lesser extent in developed countries and to a greater extent in developing ones.

Considering the above, in our study, we state the following:

H4. School digital infrastructure positively affects formation of digital literacy.

H5. School digital infrastructure contributes to a growth in the number of school-age Internet users.

3. Materials and methods

3.1. Data and variables

The survey of Kazakhstan population on ICT Use is an important source of countrywide data on the use of ICT and digital literacy conducted annually by the Bureau of National Statistics of the Republic of Kazakhstan. This data is required to monitor national and international ICT development goals and objectives.

One of the main directions of surveying the population of Kazakhstan on the use of ICT is a survey of households and household members at annual intervals.

Most of the questions in the survey list refer to the last three months preceding the interview.

The household ICT use survey targets the household for ICT access indicators and household members aged 6 and older for ICT use. The household is used as a survey unit when collecting data on access to various electronic devices, types of

Internet connection, and barriers to Internet use. Individuals are used as a survey unit to collect data on Internet use and digital literacy.

There are three options for interviewing household members:

1) interviewing each household member to fill out an individual questionnaire,

2) interviewing the head of the household on questions about each household member, and

3) random selection of one household member to answer questions for all household members.

The survey on ICT use in households is carried out using a sample observation method.

The sample population is 21,000 households.

Household survey is conducted at the primary place of residence. Data collection begins with a question about the number of household members.

To obtain data generalized to the general population, statistical weighting of the sample survey results is performed. This method is implemented by assigning a statistical weight to each surveyed household, which characterizes the total number of households represented by the part included in the sample.

The study uses the following four variables: The Share of Households with Internet Access, the Share of Internet Users Aged 6-15, the Number of Students per PC in Public Schools, and the Level of Digital Literacy. According to the Bureau of National Statistics of the Republic of Kazakhstan, the level of digital literacy is the share of users who have the skills to use a PC, a smartphone, a tablet, a laptop, standard software, and to receive online services.

The Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan has provided balanced data panel that served as the base for the study on Proportion of Households with Internet Access, Proportion of Internet Users Aged 6–15, and Number of Students per PC in Public Schools of Kazakhstan, including eighteen regions, surveyed for the period between 2016 and 2022 on four indicators. The data is publicly available at https://stat.gov.kz/ (Appendix Table A1). The number of observations in eighteen regions over seven years determines the total size of the combined sample which is 117 per indicator.

3.2. Analytical methods

The variety of approaches to determining structural elements of digital literacy is associated with the problem of assessing its development level. As noted above, scientific literature is yet to develop a generally accepted unified methodology for this. Use such a methodology would allow not just its evaluation, but also comparison of different subjects. However, research in this area allows us to get an idea of the existing estimates of digital literacy, especially for the developing countries. Gaps in the existing scientific literature encourage this work; **Figure 1** shows key indicators and research designs.

Table 1 shows the main variables for a structural model.

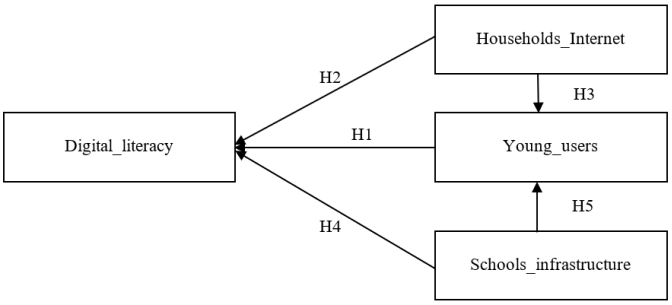

Figure 1. Research framework.

Note: Compiled by the author.

Table 1. Variables selected for a structural model.

Designation	Variables	Source
Households_Internet	The share of households with Internet access, %	BNS
Digital_literacy	The level of digital literacy	BNS
Young_users	The share of Internet users aged 6-15	BNS
Schools_infrastructure	The number of students per PC in public schools	BNS

Notes: 1) Compiled by the authors; 2) BNS is the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

Our empirical model will be using the Digital Literacy Level (Digital_literacy) indicator as a dependent variable. According to the methodology of the Bureau of National Statistics, the level of digital literacy in Kazakhstan is determined by the share of users who can use a PC, a smartphone, a tablet, a laptop; common software; and receive online services. The Number of Students per PC in Public Schools was taken as a characteristic of the school infrastructure.

To test the hypotheses of the study, we propose the following empirical model: $Digital\_literacy_{it} = \alpha Households\_Internet_{it} + \beta Young\_users_{it} + \gamma Schools\_infrastructure_{it} + \varepsilon_{it}$, where,

(Designation of the selected variables is shown in **Table 1**).

i is region, and

t is year.

Calculated using SPSS Statistics 23, SPSS Amos 24, and MS Excel.

4. Results

4.1. Data analysis

Table 2 shows descriptive statistics of the variables taken for analysis.

Table 2. Descriptive statistics.

Variables	Mean	Std. Deviation	N
Digital_Literacy	88.782	6.6924	117
Households_Internet	90.579	7.0638	117
Young_Users	78.144	11.8997	117
Schools_Infrastructure	8.50	4.584	117

Note: Compiled by the authors using SPSS Statistics 23.

Table 2 data shows the following average values for the sample:

- The average level of digital literacy in Kazakhstan in the sample is 88.8%,
- The share of households with Internet access is 90.5%,
- The share of Internet users aged 6–15 is 78.1%, and
- The number of students per PC in public schools is 8.5.

During the analyzed period, the level of digital literacy in Kazakhstan has grown. The level of digital literacy of people aged 6 to 15 has grown from 82% in 2020 to 88.8% of the total population in 2022. This is a significant progress given that in 2018 the indicator has only reached 77.3%.

Two other indicators are also growing. Specifically, in 2022, the share of households with Internet access was 90.5% and the share of school-age Internet users was 78.1%. Against this background, the number of students per PC in public schools looks modest. In 2022, on average, there was only one computer per 8.5 of public-school students in Kazakhstan. In developed countries, it is one to three students per computer. Also, according to the national guide "Statistics of the Education System of the Republic of Kazakhstan", 30% of computer equipment in public schools in a number of regions is outdated and needs replacement.

4.2. Correlation analysis

To assess the degree of tightness between the dependent variable, the level of digital literacy in Kazakhstan, and independent variables taken for analysis, the Pearson correlation coefficient was used. A correlation matrix was constructed using SPSS Statistics 23 (**Table 3**).

Table 3. Correlation matrix.

	Schools_Infrastructure	**Households_Internet**	**Young_Users**	**Digital_Literacy**
Schools_Infrastructure	1.000			
Households_Internet	−0.028	1.000		
Young_Users	−0.482	0.566	1.000	
Digital_Literacy	−0.175	0.801	0.602	1.000

Note: Compiled by the authors using SPSS Statistics 23.

The analysis of the correlation matrix has shown that the level of digital literacy in Kazakhstan has the following:

A very high correlation with the share of households with Internet access (0.80).

A high correlation with the indicator of the share of Internet users aged 6–15 (0.60).

In concurrence with this, a weak negative correlation is observed with the indicator of the number of students per PC in public schools. At this stage of the study, we can make the following preliminary conclusions:

The very high correlation between digital literacy among school-age young people and internet access at home highlights the critical role internet access plays in developing digital skills. This confirms the importance of investing in expanding Internet services to improve digital literacy in Kazakhstan.

The high correlation between the Percentage of Internet Users Aged 6–15 and the level of digital literacy in Kazakhstan indicates that early involvement of children

in using the Internet can significantly improve their digital skills. This may suggest new strategies for educational programs targeting younger age groups.

The results of the study show that most of the process of developing digital literacy in Kazakhstan occurs outside the school environment, especially at home. This might suggest that home and extracurricular educational resources are important for developing digital skills in Kazakhstan.

The lack of a significant positive correlation between digital literacy level and school infrastructure raises questions about the current use and effectiveness of school digital resources. There may be a need to reconsider approaches to the use of digital technologies in schools and improve the effectiveness of IT-related educational programs.

It is important to note that correlation analysis cannot establish cause-and-effect relationships. There may be hidden variables or external factors that influence both Internet access and digital literacy levels. Therefore, it is important to recognize limitations of such analyzes and not draw definitive conclusions about causation based on correlational data alone.

4.3. Structural model analysis

Let us apply the structural modeling method to describe the complex interrelations of various digital literacy aspects based on the selected structure of indicators using calculations performed in SPSS Amos. Structural modeling gave us a qualitative consistent model of digital literacy in Kazakhstan (**Figure 2**). A causal relationship has been established between the variables.

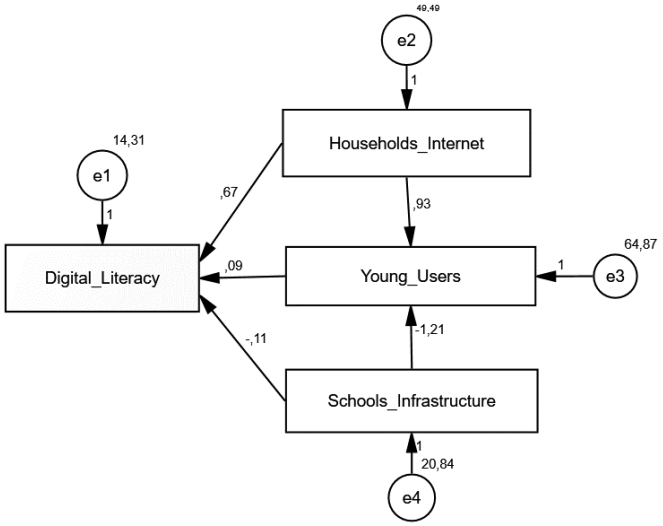

Figure 2. Structural modeling of Digital Literacy indicators.
Note: Compiled by the authors using SPSS Amos 24.

In the current study, “Digital Literacy Level in Kazakhstan” is considered as a central variable of key interest. **Figure 2** presents a model in which “Digital Literacy Level in Kazakhstan” functions as the main variable associated with various observed variables, such as Home Internet Access, Use of Internet by Youth, and School Digital Infrastructure. These connections represent the way external factors can influence overall digital literacy levels.

The model has been tested using the following criteria of fitting with the data: The chi-squared checks the null hypothesis, i.e., whether the difference between the empirical and the model-reproduced covariance matrices is equal to zero. In our model, p over 0.05 is a good fit. The model is considered adequate if the RMSEA (the square root of the standard approximation error) does not exceed 0.1. Analysis of the results allows us to conclude that the model has the best fit (the RMSEA index value does not exceed 0.1). Goodness-of-Fit Index (GFI) is at least 0.90, which means a good fit (**Table 4**).

Table 5 shows regression coefficients and their statistical significance.

Table 4. Model compliance indicators.

CMIN	**DF**	***P***	**CMIN/DF**	**GFI**	**CFI**	**RMSEA**
0.092	1	0.761	0.092	1.000	1.000	0.000

Table 5. Structural (regression) coefficients.

			Estimate	**S.E.**	**C.R.**	***P***
Young_Users	←	Schools_Infrastructure	−1.211	0.160	−7.553	0.126
Young_Users	←	Households_Internet	0.932	0.104	8.955	***
Digital_Literacy	←	Young_Users	0.094	0.043	2.198	0.028
Digital_Literacy	←	Households_Internet	0.667	0.063	10.586	***
Digital_Literacy	←	Schools_Infrastructure	−0.110	0.091	−1.206	0.228

Research Hypotheses Significant at $p^{**} \leq 0.01$, $p^{*} < 0.05$.

In the model, the estimated regression weights of the parameters The Share of Households with Internet Access → Proportion of Internet Users Aged 6–15 and The Share of Households with Internet Access → The Level of Digital Literacy are statistically significant (three asterisks mean statistical reliability of $p < 0.001$). Statistical significance of the parameter The Share of Internet Users Aged 6–15 → The level of Digital Literacy is within $p^{*} < 0.05$, which does not give grounds for its removal from the model. Statistical significance of the parameters The Number of Students per PC in Public Schools → The Share of Internet Users Aged 6–15 and The Number of Students per PC in Public Schools → The Level of Digital Literacy gives us a reason to remove the variable The Number of Students per PC in Public Schools from the model.

4.4. Analysis of variance

The results presented in **Table 6** below show that the share of households with Internet access, the share of Internet users aged 6–15 significantly affect digital literacy in Kazakhstan ($F = 122.990$, $p < 0.05$). With these results, the null hypothesis has been rejected, although alternative hypotheses have been supported.

Table 6. Analysis of variance showing the independent indicators' impact on a dependent variable.

Model		Sum of Squares	df	Mean Square	*F*	Sig.
1	Regression	3652.461	2	1.826,230	122.990	0.000[b]
	Residual	1766.981	119	14.849		
	Total	5419.442	121			

a. Dependent Variable: Digital_Literacy.

b. Predictors: (Constant), Young_Users, Households_Internet.

In summary, we can speak of the following results of testing the hypotheses put forward in this study.

This study highlights the importance of internet access for school-age young people in Kazakhstan for development of their digital skills. Increasing digital literacy among school-age young people in Kazakhstan can prepare them for successful careers and social life. That being said, hypothesis H1 is confirmed.

Access to the Internet at home for school-age young people in Kazakhstan expands their opportunities for self-education, training, strengthening social connections, expanding cultural horizons, and improving the general well-being. This is especially important in the context where educational institutions integrate online resources and technologies into curricula. The results of the study highlight the need for targeted support for households in Kazakhstan with limited access to the Internet, especially those in remote and less developed regions. Addressing this issue can help reduce the digital divide and promote a more equal distribution of educational opportunities. Hypothesis H2 is confirmed.

The results of this study clearly demonstrate that improving access to the Internet at home directly contributes to an increase in the number of young Internet users. This highlights that access to the Internet at home is a critical factor for the inclusion of Kazakhstan's youth in the digital society. This confirms hypothesis H3.

The study has not found a significant connection between digital infrastructure in public schools in Kazakhstan and digital literacy level. Digital infrastructure in public schools in Kazakhstan has little impact on the process of increasing the level of digital literacy. This indicates that the mere presence of computers in schools does not automatically lead to increased digital literacy among young people. It is also important to consider the quality of equipment, access to the Internet, as well as the availability of effective educational programs and teacher training. Hypothesis H4 is rejected.

Despite expectations, no significant relationship has been found between the number of students per PC in public schools and the share of Internet users aged 6-15. This means that the school digital infrastructure does not contribute to an increase in the use of the Internet among school-age young people. Hypothesis H5 is refuted.

5. Discussion

This study empirically examines the way key indicators affect the increase in the level of basic elements of digital literacy in a developing economy. Based on the literature review, five hypotheses are put forward. Based on the official data of the

Statistical Department of Kazakhstan, the role of Internet's accessibility in households, school digital infrastructure, as well as the number of young school-age Internet users in the process of increasing the level of basic elements of digital literacy in Kazakhstan is investigated.

The number of young school-age Internet users has been found to have a positive effect on formation of digital literacy in Kazakhstan (H1). This result confirms the conclusions of previous studies by Hassan and Mirza, 2021 Liu et al., 2020, Quaicoe and Pata, 2020; Kateryna et al., 2020 who argue that an increase in the number of school-age Internet users positively affects increasing the level of basic elements of digital literacy. Internet Access at home has also been found to have a significant stable impact on digital literacy in Kazakhstan and an increase in the share of young school-age Internet users (H2, H3). This result is consistent with previous studies by Lai and Widmar, 2021; Mahmood, 2021; Qazi et al., 2020; Tadesse and Muluye, 2020. The concurrence of the results in this model supports the argument that in conditions of COVID-19 pandemic restrictions, connecting residents of Kazakhstan to the Internet has become a top priority, especially for remote areas. The level of Internet access and the purposes of its use by the population allow us to speak of different forms of digital inequality in society caused by territorial (settlement and regional) differences. Accordingly, reducing digital inequality requires not only addressing the issues of technical access to the Internet, but also all-round raising the quality of life, digital literacy, and digital culture in Kazakhstan.

In addition, formation of the basic elements of digital literacy in Kazakhstan has been found to occur mainly at home (H2). Digital infrastructure in public schools of Kazakhstan has little impact on the process of increasing the level of digital literacy, as well as on the increase in the number of young, school-age Internet users (H4, H5). This result is consistent with the conclusions made by Schleicher, 2019 who argues that the level of school provision with digital resources is more correlated with the level of digital literacy in developing countries. Unfortunately, there is an acute problem of providing schoolchildren with computer equipment in Kazakhstan. There are 8.5 students per PC in public schools, 80% of computer equipment requires replacement in some regions of Kazakhstan.

To summarize, digital literacy of school-aged young people in Kazakhstan is key. Indicatively, in most modern world professions require mastery of digital technologies. Teaching young people of school age in Kazakhstan digital literacy guarantees their competitiveness in the labor market and contributes to the maintenance and development of an innovative economy in Kazakhstan, which further requires creative and innovative experts. Digital literacy helps school-age young people in Kazakhstan be an active part of society by allowing them to participate in social, cultural, and political life. Knowledge of the principles of online security and personal data protection are an important part of the digital literacy of the youth of Kazakhstan. The conducted research contributes to understanding of how school and home infrastructure influences digital literacy of young people important for the development of educational policies and strategies in Kazakhstan.

6. Conclusions and policy implications

Digital literacy is an essential prerequisite for the development of the open innovation concept. Without boosting the level of digital literacy, sustainable economic growth based on new open technologies is impossible, therefore, training in skills related to the digital environment must become a priority for countries wishing to build an economy based on open knowledge.

This paper explores the process of increasing the level of basic elements of digital literacy in a developing economy. The study was limited to researching user digital skills of young people of school age. The conducted research has shown that (1) the literature is yet to form a unified methodology for assessing the digital literacy. Internationally, various indicators are used to determine the level of digital literacy; (2) number of young school-age Internet users has been found to have a positive effect on the formation of digital literacy in Kazakhstan; (3) access to the Internet at home has been found to have a significant stable impact on digital literacy in Kazakhstan and an increase in the share of young school-age Internet users; (4) formation of the basic elements of digital literacy in Kazakhstan has been found to occur mainly at home. Digital infrastructure in public schools in Kazakhstan has little impact on the process of formation of digital literacy, as well as on the increase in the number of young, school-age Internet users. The relationship between school digit infrastructure and digital literacy of young people of school age is still unclear and future research may focus on exploring other potential factors influencing this relationship.

Based on the results of the study, a number of recommendations can be offered to the government, educational organizations, and industry associations for the systematic development of digital skills and competence of citizens and implementation of the strategy of an open innovation economy. First, an expanded access to the Internet at home is recommended, especially for remote and less developed regions of Kazakhstan. A special attention should be paid to vulnerable groups, ensuring equal access to digital educational resources. This could include programs to subsidize Internet services, develop digital infrastructure, and provide access to digital devices. Second, we need programs of teaching digital skills to school-aged young people integrated into curricula, starting in primary school and continuing through middle and high school. Education programs should include online security components to teach young people how to use digital technologies safely and responsibly. Third, we recommend focusing not only on the number of computers in schools, but also on the quality of digital infrastructure in public schools, including Internet speed, availability of educational resources, and supporting digital technologies. And fourth, the effective use of digital technologies in education requires provision of professional development for teachers, including training in digital skills and teaching methods in a digital environment.

These recommendations are aimed at improving the level of digital literacy among school-age young people in Kazakhstan, ultimately contributing to the development of the country’s society and economy.

6.1. Theoretical and managerial implications

6.1.1. Theoretical implications

Our results allow us to supplement numerous theoretical and empirical studies on assessment of digital literacy (Bejaković et al., 2020; Liu et al., 2020; Prete, 2022; Widana et al., 2020). Our research is valuable for the development of the "open innovation" concept. The increasing influence of digital technologies on all spheres of society affects dynamics of open innovation. In this regard, assessing the basic elements of digital literacy in a developing economy needs finding out the relationship between indicators of digital literacy and availability of Internet in households, school digital infrastructure, as well as the number of young school-age Internet users.

This study reveals important findings that further expand knowledge on formation and development of digital literacy in a developing country. In particular, we have demonstrated the vital role of teaching digital skills to young people of school age in the process of formation and development of digital literacy. The results of the study reveal the crucial role of the development of digital infrastructure at home and its positive impact on the digital literacy.

Finally, the results of this study have shown a negligible impact digital infrastructure in public schools in Kazakhstan has on the process of increasing the level of digital literacy and on the increase in the number of young, school-age Internet users. This is another important discovery of ours, which, to the best of our knowledge, has not previously been reflected in previous studies, theoretically or empirically.

6.1.2. Managerial implications

Our study offers some important recommendations for government agencies, educational organizations, and industry associations in improving the level of digital literacy. As part of improving the level of digital literacy, we need to develop and post open educational resources on digital literacy and information technologies on e-education portals, to expand the network of Public Access Centers, and to conduct activities to improve knowledge and skills of the population on the safe and effective use of digital technologies and Internet resources, as well as to promote IT competency courses.

The state, educational organizations, and industry associations need to focus on improving the level of digital literacy of schoolchildren. Programs are required to increase the level of digital literacy, which, among other things, must expand accessibility of modern digital technologies in educational process. Addressing the issue of providing students with computer equipment requires revising the standards for the maintenance of schools, updating mechanisms for financing their activities and resource centers, including strengthening control over the funds allocated for the development of school digital infrastructure.

Cybersecurity training for young people of school age must become an obligatory part of programs to increase the level of digital literacy. Also, school curricula must provide for the integration of digital literacy teaching into a wide range of subjects.

6.2. Limitations and directions for future research

The selected approaches and research methods have a number of limitations determined by the choice of specific indicators, the use of economic and mathematical methods, and economic models of development. As in any other similar studies, causal conclusions must be approached with caution. The sample in the research was limited to studying the user digital skills of young people of school age. Future research could expand the scope of coverage of other social groups: the real sector workers, the unemployed, the elderly, etc. Studying digital literacy of young people of school age is not an easy task due to its wide range. Accordingly, its assessment requires identification of individual, the most common and important aspects and indicators from the point of view of the object under study. As such, the basic elements reflecting digital literacy of a young person have been selected for the study: working with data (digital content); working with a computer as a tool. The selected key indicators of increasing the level of digital literacy are as follows: the share of households with Internet access, the share of Internet users aged 6-15, and the number of students per PC in public schools.

A connection of school digital infrastructure in increasing the level of digital literacy of young people is still unclear. Future research could focus on exploring other potential factors that may affect this relationship. Also, further research can focus on the following aspects: the study of user digital skills of young people of school age: working with media material; communication in the digital sphere; attitudes towards technological innovations.

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Appendix

Table A1. Data for analysis.

Regions	Years	The Share of Households with Internet Access, %	Level of Digital Literacy	The Share of Internet Users Aged 6–15	The Number of Students per PC in Public Schools
	2016	73.2	72.3	59.4	9
	2017	73.7	71.9	62.8	9
	2018	75.7	75.6	70.7	9
Akmola	2019	81.5	80.3	76.4	9
	2020	85.6	85.7	80.3	6
	2021	89.21	87.6	83.4	3
	2022	90.34	87.6	85.7	3
	2016	82.4	84.2	61.3	12
	2017	86	86.9	68.1	12
	2018	90.8	87.1	69.7	9
Aktobe	2019	91.7	90.4	75.7	8
	2020	94	93.1	82.6	6
	2021	94.45	95.8	87.7	4
	2022	98.35	95.8	91.6	3
	2016	95.1	86.2	54.3	9
	2017	92.7	87.8	67.5	10
	2018	96.4	90.0	74.6	10
Almaty	2019	97	90.4	69.7	11
	2020	97.2	94.4	86.8	6
	2021	98.73	94.6	87.7	4
	2022	98.44	94.6	85.1	4
	2016	85.6	71.6	68.2	14
	2017	88.4	79.8	75.7	12
	2018	93.6	81.3	70.5	11
Atyrau	2019	93.9	84.1	72.5	12
	2020	93.8	91.2	87.2	8
	2021	93.76	88.0	86.1	9
	2022	95.13	88.0	87.1	8
	2016	87.4	94	57.3	7
	2017	81.3	81.6	58.8	8
	2018	88.6	94.5	68.5	8
West Kazakhstan	2019	88.9	94.7	76.2	9
	2020	89	94.8	82.8	6
	2021	89.45	95.3	81.2	4
	2022	93.09	95.3	81.4	4
	2016	83.6	73.7	59.6	11
Zhambyl	2017	89.9	77.6	60.1	11
	2018	92.5	86.5	77.4	9

Table A1. (*Continued*).

Regions	Years	The Share of Households with Internet Access, %	Level of Digital Literacy	The Share of Internet Users Aged 6–15	The Number of Students per PC in Public Schools
	2019	94.2	89.4	71.8	9
	2020	95.9	92.3	85.6	7
	2021	96	94.2	90.6	4
	2022	97.11	94.2	87.9	4
	2016	74	74.5	63.8	9
	2017	78.6	80.1	65.0	8
	2018	78.3	85.2	70.3	8
Karaganda	2019	86.4	94.1	63.0	8
	2020	89.9	94.6	91.2	5
	2021	94.27	96.6	95.0	4
	2022	94.62	96.6	95.4	4
	2016	78.3	79	63.5	8
	2017	79.9	80.6	72.4	8
	2018	80.3	82.1	72.5	8
Kostanay	2019	83.4	85.1	77.1	8
	2020	87.5	85.4	86.5	5
	2021	88.15	90.6	90.4	4
	2022	96.01	90.6	91.7	4
	2016	96.9	95.2	62.9	13
	2017	98.8	91.6	65.7	13
	2018	99.6	91.9	64.7	13
Kyzylorda	2019	99.7	93.5	65.9	11
	2020	99.7	97.5	71.9	8
	2021	98.04	99.4	85.7	4
	2022	98.62	99.4	87.7	4
	2016	82.3	78.6	64.5	17
	2017	86.7	86.7	64.4	20
	2018	88.1	93.2	67.6	14
Mangistau	2019	90	94.0	70.8	16
	2020	90.2	95.5	84.1	7
	2021	97.94	95.5	87.7	5
	2022	98.2	95.5	87.9	5
South Kazakhstan	2016	87.1	80.15	64.3	15
	2017	91.7	83.2	70.6	16
	2016	88.4	82.7	51.9	6
	2017	79	83.3	67.3	5
	2018	83.8	85.5	77.4	5
Pavlodar	2019	90.9	84.1	80.9	5
	2020	91.8	93.5	85.6	4
	2021	95.59	92.9	97.5	3

Table A1. (*Continued*).

Regions	Years	The Share of Households with Internet Access, %	Level of Digital Literacy	The Share of Internet Users Aged 6–15	The Number of Students per PC in Public Schools
	2022	96	92.9	99.4	3
	2016	80.3	78.8	62.9	5
	2017	78.9	79.6	67.7	5
	2018	81.9	80.9	67.4	5
North Kazakhstan	2019	82.6	83.2	75.2	5
	2020	89.5	85.8	90.6	4
	2021	89.7	86.1	92.1	3
	2022	91.3	86.1	91.4	3
	2016	73.3	77.2	60.1	9
	2017	73.3	76.7	70.3	8
	2018	79.7	81.9	70.5	7
East Kazakhstan	2019	83.1	83.8	77.5	7
	2020	85.8	87.9	87.6	5
	2021	89.54	89.5	89.1	4
	2022	95.3	89.5	90.5	4
	2016	99	93	64.7	14
	2017	93.3	91.8	77.9	16
	2018	95.6	94.8	78.6	19
Astana city	2019	99	97.4	89.4	20
	2020	99.2	97.8	91.3	8
	2021	99.31	98.0	98.4	7
	2022	99.41	98.0	98.4	6
	2016	88	86.1	72.6	15
	2017	87.4	89.9	66.1	16
	2018	89.4	92.9	65.4	14
Almaty city	2019	89.7	93.8	77.9	15
	2020	92.4	95.0	86.3	3
	2021	93.72	96.3	99.9	3
	2022	97.38	96.3	99.4	3
	2018	93.3	88.4	83.7	15
	2019	96.7	92.3	84.2	16
Turkestan	2020	98.4	93.7	87.0	12
	2021	98.96	95.6	88.5	7
	2022	99.57	95.6	98.4	7
	2018	90.7	85.0	66.8	20
	2019	91.3	85.1	66.3	23
Shymkent city	2020	91.1	86.8	77.0	5
	2021	96.17	90.0	95.0	4
	2022	98.1	90.0	94.1	4