Ukrainian Students' Digital Competencies: Various Aspects of Formation and Impact on Students' Learning Achievements

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Abstract. In different countries and economics, we can observe the difference in learning students' achievements depending on their digital competencies. There are some international studies, such as PISA (Program International Student Assessment) and ICILS (International Computer and Information Literacy Study), which allow to evaluate some associative relationship and to make a conclusion about using digital technologies in the learning environment. In 2018 Ukraine participated in PISA for the first time in the Paper-Based Assessment (PBA) format and didn't participate in ICILS. Now we don't have any national or international studies, which will be able to answer a question about readiness Ukrainian students to Computer-Based Assessment (CBA), only we have some results from PISA 2018. This research presents analyze the PISA 2018 Database and some other results of studies. We studied how digital technologies influence on the student's achievement of main literacy domains. So, in other words, we wanted to evaluate how the digital environment impacts students' readiness for effective implementation in a changing digital world. The results of Ukraine and other countries are useful for the formation of key policies for Ukraine concerning the development of the digital competencies of Ukrainian students.

Keywords: Program International Student Assessment (PISA), Student Achievement, Information and Communication Technologies (ICT), Digital Competence.

1   Introduction

Digital competence in the digital transformation of the current decade is becoming more relevant [1]. The EU recognizes digital competence to be one of eight key competencies

required for any person to live his/her full life [2]. Thus, building the students' digital competence becomes a vital task for educational institutions to fulfill. Ubiquitous digitization increases the requirements imposed on the specialists' digital competence. Whilst the computers and the internet play a central role in our personal and professional life, the students who do not gain basic digital skills of reading, writing, and navigating through the digital environment cannot participate the economic, social and cultural life [3, p. 15].

Researchers in the field of Education have examined digital technologies and informational and communication technologies (ICT) in Ukraine, studying different aspects of ICT influence on academic progress, motivation, and readiness for digital learning at both higher education [4] and secondary school [5]. However, the previous research does not evaluate the digital competency level of different groups of learners and their readiness to advance and make progress within the digital environment.

International research projects such as PISA (Program International Student Assessment) and ICILS (International Computer and Information Literacy Study), which directly assess both digital and general competencies, allow us to evaluate some associative relationship and to make a conclusion about using digital technologies in the learning environment.

The cross-national nature of the PISA and ICILS data are the basis of a growing body of analyses that replicate and extend models that describe these relationships in different contexts. By comparing the results across different countries and economies, the research can develop generalizable models that can guide future educational policy. Based on the PISA 2009 data [6] from 17 countries and economies, J. Nauman built a model of online reading engagement, where he outlined the connection between the digital competence and digital reading [7]. That model served to develop a practical recommendation to improve the process of education.

Unfortunately, research in Ukraine does not adequately evaluate the digital environment and the quality of gained digital competence in Ukraine. At the country level, we still do not have the tools to monitor and evaluate digital skills and competence. At the legislative level, we do not define the basic terms such as "digital skills" and "digital competence [8, p. 10]. As a result, previous research conducted by Ukrainian contributors [9] does not describe the whole picture of students' digital competence and does not allow comparison with other countries.

For the first time, Ukraine participated in PISA in 2018. However, the assessment in Ukraine was held in a paper format. Thus, we could not evaluate the students' readiness for the digital world, as they did not have a chance to demonstrate their digital skills (in particular, digital reading).

Herewith, we use the analysis of the international data to generalize the influence of ICT on the progress of students' learning in Ukraine.

This research aims to define the factors related to the students' digital environment and assess their influence on the literacy rate in reading, mathematics, and natural sciences of Ukrainian students according to PISA 2018 results.

2   Theoretical Background

PISA (https://www.oecd.org/pisa/) is a Program for International Student Assessment that includes over 90 world countries and economic regions. The program takes place every three years. In each three-year cycle, PISA uses direct assessments to measure students' literacy rate in reading, mathematics, and natural sciences. In selected cycles, the program also assesses the participants' competence with the additional frameworks such as global competence, financial literacy, etc. The main goal of PISA is not to rate the students' level of knowledge, but to assess the level of their readiness to live in the digital world and solve the practical tasks they may face on their career path. In most countries, the assessment occurs in digital format.

In addition to the direct assessments of competencies, PISA also uses questionnaires to collect information the students' contextual characteristics. Combining information from the tests and questionnaires enables analysis of how different contextual factors correlate with student progress.

In PISA 2012, 29 OECD countries and 13 partner countries and economies chose to distribute the optional ICT familiarity component of the student questionnaire. PISA 2012 research [3] assessed the effectiveness of ICT applicability in school and at home and its influence on assessment results on the main literacy frameworks.

The results of the research do not indicate any direct correlation between level of financial investment in digital technologies and quality of learning outcomes. Rather, students' achievements to depend more on how often and for what reason the digital equipment is utilized during the education process, how motivated are students to use computers for solving their tasks, and if the teachers are capable of effective methods of teaching leveraging computes and digital technologies.

The thematic studies [10] and local research [11], that rely on PISA analytical reports [12] indicate that providing students and teachers with computers is not enough to guarantee them the digital competence and better progress. This finding is also seen in results of the international ICILS 2018 research held by IEA [13].

This paper examines the Ukrainian students' readiness to live in the digital environment by assessing the influence of several factors that characterize digital competence on students' performance according to PISA 2018 results. Although the survey did not contain direct questions to students about leveraging ICT when studying, other data provide a snapshot of the digital environment in Ukrainian schools.

In terms of this work, we set the following tasks:

1. Define the formation conditions of the Ukrainian students' digital competence: access to the Internet and availability of computers in school and at home, digital learning at school, the activity of Internet using.
2. Define the influence of digital competence on the Ukrainian students' performance on the main subjects and in particular, define the value of school education.

3 Methods and Study Materials

This work leverages the results of its own analysis of PISA materials, as well as uses the materials from OECD analytical reports and PISA datasets in SPSS format (https://www.oecd.org/pisa/data/2018database/). To analyze the Ukrainian students' results we utilized data from the PISA 2018 research [14]. These data include computed scale scores for the different skill assessments, responses of students and school administrators to individual questions, and computed index scores based on multiple questionnaire responses. Computed index scores are standardized to have a mean of zero for OECD countries and a variance of 1 across OECD countries, and the scores are usually distributed normally in the range from -3.5 to 3.5 [15, p. 22].

The Index of computer availability in-home (ICTRES) is computed from items ST011 and ST012 [16], [15, p. 305]. If the ICTRES index is greater than zero, the students' availability of computers, educational software and access to the Internet is higher than in the OECD countries. If the ICTRES index is less than zero, the students have fewer digital resources than on average students from OECD countries.

The Index of Economic, Social and Cultural Status (ESCS) is calculated using a variety of student background variables that describe the relative economic, social and cultural advantage of different students' families. This index is historically a strong predictor of student outcomes. If the ESCS index is less than 0, the students have less advantaged family backgrounds [15, p. 339].

The Index of computer availability in schools (RATCMP1), is calculated from item SC004 [16]. This index describes the ratio of students to available computers in a school. If the index is less than 1, there are more students than computers, and if the value is greater than 1, there are fewer students than computers.

The main statistics and the coherence of statistical connections were calculated based on the testing results on the main subjects, students' surveys [15], and surveys of the schools' principals [17]. We utilized the methods of frequency analysis, calculation of mean values, calculation of the fault level, and the methods of correlation and regression analysis recommended for processing PISA results [15].

For all calculations, we used the software environment for statistical study R that included the package for international research results processing **intsvy** [18] and the technologies described here [15]. To analyze the influence of the school system on students' ability to gain the main digital competence we leveraged the method of hierarchical regression analysis in the R environment with the **lme4** package [19]. We also leveraged MS Excel for calculations and the presentation of the results.

4 Main Findings

4.1 The Digital Environment of the Ukrainian Students

The PISA 2012 results [3], the necessary (albeit insufficient) conditions for gaining skills and knowledge in the digital environment are the availability of digital equipment

and Internet access. These factors are largely dependent on the primary level of the students' socioeconomic status.

According to PISA 2018, 89.2% of Ukrainian students reported they have computers at their homes to do homework, 58.6% of students said they own educational software, and 97.7% of students have access to the Internet.

The level of digital resources availability in Ukraine is lower [20] compared to the OECD countries and other countries that perform highly on literacy outcomes. Figure 1 displays the comparison of Ukraine with neighboring countries and the OECD average.
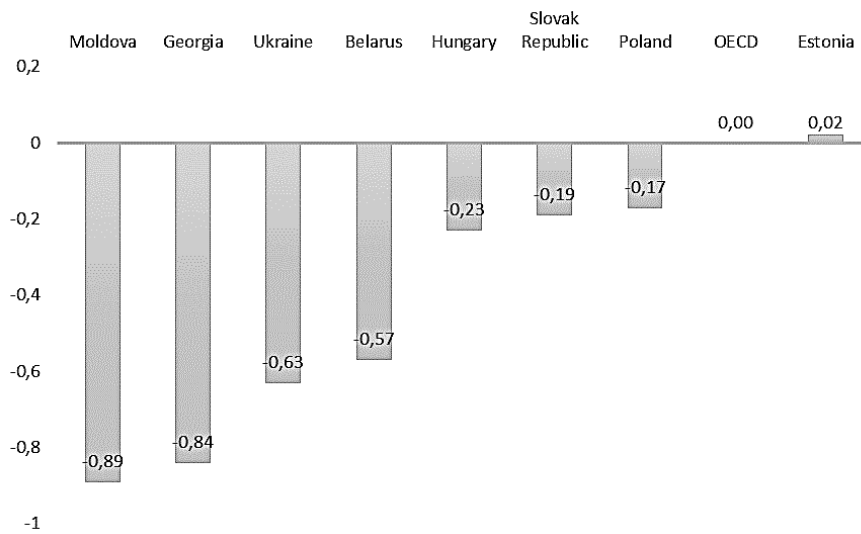

Fig. 1. The ICTRES index values for different countries (Source: Own work)

In Ukraine, almost 70% of principals working in schools where 15-years old students study reported they lack digital equipment with access to the Internet, the Internet speed is poor, and their software is outdated. Despite the lack of physical resources, the principals reported adequate access to effective professional resources for the teachers to utilize to learn how to use digital equipment, and they also have access to useful educational online platforms [20, p.167].

Internationally, the countries with higher academic performance rates are better equipped with computers and other digital tools. Comparing the relation of the number of computers per student (RATCMP1), we can see that only 6 out of 10 students are provided with a computer (Fig. 2). The number of computers per student in Estonia, Slovakia, and the average number in OECD countries is higher.
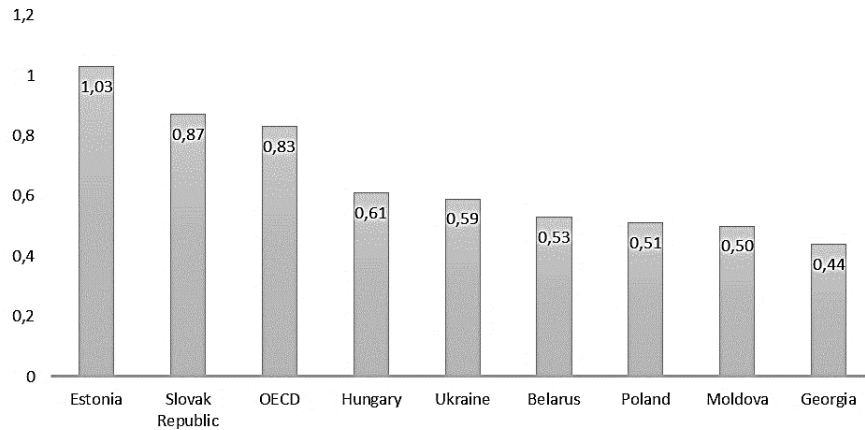
Fig. 2. Index of computer availability per student (RATCMP1) in different countries (Source: Own work)

The availability of computers and Internet access is a necessary precondition for developing students' digital competence. The sufficient condition is self-teaching and actual implementation of the gained skills and knowledge.

According to the survey results on item ST176 [16], Ukrainian students mostly utilize the Internet to communicate in messengers and to search for information. Less often, they search for some practical "know-how" information, read news and emails, or participate in forums (Fig. 3).
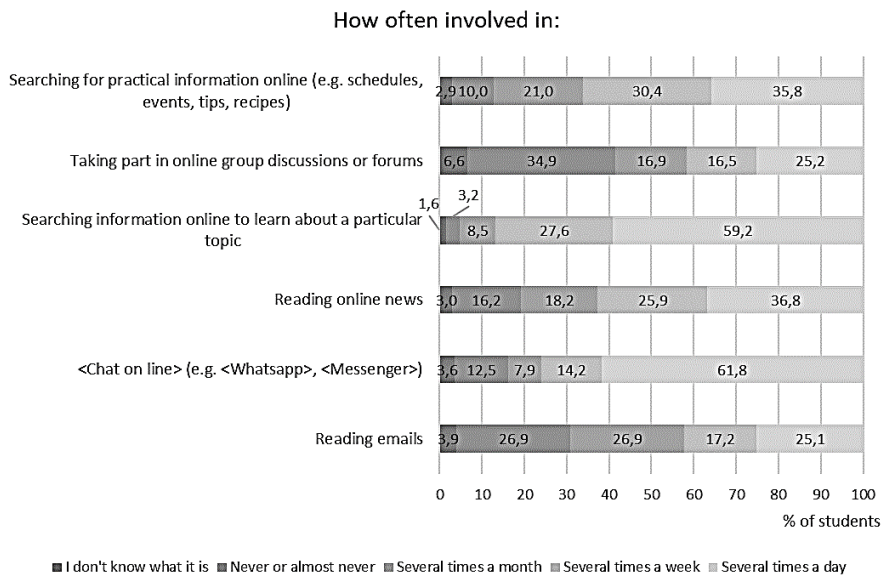

Fig. 3. Percentage distribution of students' answers on the usage of Internet resources (Source: Own work)

Also, 54.2% of students answered that they use digital equipment for reading, 65,3% of students have some skills and knowledge with data security in the digital environment (calculated on the basis of answers to ST168 and ST166 items [16]).

A large proportion of students do not learn their digital skills at school (Fig. 4). On average, 50% of students learned data security and 40% of students learned basic digital competence connected with the usage of the Internet and searching data outside of school (calculated based on answers to ST158 items [16]).
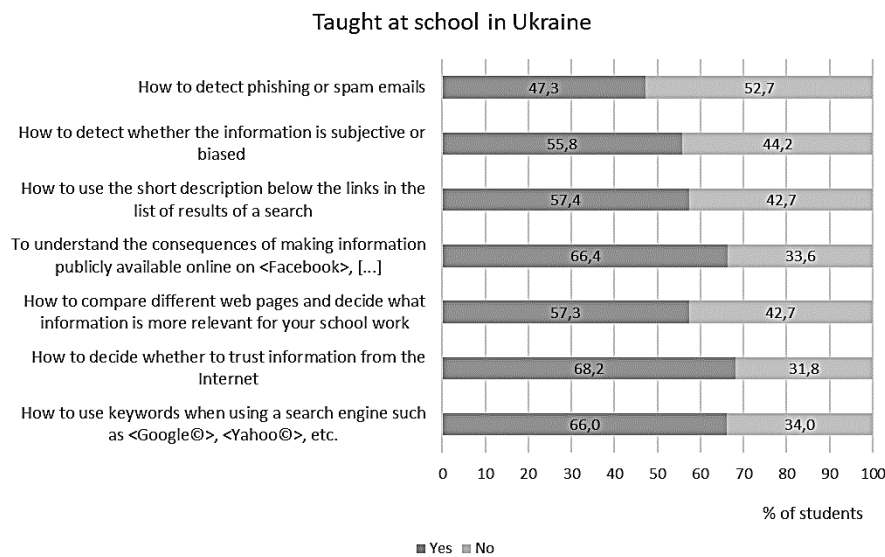
Taught at school in Ukraine

Category	Yes	No
How to detect phishing or spam emails	47,3	52,7
How to detect whether the information is subjective or biased	55,8	44,2
How to use the short description below the links in the list of results of a search	57,4	42,7
To understand the consequences of making information publicly available online on <Facebook>, [...]	66,4	33,6
How to compare different web pages and decide what information is more relevant for your school work	57,3	42,7
How to decide whether to trust information from the Internet	68,2	31,8
How to use keywords when using a search engine such as <Google©>, <Yahoo©>, etc.	66,0	34,0

% of students

■ Yes ■ No

Fig. 4. Percentage distribution of students' answers on teaching digital competence in schools (Source: Own work)

4.2 Digital Skills and the Students' Performance of the Main Disciplines

We assessed what digital resources, knowledge, and skills influence Ukrainian students' performance on the main disciplines. We built separate regression models to estimate the relationships, where the target variables were students' scores in reading, mathematics, or natural sciences in PISA points, and the predictors were the ICTRES or RATCAMP1 index.

The students who has a higher ICTRES index has on average 20-25 points PISA scores in reading, mathematics, and natural sciences. We observed the same coherence with the school resources. In schools, where principals reported a higher index of computer availability per student, students have at average 17 points higher PISA scores.

However, because ICTRES is correlated with ESCS, it is difficult to estimate an effect of ICT resources that is clearly independent of student background or the average school socioeconomic context. If we build a regression model of dependence on the students' performance (in PISA points) from the ESCS and ICTRES indexes, the influ-

ence of the ICTRES index is not significant. Ideally, the model should include interaction terms to estimate the degree to which ICTRES has a magnifying effect on ESCS with respect to literacy. Unfortunately, with such small between-school variation in both the effect of ESCS and the skewed ICTRES distribution, potential interaction effects cannot be estimated with the current data using this model. Based on the current results, the most likely interpretation is that the students' performance overall depends more their socioeconomic status, with ICT resources playing a redundant role, and likewise, the average performance at school depends largely on the socioeconomic status of the students studying in that school.

Ukrainian students who use Internet for communication and searching for data are considered active readers of information available online [20, p.109]. These active online readers have higher scores in reading literacy than the students who do not use online resources, despite their socioeconomic status (Fig. 5).
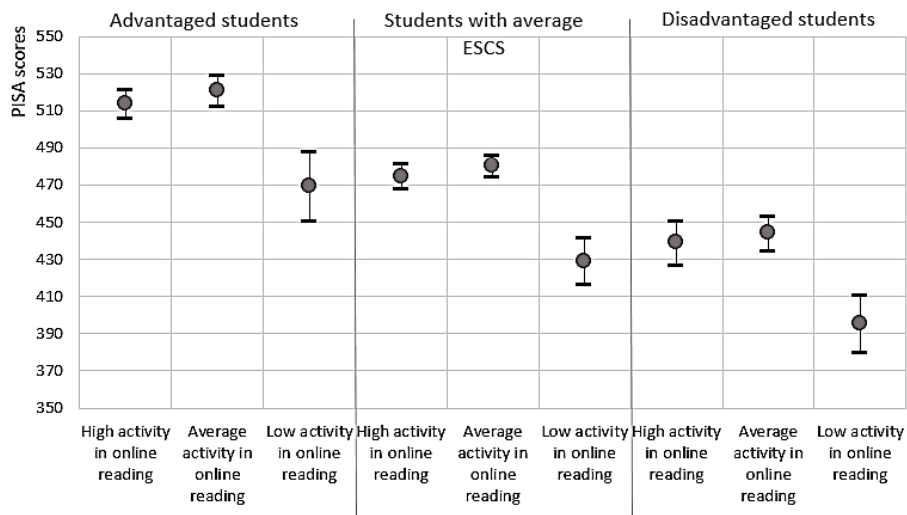

Fig. 5. Average scores in digital reading of students with different socioeconomic status (Source: Own work)

Considering the influence of the book format (regarding the ST168 question about paper vs digital books [16]), we can claim that the format does not influence the results. Although students who do not read books tend to have lower scores and students who read in both formats have higher scores, the difference in performance between students who read paper and those who read digital is not significant (Fig. 6).

The students were asked a question about challenges with the tasks from the reading section. They had to agree or disagree on a statement: "I was confused when I had to work with the pieces on different pages (ST163). These situations often happen when a person reads from the digital devices and must switch between two files or open hyperlinks. The students who confirmed they had difficulties reading in that format received fewer points for reading (Fig. 7).
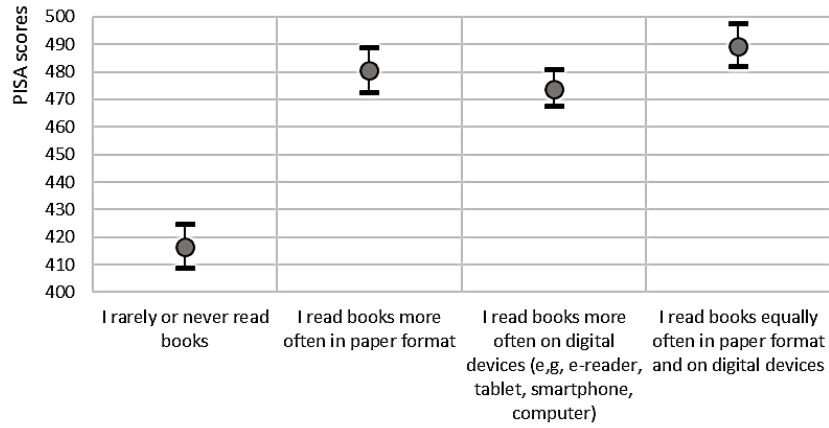
Fig. 6. The average scores in reading depending on the format of the books that students read
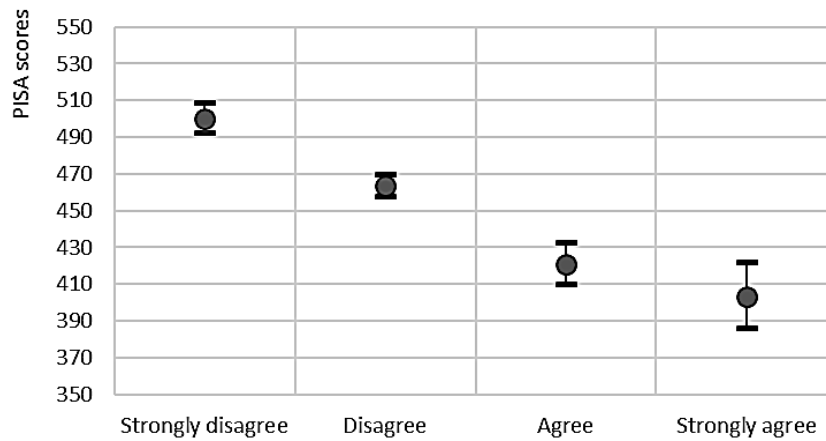(Source: Own work)

Fig. 7. Average scores for reading and perceiving text when having to switch between pages
(Source: Own work)

The analysis of the performance in reading, mathematics, and natural science can not confirm that school education has a positive or negative influence on students gaining knowledge or skills working with digital information. Self-educated students tend to have higher scores than students who received digital skills at school, but this difference can be explained by ESCS. Advantaged students are more likely to be self-educated in ICT and also more likely to have higher performance in literacy. These relationships are independent of any potential school effects. But we can see that the students who were more successful received their digital skills out of school (Table 1). Values in the table that are in bold are statistically significant.

Table 1. Scores difference of students who received digital skills inside and outside school

Taught at school in Ukraine	Reading	Math	Science
	Average scores of students, who answered that they mastered these skills inside of school		
	449.9	437.63	452.6
	Scores difference of students who answered that they mastered these skills outside of school		
How to use keywords when using a search engine such as <Google©>, <Yahoo©>, etc.	6.5	**10.68**	7.42
How to decide whether to trust information from the Internet	**-8.86**	-5.45	-5.65
How to compare different web pages and decide what information is more relevant for your school work	**19.04**	**14.41**	**14.6**
To understand the consequences of making information publicly available online on <Facebook>, [...]	-0.86	1.79	1.88
How to use the short description below the links in the list of results of a search	5.4	6.75	5.44
How to detect whether the information is subjective or biased	**10.06**	4.62	**9.14**
How to detect phishing or spam emails	**11.32**	**10.57**	**10.44**

We also examined the data by constructing multilevel models [21, p. 201]. The advantage of multilevel models (or mixed regression models) is that they can together estimate relationships between variables on the school level and on the student level. Thus, we can determine the degree to which differences in student outcomes are the result of differences between students or the result of differences between the schools that they attend. The results of a mixed regression model include coefficients describing the average performance and predictor effects within each school, as well as the degree to which that vary between schools. The intraclass correlation coefficient (ICC) is the ratio of the variability between schools to the total variation (within and between schools) [22].

Considering the dependence of the level of Ukrainian students' success on the main disciplines from their socioeconomic status, we can claim that the variability of the results is explainable primarily by student-level differences.

In Figure 8 illustrates the variation of PISA reading scores in accordance with the students' socioeconomic status. The lines on the graphs depict the regression lines for certain schools. Mostly, these lines are situated in the center of the scattering graph and have similar slopes. The similarity of the lines indicates that the relationship between socio-economic background and student performance is relatively consistent, even across schools with very different average levels of socio-economic backgrounds.

The intraclass correlation coefficient (ICC) of this model is 0.28. The main interpretation of this result is that approximately a third of the variability of the results can be

attributed to the influence of a school after the effects of socio-economic conditions are considered. The diagram proves that in most of the schools, variability in students' performance depends on their socioeconomic status. However, there is also a place for the influence of location and segregation. Some schools provide for a high or middle level of performance regardless of the socioeconomic status.
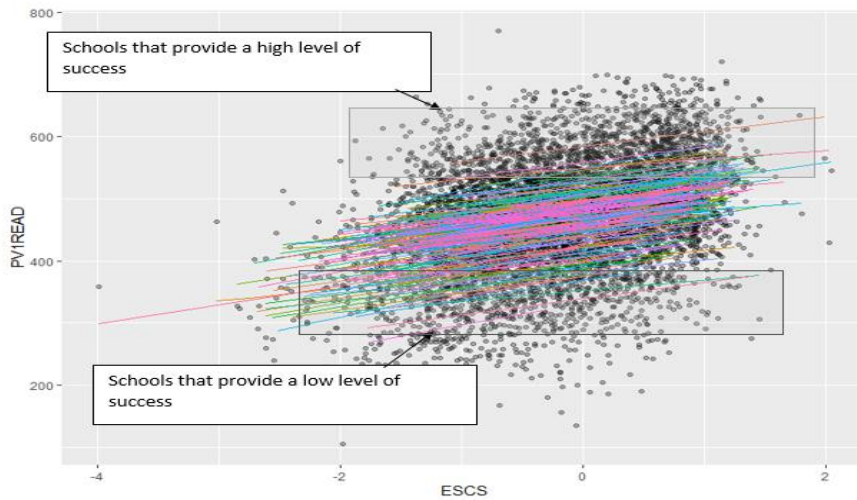

Fig. 8. The variation of PISA reading scores (PV1READ) in accordance with the students' socioeconomic status (Source: Own work)

The dependence of a level of digital reading from students having available digital devices at home does not influence the students' performance (Fig. 9). According to the regression model, its influence of the performance is consistently minor across schools, though the variability of results among schools is big, and the ICC equals 0.46.
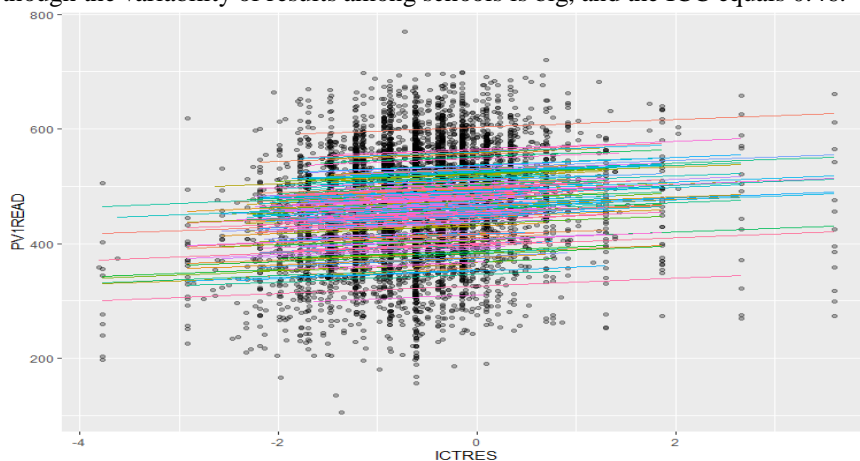

Fig. 9. Dependence of the PISA reading scores (PV1READ) from the index of computer availability (ICTRES) (Source: Own work)

The model of the online reading activity dependence on the availability of digital devices at home (Fig. 10) indicates that, on average, there is little variation in either online reading habits (ICC=0.041) or ICT resources between schools. However, there appears to be substantial variability in the relationship across schools, suggesting that in some contexts, differences in availability of ICT for students may explain to frequency of online reading while in other contexts, it does not. This relationship is difficult to interpret because both variables have skewed distributions ($skew_{ICTRES} = 0.44$; $skew_{onlineread} = -0.43$). The non-normality produces an artificial restriction of range that has a minimizing effect on observed relationships; if the indices were measured using items that are more sensitive to variations within Ukraine, the observed relationships would likely be higher, but it is not possible to determine the degree of underestimation using the current data.
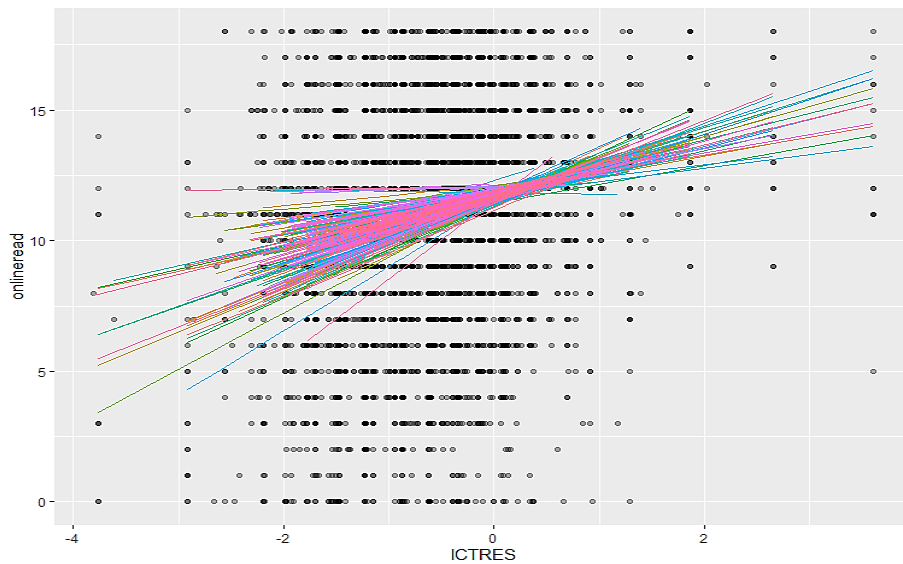

Fig. 10. Dependence of online reading activity (onlineread) from the index of computer availability (ICTRES) (Source: Own work)

5   Discussion: Computer vs Paper Assessment

The PISA migration to computer testing was phased (in 2018, 9 countries still held their testing in paper format). Switching to computer testing was motivated by several factors: the tests are simpler and cheaper to administer, it facilitates more complicated tasks, it simplifies data collection and analysis, it provides for ability to get more information about the process of testing (for example, to evaluate how much time students spent on certain tasks), etc. [23].

In addition, proceeding to computer testing reflects global changes in our society. The widespread availability of digital devices changes the methods of finding and accessing information. Some competences, such as the ability to process big volumes of data or the ability to work with an overabundance of data, become essential. Utilizing digital devices for reading and solving practical tasks such as adding funds, registering to the electronic systems, participating in economic and social processes is a must. Thus, PISA implementation of a computer format is a logical consequence of digitalization.

The differences between PISA tests in paper and digital formats in most cases are caused by variety of tests and the ways of interaction. For instance, the digital reading tests in digital format contain the elements (menu, scroll bars) for navigation between the parts of the text [24], and the tasks in natural science contain the computer simulators that help to assess the students' ability for researching and interpreting the results.

In all these tests, the data that students see on the screen are part of their interaction with the task, such as clicking, scrolling, or else. Thus, all tests in digital format require digital competence and skills of working with the computer.

Since 2021, testing in Ukraine will be in digital format and the students will have to complete tasks that could not exist in paper format. Thus, the PISA results of Ukrainian students will depend on their digital competence level as well.

Since we cannot rely on PISA 2018 results to predict the outcome of digital testing in 2021, the experience of other countries can be useful for our research. However, different countries have their own peculiarities, which may make generalizing their results problematic.

Some countries demonstrated much better results after switching to digital testing, while several researchers claimed the decrease of the literacy rate exactly after switching to digital PISA [25].

6 Conclusions and the Research Perspective

The analysis of the international PISA research, local Ukrainian researches, and additional data collected on this topic allows us to make some generalization.

From the received results we can conclude that Ukraine, comparing to other countries is less provided with computers and digital devices, and scholastic education (to the students' opinion) only partly provides for digital competence.

Though, according to the PISA 2018 results, the level of Ukrainian students' digital competence is impossible to assess. We can only observe the associative links between the student's performance and the disciplines and factors connected to leveraging digital devices and the Internet in the process of education.

In most cases, students with lower PISA scores in subject literacy are also characterized by lack of digital devices, access to the Internet and also, lack of activity utilizing online materials.

What is more, although there is a difference between levels of digital competence of students who have free access to digital devices, and those who do not, we consider this difference to be connected with the students' socioeconomic status. The availability of

digital devices correlates to socioeconomic status. Currently, availability of ICT and instruction of ICT in schools may be less effective than non-scholastic resources in supporting the development of ICT skills.

To define the main strategies of how we can improve the students' digital competence, we consider advantageous to widen the research on the experience of leveraging digital devices and up-to-date methods of teaching among the countries that have similar conditions of growth and development to those we have in Ukraine.

In addition, comparing the results of the countries that switched from PISA paper to digital format showed several distinctions related to different categories of students, that we have to study and analyze.

Another topic for future investigation and analysis is the effectiveness of utilizing various teaching methodologies meant to improve the students' digital competence.

Additional research on the other countries' experience will allow us to develop recommendations on how to improve digital education, and thus to improve the general level of Ukrainian students' performance.

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