

Formation of digital inclusion in the educational system of Kazakhstan in a system of equal access

Dmitriy Lepeshev^{1*}, Assel Kalymova², Nina Stukalenko³, Dinara Doskenova⁴,
Nurgul Shubayeva⁵

¹ Research Laboratory “Inclusive Education and Neurodiversity”, Ualikhanov University, Republic of Kazakhstan
^{2,3,4,5} Department of Pedagogy, Psychology and Age Development, Ualikhanov University, Republic of Kazakhstan

*Corresponding author E-mail: d_Lepeshev@mail.ru

ABSTRACT

Digital changes in education systems have made the problem of ensuring equal access to digital resources, infrastructure and learning opportunities more urgent. The purpose of the study is to analyze the formation of digital inclusion in the education system of Kazakhstan and identify factors that determine inequality of participation in the digital educational environment. A mixed design was used, which involved a synthesis of a quasi-experimental approach (pre-/post-test), quantitative questionnaires and qualitative analysis of open-ended responses from students and teachers. The total sample consisted of 380 participants. The results showed an average level of digital inclusion ($M = 63.8$, $SD = 11.4$). More than a third of students (34.7%) used a smartphone as their main learning device. This is due to reduced indicators of digital inclusion ($t(318) = 5.14$, $p < .001$, $d = 0.81$). Only 26.9% had a stable Internet connection. ANOVA indicated statistically significant SES gaps ($F(2,317) = 28.41$, $p < .001$): students with high SES ($M = 71.8$) outperformed students with average ($M = 64.3$) and low SES ($M = 57.2$). Regression analysis confirmed that digital competence is the strongest predictor of digital inclusion ($\beta = 0.36$, $p < .001$). The study indicated that there are the following barriers to the development of digital inclusion: technical, cognitive-navigational, organizational and psychological. At the same time, the experimental intervention (digital training, LMS standardization, digital tutoring) contributed to the increase in the level of digital inclusion. Therefore, the study made an empirical contribution to the understanding of digital inclusion in Kazakhstan and pointed to the interaction of infrastructural, cognitive, and social factors.

Keywords: First keyword, Second keyword, Third keyword, Fourth keyword, Fifth keyword

1. Introduction

The digital transformation of education systems in the world has raised the important issue of ensuring equal access to quality educational services. In developing countries, in particular in Kazakhstan, the digitalization of education is uneven and reflects regional, socio-economic and infrastructural gaps. Despite public investments in the development of digital infrastructure, connecting universities to high-speed Internet, and introducing electronic platforms and digital resources, the problem of digital inclusion remains one of the important challenges in the development of national education policy [1], [2]. Particular attention has been paid to the problem of ensuring equitable access to digital technologies for students from different social groups, rural areas, children with special educational needs and vulnerable families. Modern scientific literature indicates that digital inclusion is an important system that ensures access to technologies, the formation of digital competence and overall participation in the digital society [4], [5], [6].

Previous studies have described the specifics of the development of digital infrastructure, distance learning and digital educational platforms [7], [8], [9]. Recent scientific literature has indicated that digital inclusion is

a phenomenon that is related to access to technologies and to social, pedagogical and organizational conditions [10], [11]. Rimmerman emphasized that digital technologies during the pandemic and the post-pandemic period have become a key tool for social and educational inclusion [12]. Kaarakainen and Saikkonen's research has shown that already from adolescence, educational gaps begin to determine the trajectories of digital accessibility: schoolchildren and students with higher educational and social capital have better opportunities to form digital competence [13]. At the same time, Polikhronidi indicated that inclusive education requires holistic changes in the organization of learning, support for teachers and adaptation of the learning environment, in which digital tools have been an important means of accessing content and interaction [14]. In turn, Pulak and Tomaszewska and Mihaescu and Andone drew attention to the fact that effective student participation depended on the formation of specific competencies: the ability to work with online resources, interact in digital environments, and independently organize learning [15], [16], [17]. However, to a lesser extent, the authors have focused on the social aspects of inclusion, in particular, barriers to access, regional differences and inclusion of vulnerable groups. Thus, there remains a scientific gap that this study will fill [18], [19].

For this reason, the study of digital inclusion in Kazakhstan is relevant and important within the framework of the implementation of current state programs ("Digital Kazakhstan", "Digital School") and global initiatives of the UN and UNESCO on sustainable development. Despite the presence of individual studies that analyze the development of digital education in Kazakhstan, there is still no empirically substantiated analysis of digital inclusion as a multidimensional phenomenon. The scientific problem lies in the insufficient theoretical and practical development of systemic criteria for digital inclusion in the educational environment, mechanisms for reducing digital inequality between regions and social groups [20]. Thus, an important question arises that will need to be addressed: how is digital inclusion formed in the educational system of Kazakhstan and to what extent have existing practices ensured equal access to digital educational opportunities? Therefore, the purpose of the study is to conduct an analysis of the formation of digital inclusion in the educational system of Kazakhstan within the framework of ensuring equal access to digital resources, services and infrastructure.

To achieve the goal, the following tasks are provided:

1. To analyze the level of digital inclusion (accessibility of infrastructure, digital skills, use of platforms, barriers) based on quantitative and qualitative data.
2. To identify factors affecting digital inequality, and outline areas for optimizing state policy and practices of educational institutions.
3. To identify the main barriers that affect the development of digital inclusion.

Research hypotheses:

H1: The level of digital competence of pupils/students is a significant predictor of educational participation in the digital environment (frequency of platform use, success in completing online tasks).

H2: Students from families with higher socio-economic status have a statistically higher level of digital inclusion than students with lower SES.

H3: The gap in internet speed and platform accessibility significantly affects the overall level of digital inclusion.

H4: Teachers' readiness for digital work (digital competence, training) is positively correlated with the level of digital inclusion of pupils/students.

2. Research method

2.1. Research design

The study is based on a quasi-experimental and comparative-explanatory design.

The quasi-experimental component involved the implementation of a targeted set of measures to increase digital inclusion (digital training, methodological support, optimization of the use of platforms) in experimental educational institutions and comparing them with control institutions.

The comparative-explanatory component was aimed at establishing links between the level of digital inclusion and:

- digital competence of education seekers (H1),
- socio-economic status of the family (H2),
- quality and speed of Internet connection and accessibility of platforms (H3),
- digital readiness of teachers (H4).

Thus, the study was carried out in a mixed design with a priority on quantitative data and their supplementation with qualitative materials (semi-structured interviews, focus groups).

2.2. Participants

The study involved 380 participants who were recruited from structural divisions of universities of the Republic of Kazakhstan). The sample consisted of students of various educational programs and teachers. This, in turn, made it possible to conduct an analysis of digital inclusion in higher education.

The sample was purposeful. A total of 320 students were recruited. Educational level - bachelor's degree (1-4 courses). The age range ranged from 17-23 years. Specialties / educational programs included the following areas: pedagogy, psychology, inclusive education, social and humanitarian specialties, information technologies. Thus, students were recruited from different faculties and courses. In this way, the level of digital inclusion in different academic settings was assessed.

60 teaching staff of Ualikhanov University were also recruited for the study. The age range ranged from 27-65 years.

The distribution of the study groups was as follows:

Experimental group (N = 190) students and teachers. Participants underwent programs to improve digital competence and inclusive digital support.

Control group (N = 190) students and teachers

Studied as usual without intervention.

Overall, the sample of 380 participants provided statistical power for regression and comparative models (power $\geq .80$). Therefore, the sample was representative of the university environment (See Table 1).

Table 1. Characteristics of study participants (N = 380)

Parameter	Categories	N	%	Description
Participant Type	Students	320	84.2%	Main research group
	Teachers	60	15.8%	University teaching staff
Faculties / areas of study (students)	Pedagogy	110	28.9%	Pedagogical education programs
	Psychology	70	18.4%	Educational programs in psychology and age development
	Inclusive education	55	14.5%	Students of inclusive pedagogy specialties
	Social and humanitarian specialties	85	22.4%	Sociology, history, cultural studies, philology
Course of study (students)	1st year	80	25.0%	Initial level of digital competence
	2nd year	85	26.6%	Intermediate level of platform proficiency
	3rd year	75	23.4%	Active use of educational services
	4th year	80	25.0%	High level of digital autonomy

Parameter	Categories	N	%	Description
Experience using digital technologies (self-assessment)	Low	52	13.7%	Limited experience, need for support
	Medium	198	52.1%	Regular but non-systematic use
	High	130	34.2%	Free command of platforms and services
Participation in research groups	Experimental group	190	50%	Digital support program participants
	Control group	190	50%	Regular learning mode
Teaching experience (teachers)	Up to 5 years	12	20%	Young professionals
	5–15 years	25	41.7%	Experienced teachers
	Over 15 years	23	38.3%	High pedagogical experience
Frequency of use of digital platforms	Daily	145	38.2%	Online classes, LMS, digital materials
	3–4 times a week	162	42.6%	Blended form of learning
	1–2 times a week	73	19.2%	Episodic use

2.3. Data collection tools and procedure

The study used various tools for data collection and processing. The Digital Inclusion Questionnaire for students was important in the study. It consisted of an access block: availability of a device, type of connection, stability of the Internet; a usage block: frequency of entry to platforms, types of activities (viewing materials, completing tasks, participating in forums/chats); a barrier block: technical, linguistic, cognitive, socio-economic, motivational; a subjective assessment block: feeling of inclusion/exclusion in the digital educational environment.

An adapted survey scale was also created, which was focused on the main components of digital literacy (information literacy, communication, content creation, security, problem solving). The response format is a 5-point Likert scale (from “strongly disagree” to “strongly agree”). The questionnaire for teachers/lecturers contained the following information:

- Data on experience, length of service, participation in digital trainings.
- Self-assessment of digital competence and readiness to implement digital tools.
- Data on platform usage practices and support for students from vulnerable groups.
- Formalized quasi-experimental protocol
- Description of the intervention content (digital trainings, micro-courses, consultations on the use of educational platforms, support measures for students with low digital inclusion).
- Time frames (duration of the experiment, number of sessions).

Qualitative instruments were also used, in particular, interviews were conducted with students and teachers regarding barriers to digital inclusion and successful practices. The research procedure consists of several stages. At the pre-test stage, an initial survey of students and teachers was conducted in all selected institutions (experimental and control). At this time, the level of digital inclusion, digital competence, SES, resource provision, and teacher readiness were measured. Base groups were formed: by region, by SES, by participation in the experiment (experimental/control institutions).

During the formative (intervention) stage, a digital inclusion support program was implemented in the experimental institutions. The program included training for students in basic and advanced digital literacy, consultations on the use of educational platforms, and additional support for students from low socioeconomic status (SES) backgrounds. An important complementary component of the intervention was the enhancement of teachers' qualifications in digital didactics and the inclusive use of technologies. In contrast, the

educational process in the control institutions continued in a traditional format without a specially organized program. At the control stage, the same groups of students and teachers were re-surveyed, and indicators before and after the intervention were compared between the experimental and control institutions.

2.4. Data analysis

Data analysis was carried out in several stages using SPSS 29, R 4.3 software. Descriptive, comparative and predictive statistical methods were used for quantitative analysis. At the same time, thematic analysis was used for qualitative analysis. First, missing values were checked (exclusion limit: >30% of omissions). Outlier analysis was performed based on the IQR and Mahalanobis distance methods for multidimensional data. Internal consistency of scales was assessed (Cronbach's α , KR-20). Comparison of indicators was performed based on paired samples *t*-test for intragroup changes (before/after). In particular, data such as digital competence; level of digital inclusion; frequency of platform use; subjective barriers were taken into account.

Independent-samples *t*-tests (or the Mann–Whitney *U* test when the assumption of normality was violated) were used to compare experimental and control groups after the intervention. Analysis of variance (ANOVA) was applied to compare three or more subgroups (e.g., courses and majors). Effect sizes were calculated using Cohen's *d* for *t*-tests and η^2 or partial η^2 for ANOVA/ANCOVA, along with confidence intervals for effect sizes. Pearson's *r* correlation matrices were used to examine relationships among quantitative variables, including digital competence, level of digital inclusion, socioeconomic status (SES), internet access, frequency of platform use, motivation, and teaching readiness. Qualitative data analysis involved transcription of interviews followed by the identification of thematic blocks, specifically focusing on barriers to inclusion, digital motivation, teacher experience, and infrastructure-related challenges. Comparisons between student and teacher results were conducted using a triangulation approach.

3. Results and discussion

The analysis of digital infrastructure indicated that, for the majority of students, access to technical resources was uneven. The majority of respondents (58.8%) have their own laptop, which they use as their primary learning device. However, it was found that 34.7% of students work mainly from a smartphone, which potentially limits the ability to perform complex interactive tasks, edit documents, or participate in synchronous online sessions. The stability of the Internet connection also varied. Only 26.9% of students indicated a high-quality, stable, and fast connection. Approximately half of the respondents (49.3%) indicated average stability. At the same time, 23.8% of participants encountered technical difficulties during their studies.

Comparing students with high and low Internet stability showed a statistically significant difference in the level of digital inclusion:

- $t(318) = 4.92, p < .001$. This determined the decisive influence of the quality of the Internet on the possibility of full involvement in digital educational processes.
- At the same time, the level of digital competence of students was assessed on an integral scale (1–5 points). The overall indicator was $M = 3.42, SD = 0.64$
- The majority of students had an average level of digital skills (61.9%). However, 19.7% showed high results. At the same time, 18.4% had a low level of competence.
- The strongest components of digital competence were: communication and interaction in the online environment ($M = 3.71$); information search and evaluation ($M = 3.56$).
- The lowest values were: digital content creation ($M = 3.08$); digital security and privacy ($M = 3.11$).
- This indicates that students confidently use basic online tools, but have insufficient skills in working with more complex content, and are also not sufficiently aware of digital security. Educational digital platforms are widely used in the university's educational process. The most common platforms were: Moodle / University LMS – 89.1%; Microsoft Teams – 74.4%; Zoom – 67.8%; Google Classroom – 41.2%
- An important factor in digital inclusion is the frequency of platform use. The results showed that: 38.2% of students use the LMS daily; 42.6% – 3–4 times a week; 19.2% – 1–2 times a week. Students with high frequency of platform use demonstrated a significantly higher integral level of digital inclusion:

- $M = 69.4$ (frequent use) vs. $M = 58.1$ (episodic use)
- $t(318) = 7.21, p < .001$

This means that regular interaction with the digital learning environment is a key element in the formation of digital inclusion.

Table 2. Digital inclusion indicators by main components (N = 380)

Digital Component	Inclusion Indicators	Mean (M)	SD	Notes
Access to Infrastructure	Laptop availability (%)	58.8	-	Main learning device
	Internet stability (1–5)	3.14	0.92	Higher stability → higher CI
Digital skills	Integral scale (1–5)	3.42	0.64	Medium level
	Online communication	3.71	0.66	Highest component
	Content creation	3.08	0.71	Lowest component
Using platforms	LMS frequency (1–4; 1=rarely, 4=daily)	3.11	0.81	Mostly daily use
	Online task completion success (0–100)	72.5	12.4	Reflects learning effectiveness
Integral Digital Inclusion Index	Score (0–100)	63.8	11.4	Medium level of inclusion

At the same time, socio-economic status has become one of the important factors in the development of digital inequality. For example, students with low SES demonstrated a lower level of digital inclusion ($M = 57.2$) than students with medium ($M = 64.3$) and high SES ($M = 71.8$). This was also confirmed by data from a one-way analysis of variance. This analysis revealed statistically significant differences between groups ($F(2,317) = 28.41, p < .001$). Therefore, students with a better socio-economic status had greater opportunities for full participation in the learning environment.

Table 3. Level of digital inclusion by SES (N = 320)

SES group	N	M digital inclusion	SD	95% CI
Low SES	104	57.2	9.8	55.3–59.1
Middle SES	148	64.3	10.4	62.6–66.0
High SES	68	71.8	9.2	69.6–74.0
ANOVA	-	$F(2,317)=28.41, p<.001$	-	-

To determine the effectiveness of the intervention in increasing digital inclusion, an analysis of the dynamics of indicators before (pre-test) and after (post-test) the experiment was carried out in the experimental (N = 190) and control groups (N = 190). At the initial stage (pre-test) no significant differences were visible between the groups ($p > .05$).

After the intervention, the experimental group had an increase in the integral level of digital inclusion, digital competence and frequency of use of digital learning platforms. In contrast, only minor changes were recorded in the control group. Thus, after the intervention, the level of digital inclusion in the experimental group increased by an average of 8.6 points. In the control group, the increase was only 1.1 points and is not significant. This indicates the importance of engaging in a digital inclusion support program.

Table 4. Pre-test / Post-test of the level of digital inclusion

Group	Pre-test M (SD)	Post-test M (SD)	Δ Change	t	p
Experimental (N=190)	62.8 (10.9)	71.4 (9.6)	+8.6	t(189)=11.42	<.001
Control (N=190)	63.1 (11.2)	64.2 (11.0)	+1.1	t(189)=1.39	.166

The experimental group that received training and methodological support had an increase in digital skills (by 0.50 points on a scale of 1–5). In the control group, the changes were minimal and implausible.

Table 5. Pre-test / Post-test of digital competence (1–5 points)

Group	Pre-test M (SD)	Post-test M (SD)	Δ Change	p
Experimental (N=190)	3.38 (0.62)	3.88 (0.58)	+0.50	<.001
Control (N=190)	3.41 (0.63)	3.46 (0.61)	+0.05	.214

In the experimental group, after the intervention, there was a noticeable increase in digital activity. In particular, more regular learning practices in the digital environment were formed. Participants indicated that after the trainings it became easier for them to complete tasks on the platform, navigate the course structure, download materials, use forums and the feedback system. As indicated by the quantitative data, students in the experimental group moved from situational use of platforms to more systematic and daily use. If before the intervention, a significant proportion of users worked with the LMS episodically (1–2 times a week), then after completing the program, most students interacted with the platform at least 3–4 times a week.

Table 6. Pre-test / Post-test frequency of LMS use (1-4 points)

Group	Pre-test M	Post-test M	Δ Change	p
Experimental (N=190)	3.02	3.49	+0.47	<.001
Control (N=190)	3.05	3.11	+0.06	.301

Thus, the digital intervention increased the formation of digital inclusion of students. At the same time, the participants' digital competence increased significantly in the experimental group. It was found that students' academic characteristics also influenced access to digital education. In particular, students in pedagogical and psychological specialties indicated a higher level of digital inclusion (M = 65.9) than students in other humanities (M = 61.7). Between-year analysis showed an increase in digital inclusion from year 1 to 4, although this effect was weaker ($F(3,316) = 4.19, p = .006$).

Table 7. Academic Characteristics and Digital Inclusion (N = 320)

Academic Variable	Category	N	M	SD	Statistical test
Specialty	Pedagogy/	180	65.9	10.7	t(318)=3.02, p=.003
	Psychology				
	Other Humanities	140	61.7	11.8	
Course of Study	1st year	80	61.4	11.5	$F(3,316)=4.19, p=.006$
	2nd year	85	63.8	10.8	
	3rd year	75	64.9	11.2	
	4th year	80	67.1	10.3	

A regression model with five predictors was constructed to identify the factors influencing digital inclusion. The model was found to be statistically significant ($R^2 = 0.465$). This indicated that SES, infrastructure, digital skills, and LMS use explained almost half of the variation in digital inclusion among students.

Table 8. Multiple regression of predictors of digital inclusion

Predictor	β	t	p	Value
Digital Literacy	0.36	7.11	<.001	Strongest predictor
SES	0.29	6.84	<.001	Social status impact
Internet Stability	0.24	5.29	<.001	Infrastructural factor
Laptop Availability	0.19	4.42	<.001	Technical capability
Frequency of LMS Use	0.17	3.16	.002	Learning activity
Overall Model:	$R^2 = 0.465$	$F(5,314) = 54.63$	<.001	Explains 46.5% of CI variation

Although the infrastructural aspects of digital inclusion showed some progress, the results of the qualitative analysis indicated the presence of several key barriers that made it difficult for students to fully engage in the digital educational environment.

In particular, technical barriers played an important role. The most frequently mentioned barriers were unstable or slow internet (mentioned by 48.2% of students), limited device power (old laptops, weak smartphones), platform problems, and the difficulty of participating in video lectures from mobile devices. These barriers affected students with low SES more. Cognitive and navigational barriers also played an important role. Students reported difficulties with navigating the LMS interface, understanding the course structure and finding the necessary materials, completing complex interactive tasks, and

digital safety. The most difficult component of digital competence was digital content creation ($M = 3.08$). This, in turn, limited the transition from passive to active learning formats. Organizational barriers also had a separate place. This category included an excessive number of different platforms (LMS + Teams + Zoom + Google Classroom), different requirements of teachers regarding the format of completing tasks, and insufficient integration of digital resources into curricula. Students emphasized that the lack of uniform rules affected the quality of work planning in a digital environment.

Psychological and motivational barriers are also noticeable. Despite the intervention's results, some students demonstrated low confidence in their digital abilities and fear of making mistakes when working with platforms. This determined the need for professional psychological help.

Table 9. Barriers to digital inclusion with example quotes

Barrier Type	Problem Description	Examples of student quotes	Examples of teacher quotes
Technical Barriers	Unstable internet, weak devices, technical failures during online lectures and tests, difficulty working with large files. Especially common for students with low SES.	“During lectures, the internet often goes down, and I miss important parts of the lesson.” (Student, 1st year)	“Half of the group cannot connect to Zoom at the same time.” (Teacher, Department of Pedagogy)
Cognitive/Navigational Barriers	Difficulty navigating the LMS, difficulty finding materials, inability to complete interactive tasks, low digital literacy.	“My old laptop can't handle working in Teams. I often have to reload everything.” (Student, 3rd year)	“Students often say that they cannot open assignments due to weak smartphones.” (Teacher, Department of Psychology)
Organizational barriers	Lack of standards for	“I spend a long time	“Some students do not read

	course structure, different teacher requirements, using multiple platforms at the same time, message overload.	looking for where the teacher uploaded the presentation. In each course, it's in a different section.”	the instructions in the LMS and do not know where to find the assignments.” (Teacher, Department of Inclusive Education)
		(Student, 2nd year)	
Psychological/motivational barriers	Low digital confidence, fear of making a mistake, anxiety about technical tasks, information overload.	“I don't always understand how to attach a file to an assignment.”	“The platform is difficult to navigate, and this creates an additional burden on me as a teacher.” (Teacher, Department of Age Development)
		(Student, 1st year)	

Thus, the study was aimed at analyzing the features of the formation of digital inclusion in the educational system of Kazakhstan. The first task was to assess the digital inclusion of students based on the analysis of the digital infrastructure, the level of digital skills and the frequency of use of digital platforms. The results showed an average level of digital inclusion ($M = 63.8$). This indicator generally aligned with the opinions of other scientists who reported uneven digital readiness among students in countries where the digital transformation of the education sector is taking place gradually [20], [21]. However, other scientists have emphasized the importance of leveraging innovative technologies, namely AI, to develop an effective digital environment [22], [23], [24], [25].

In addition, the study of digital infrastructure showed its fragmentation. In particular, it was found that 34.7% of students use a smartphone as their main device. At the same time, 23.8% had an unstable Internet connection. These indicators generally indicated and confirmed other theoretical models of digital inequality, which indicate that access to quality equipment and connectivity is an important and even basic prerequisite for the formation of a quality digital inclusion environment [26], [27].

The level of digital skills of students was also average ($M = 3.42$). However, the strengths were manifested in communication indicators. At the same time, the weaknesses were the skills of creating digital content. Such data can be compared with other authors, who indicated that productive skills and digital safety are the least developed among students [28], [29], [30]. The frequency of LMS use was one of the strongest predictors of digital inclusion ($t = 7.21$, $p < .001$). Regular digital activity formed sustainable skills. This situation has been confirmed in other international studies [14], [31]. At the same time, the data obtained from the second task revealed pronounced differences between groups of students depending on socio-economic status, type of device, Internet stability and academic characteristics. In particular, students with low SES showed a lower level of involvement in digital inclusion ($M = 57.2$). At the same time, students with high SES had the highest ($M = 71.8$). This situation is quite natural and generally consistent with the concept of the “second wave of digital inequality”, in which access and quality of the digital environment play an important role [32]. It is also worth noting that the difference between laptop and smartphone users was statistically significant ($d = 0.81$). This made it possible to confirm the trends, in particular, as shown in other works, educational efficiency decreased when using mobile devices as the main ones [33]. At the same time, unlike other studies, this work has important unique features. In particular, the text shows that students of pedagogical and psychological specialties showed a higher level of digital inclusion. This fact can be explained by the greater number of courses that actively used LMS.

The regression model indicated that digital competence ($\beta = 0.36$) and SES ($\beta = 0.29$) are the most important predictors of digital inclusion. This confirmed the thesis about the multilevel nature of digital inequality and the importance of investments in the development of technical and cognitive resources [18], [34]. At the same time, a qualitative analysis of student and teaching made it possible to identify several important barriers. In particular, technical, cognitive-navigational, organizational and psychological. This confirmed the ideas about the multifactorial nature of digital inclusion, in which difficulties arose due to the lack of technology and due to emotional, organizational and didactic factors [35]. It is especially important that teachers also noted difficulties associated with platforms. Thus, this indicated the importance of digital training of all educational

staff. For this, various strategies for increasing digital inclusion are indicated in the scientific literature. In particular, training, digital tutoring, and standardization of LMS courses became important, which indicated high effectiveness. For example, those participants who actively used individual self-organization strategies had a higher level of digital activity and confidence.

The study confirmed a number of hypotheses. In particular, H1, which was related to the fact that digital competence plays the role of an important predictor for the formation of digital inclusion, was confirmed. The results of multiple regression showed that digital competence is the most significant predictive factor of digital inclusion. The standardized β -coefficient ($\beta = 0.36$, $p < .001$) was the highest among all predictors. Thus, as proven in other articles, the development of skills to work with digital services, platforms and information security ensured the real involvement of students in the digital educational space [4], [36], [37]. This result is consistent with other authors who indicated that competence is identified as a central element of digital participation [12], [38]. At the same time, the following hypothesis – H2, which was related to the fact that students with higher SES had a higher level of digital inclusion, was also confirmed. A one-way analysis of variance indicated that there were differences between SES groups ($F(2,317) = 28.41$, $p < .001$). However, the gap between low and high SES was almost 15 points on the digital inclusion index. This indicated that socioeconomic status acted as a factor affecting access to technology, Internet quality, and frequency of interaction [39], [40]. H3 was also supported, which was that Internet stability and device type affected digital inclusion. Besides, t-tests indicated significant differences between students with stable and unstable Internet and students using a laptop vs. smartphone as their primary device. The effect size (Cohen's $d = 0.81$ for device type) indicated the impact of technical conditions on students' ability to fully participate in digital learning. However, the last hypothesis (H4), which was that teachers' digital readiness is related to students' digital inclusion, was partially confirmed. This hypothesis was confirmed in qualitative data and indirectly in quantitative data. However, it could not be confirmed in the form of a direct quantitative correlation, since there was no separate scale to measure teachers' digital readiness. In general, other scholars also agree that trained teachers contribute to the improvement of the development of a digitally inclusive environment [22], [41].

However, the study has its limitations. Despite having an experimental and control group, the study was not randomized. Participants were divided based on academic groups, which may affect internal validity. In addition, the intervention lasted for a limited period. This may not fully reflect long-term changes in digital inclusion. There are also limitations regarding the measurement of teachers' digital readiness. Although qualitative data indicated that teachers' digital readiness had an impact on student inclusion, no standardized scale was used to quantitatively measure teachers' digital competence. This in turn limited the ability to conduct a full statistical analysis regarding the role of pedagogical digital readiness in shaping digital inclusion.

4. Conclusions

Thus, the level of digital inclusion (infrastructure, digital skills, use of platforms) indicated that university students generally have an average level of digital inclusion. The main problem areas were the instability of the Internet for some students, significant dependence on smartphones, insufficient digital content creation skills and low digital security. The regularity of LMS use became an important factor in the development of digital inclusion.

At the same time, the study showed the presence of digital inequality, which is caused by socio-economic, technical and academic factors. The stability of the Internet and the type of device are decisive for involvement in the digital educational environment. The regression model indicated that digital competence is the strongest predictor of digital inclusion ($\beta = 0.36$). Thus, there is a multifactorial nature of digital inclusion, as technical, cognitive and social aspects interact with each other. The study identifies four groups of barriers to digital inclusion: technical – unstable internet, weak devices, cognitive – difficulties in navigating the LMS, lack of digital skills, organizational – lack of standardization of courses and platforms, and psychological – low digital confidence, information overload.

However, the study indicates that to increase the development of digital inclusion, it is necessary to conduct regular training, digital tutoring, unification of LMS, use of planners and micro-groups of

mutual assistance. Thus, digital inclusion is formed on the basis of technical conditions and pedagogical support.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper."

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Author contribution

D. Lepeshev, A. Kalymova, N. Stukalenko: study conception and research design; A. Kalymova, D. Doskenova, D. Lepeshev: data collection; D. Lepeshev, A. Kalymova, N. Stukalenko: analysis and interpretation of results; D. Lepeshev, N. Subayeva: draft preparation. All authors approved the final version of the manuscript.

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Appendices

Appendix A. Student Digital Competence Scale

Scale: 1 – not at all able; 5 – highly able

Component 1. Information Literacy

I can effectively search for educational information on the Internet.

I can assess the reliability of sources.

I can structure and store digital materials.

Component 2. Communication in the digital environment

I interact effectively in educational chats, forums, LMS.

I follow the rules of digital etiquette.

I can organize online collaboration.

Component 3. Digital content creation

I can create presentations, videos or graphic materials.

I can work with online office tools

Component 4. Digital security

I understand the principles of personal data protection.

I can use secure services and privacy settings.

Appendix B. Digital Inclusion Assessment Questionnaire

Part 1. Access to Infrastructure

What is the main device you use for learning?

Rate the stability of your internet connection (1–5).

Do you have constant access to the university's learning platforms?

Part 2. Use of digital platforms

4. How often do you use the LMS? (1 – rarely; 4 – daily)

5. How often do you complete online tasks on time?

Part 3. Socio-economic characteristics

6. Level of family's technical support (low / medium / high).

7. Availability of your own laptop.

8. Ability to use additional digital services.

Appendix C. Pre-/post-test of digital skills (short version)

Block 1. Analytical skills

I can clearly formulate a learning problem.

I can break down complex tasks into stages.

It is easy for me to assess the quality of the information I find.

Block 2. Communication skills

I interact effectively with team members during online tasks.

I can formulate messages in chats/forums competently.

Block 3. Digital creativity

I generate new ideas in digital projects.

I use AI tools or digital services for creative solutions.

Scale: 1–5; total integral score (15–75).

Appendix D . Interview Guide for Students and Teachers

D1. Instructions for the researcher

The interview was conducted online (Zoom/Teams) or in writing (open-ended responses).

Duration: 15–25 minutes.

Participants were guaranteed anonymity and voluntary participation.

Permission to use the responses for scientific purposes was obtained in accordance with the ethical requirements of the university.

D2. Interview questions for students

1. Access to digital resources

What device do you most often use for learning?

How stable do you consider your internet connection?

Do technical conditions affect your participation in learning?

2. Experience with digital platforms

Which platforms (LMS, Teams, Zoom) do you use most often?

What is the most difficult thing for you in working with the LMS?

Are the teachers' instructions for online tasks clear enough for you?

3. Digital skills and self-confidence

How confident are you in your digital skills?

Which skills or tools cause the most difficulties?

Which skills would you like to improve?

4. Barriers to participation

What are the main difficulties you face during online learning?

Do you experience psychological difficulties (overload, insecurity, fear of making mistakes)?

5. Strategies and support

What helps you the most in learning in a digital environment?

What additional support do you need from the university or teachers?

D3. Interview questions for teachers

1. Use of digital platforms

What platforms do you use in teaching?

What difficulties do you observe in students when working with the LMS?

Are there enough technical capabilities to conduct online classes?

2. Digital readiness of teachers

How much do you assess your own digital competence?

Which digital tools need additional development?

3. Organizational barriers

Do you have enough methodological recommendations for structuring courses in the LMS?

Is there a need to standardize digital courses?

4. Experience working with students

What typical difficulties do you observe with students during online learning?

Which groups of students (by major, SES, skills) need the most support?

5. Strategies for improving digital inclusion

What university measures do you consider the most effective?

What additional tools or training should be implemented?