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Process assessment of the level of ICT mastering in Russian schools.

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Publications

1	Dvoretzkaya I. School Digitalization from the Teachers' Perspective in Russia // Proceedings of the International Association for Development of the Information Society (IADIS) International Conference on Cognition and Exploratory Learning in Digital Age (15th, Budapest, Hungary, October 21-23, 2018) – 2018. P.367-370
2	Dvoretzkaya I. V. On the Formation of a Common Vision of the Use of Information and Communication Technologies in the Classroom //Russian Education & Society. – 2019. – T. 61. – №. 2-3. – C. 101-107.
3	Dvoretzkaya I., Uvarov A. Make use of SELFIE data to generate targeted recommendations for school teams: two instruments // Proceedings of the International Association for Development of the Information Society (IADIS) International Conference on Cognition and Exploratory Learning in Digital Age (17th, Lisbon, Portugal, November 18-20, 2020) – 2020.P.383-386.

4	Dvoretzkaya I., Uvarov A. School Digital Transformation Assessment: from Numerical Representation to a Qualitative Multi-dimensional Analysis, in: Proceedings of the 4th International Conference on Informatization of Education and E-learning Methodology: Digital Technologies in Education (IEELM-DTE 2020) / Ed. by M. Noskov, A. Semenov, S. Grigoriev. Vol. 2770: Informatization of Education and E-learning Methodology: Digital Technologies in Education-2020. Krasnoyarsk : CEUR Workshop Proceedings, 2020. P. 16-27.
5	Dvoretzkaya I. V., Uvarov A. Yu. Evaluation of the use of innovative teaching and learning supported by digital technologies in school based on quantitative data // Otechestvennaya i zarubezhnaya pedagogika. 2020. Vol. 1. No. 66(2). pp. 29-45. [in Russian]
6	Uvarov A. Yu., Vikhrev V. V., Vodopyan G. M., Dvoretzkaya I. V., Kochak E., Levin I. Schools in an evolving digital environment: digital renewal and its maturity // Informatics and Education, No. 7, 2021. P. 5-28 [in Russian]
7	Dvoretzkaya I., Uvarov A. (2021) Innovative ICT-supported Teaching and School's Digital Renewal Stages. In: Wen Y. et al. (eds.) Lecture Notes in Educational Technology, Springer (in print)

Scientific conferences

Findings of this doctoral thesis were presented at the following scientific conferences:

1. eSTARS–2017
2. III International conference "Internet after globality" - 2018 CELDA–2018, 2020
3. XX April International Conference – 2019
4. IX International Online Conference of the Eurasian Association for Educational Quality Assessment (Online) – 2020
5. 4th International Conference on Informatization of Education and E-learning Methodology: Digital Technologies in Education (IEELM-DTE 2020)
6. 5th International Conference on Informatization of Education and E-learning Methodology: Digital Technologies in Education (IEELM-DTE 2021)
7. "Fundamental problems of teaching mathematics, computer science and informatization of education" (October 1-3, 2021, Yelets, Lipetsk region, Yelets State University named after I.A. Bunin)

8. XXIII April International Conference – 2022

Intermediate results of the dissertation research were discussed at seminars of the HSE Centre for Educational Leadership Development, HSE, Laboratory for Digital Transformation of Education, postgraduate seminars of the Institute of Education Higher School of Economics and of Laboratory for Digital Transformation of Education of HSE, an internal seminar of IO HSE as well as a seminar of the Centre for Research ICT in Education (CRITE) Trinity College, Dublin, Ireland.

Glossary

Information and Communication Technologies (ICT) –

- Techniques and methods of using computer technology for collecting, storing, processing, transmitting and using data (GOST 34.003-90);
- resources needed to collect, process, store and disseminate information (ISO/IEC 38500:2015).

Digital technology (DT) is a term used to refer to ICT in a socio-political context, emphasizing the changes that occur due to ICT (Negroponte, 1996).

Digital renewal of general education – a multidimensional complex process extended over time. It includes adjustment of learning outcomes, content and curriculum, teaching and learning, and it affects all aspects of school work by using the potential of the digital educational environment (Uvarov et al., 2021).

Computerization is the initial stage of the digital renewal of general education, during which schools are equipped with computers to form the computer literacy of students and teachers, as well as to use computers in solving routine tasks (Ershov, 1988).

Early informatization is the stage of digital renewal of education, during which digital educational resources and teaching materials are distributed for teaching and learning. At this stage technical and pedagogical conditions to use them in classroom are shaped (Uvarov et al., 2021).

Mature informatization is the stage of digital renewal of education, during which the educational environment of the school is saturated with modern digital technologies (f.e., broadband access to the Internet for all school community members, personal digital devices are available to all school community members, the use of cloud services, etc.), development innovative ICT-supported ways of teaching and learning (including interdisciplinary learning projects. Individual learning plans are established for students (Uvarov et al., 2021).

Digital transformation is an evolutionary process, supported by modern technologies, on the way to a radical increase in productivity enterprise through transformations in business and operating models, in the methods of interaction with external and internal clients. Toward digital transformation enterprises (Westerman, Bonnet, & McAfee, 2015):

- turn their customers into partners;
- reveal the creative potential of the staff;
- transform their products into services;
- make business processes more flexible, scalable and natural;
- review (or develop a new) their business model.

Digital transformation of the school is a school-level evolutionary process, supported by modern technologies, on the way to a radical increase in the efficiency of the teaching and learning through transformations in the goals, content of education, teaching and learning methods, in order to ensure the required academic achievements.

Digital Transformation of Education (DTE) – is the next stage of digital renewal aimed at renewal at system level:

- school's interaction with the local community (parents, business representatives, officials, politicians);
- goals and content of teaching and learning;
- tools, methods and organizational forms of teaching and learning.

DTE takes place in an evolving digital environment and relies on the use of digital teaching and learning materials, digital tools and services. (Semenov, 2015, Uvarov et al., 2019).

Process – a multi-level sequences of events extended over time (vom Brocke et al., 2021).

Process assessment is an assessment of the process as a whole, made in relation to the goals of the process (or system of goals) based on the perceptions and beliefs of the education actors regarding changes (Begicevic Redjep et al., 2021).

Indicator is a characteristic of a process that captures its essential aspect in order to understand it and allows one to judge the state and changes of this process (Nardo et al., 2008).

Innovative ICT-supported teaching and learning – is treated as the presence in teaching practice of any innovative and ICT-supported methods declared by teachers, regardless of

their scale and specification.

Common (shared) vision is a jointly developed picture that everyone in company follows. It can be defined as "...At its simplest level, a shared vision is the answer to the question, "What do we want to create?"" (Senge, 1990).

Introduction: relevance of the research topic

In recent years, digital transformation of all areas of the economy and social sphere is in focus in Russia and around the world ¹. It affects the general education directly^{2,3}. The issues of digital technologies into the school and its effective use are widely discussed in literature⁴. The fact that government support for the introduction of digital technologies (as a priority for the development of school education) turns out to be quite large-scale, sets the requirements for assessing the results of digital technologies and the management of education system⁵.

The discussion about the assessment of promotion of schools in their use of digital technologies both in our country and abroad receives a new kick in 2018, when in scientific and practical discourse there is an idea of the digital transformation of education as a stage in the development of the education system is grounded⁶. Starting from it terms "digital transformation" / "digital transformation" is widely in use.

Starting from the end of 10s concept of smart school and smart education are discussed widely. Being closely related to the digital environment they are treated as target (desired) state for school or education system. It was then that the idea of this study was shaped as a continuation of previous attempts to answer the question of how to assess the promotion (advancement) of schools towards the use of digital technologies in school education at the macro level (at the regional or country level), undertaken over several decades.

Previous research findings emphasize the need to conceptualize digital transformation of education differing it from previous stages of ICT implementation in school. Describing the process of digital technologies (DT) spread in educational organizations that take place

¹ "In the coming decade, we will have to carry out a digital transformation of the entire country, all of Russia, to introduce artificial intelligence technologies and big data analysis everywhere" - from a speech by Russian President Vladimir Putin, 4.12.20. <https://tass.ru/ekonomika/10172635>

² The Ministry of Education announced a global experiment on the digitalization of education https://obrmos.ru/go/go_scool/news/go_go_scool_news_zifr_exp.html?cmtx_page=2&cmtx_sort=3
<https://education.ec.europa.eu/document/digital-education-action-plan>

³ <https://education.ec.europa.eu/document/digital-education-action-plan>

⁴ An idea of the complex subject field is demonstrated by the work of international organizations in the evaluation of educational policy, for example <https://www.infodev.org/articles/quick-guide-ict-and-education-unesco>

⁵ See Trucano, Michael for details. 2005. Knowledge Maps: ICT in Education. Washington, DC: infoDev / World Bank. Available at: <http://www.infodev.org/en/Publication.8.html>

⁶ The relevance is indicated by UNESCO: the topic of the next global monitoring of education is digital technologies in education <https://en.unesco.org/gem-report/fellowship>

for more than a dozen years (in the English-language literature - ICT in education), various authors talk about the computerization of education, its informatization and transformation. Transition of the school to solving the problems put forward by the emerging information society have been studied for a long time (A.P. Ershov, A.L. Semenov, A.Yu. Uvarov, J. Kershaw, F. Kumbas, J. Baldrige, R. Kozma, W. Pelgrum and others). With the spread of the ideas of transformation into the educational discourse (by analogy with other areas of human activity, where the processes of digital transformation began earlier), the digital transformation of the school is understood as an increase in the effectiveness of the school by changing the content, curriculum, ways of teaching and learning taking place in the digital environment. The goal of the digital transformation of the school is the achievement by each student of all the required academic achievements (Semenov, 2020a). This definition is based on the assertion that only the saturation of the digital educational environment of the school with new digital tools and devices does not lead to an increase in the results of its work (Cuban, 2000; Trucano, 2016; Uvarov, 2011), since it does not affect the model of teaching and learning. On the contrary, due to qualitative organizational changes, the transformation of schools into learning organizations, changes in the organization of the educational process, it is possible to implement such a school model in which all the required educational results are achieved by each student through the transition to personalized organization of the educational process (Cuban, 2000; Trucano, 2016; Uvarov, 2011). This observation is confirmed by a number of authors who regard the active role of the school in the adoption, use and mastering of digital technologies (N. Selwyn, P. Kamylyis, L. Cuban, S. Bocconi, A. Uvarov).

Number of reviews dedicated to the assessment of digitalization evidence that there are dozens of different of descriptions (models) of the processes of mastering and using digital technologies. These models include predictive, normative and based on real data of schools. There are works dedicated to the issues of data collection and rethinking the already collected data, to the conceptualization and measurement methodology: works of N. Law, W. Pelgrum (Plomp, Pelgrum, Law, 2007), as well as in the work of experts from the UNESCO Institute for Education Statistics and Eurostat (European Commission, 2019; Ranguelov, Stanislav, Dalferth, & Noorani, 2011). The need to obtain information about the changes associated with the use of digital technologies in the school is defined the

works of N. Kovaleva, L. Gokhberg (Gokhberg & Kovaleva, 2004), J. Momino (Mominó & Carrere, 2016), R.Kozma (R. B. Kozma, 2005), F. Scheuermann and F. Pedro (Scheuermann & Pedro, 2010). In recent years, there has been growing discussion about the need for a coordinated and integrated use of multivariate sources of information about changes in various areas of human activity due to the transition to a digital society (Global Working Group on Big Data for Official Statistics, 2021; Organization for Economic Cooperation and Development, 2019; L .M. Gokhberg et al., 2018). These studies show that there is a need in theoretical, methodological and practical improvement of the analytics of the use and dissemination of ICT in general education in terms of describing transformational changes. There is a borrowing primarily from business (since the methodological background of description and management is much more extensive there) of the understanding that controlled transformational changes in the education are impossible without understanding and explicitly describing the processes, their changes and factors (Mominó & Carrere, 2016; Scheuermann & Pedro, 2010; UNESCO, 2016). Researchers of changing school practices (Lee & Broadie, 2016) and building promising models of school agree with it as they consider changes in school work in the context of digital transformation.

Worth to mention that the discussion about discussion about the need for evidence-based assessment of digital transformation of all areas (van Kessel et al., 2021, Małkowska, et al., 2021, Rodriguez-Abitia & Bribiesca-Correa, 2020) is getting a new kick-off after the start epidemics of COVID-19. In educational discourse it unfolds two directions: (1) attempts of evidence-based management of the education system in a crisis and forced transition to distance learning (UIS, 2021, Kyzym et al., 2021, Begicevic Redjep et al., 2021, Glahn, 2021, Tilibaşa & Acatrinei, 2020), (2) developments of indicators of school changes based on existing secondary data (Sepúlveda, 2020):

1. The lack of measurements of the adoption, use and mastering of digital technologies in different education systems at national levels is planned to be compensated through the Global Education Monitoring (GEM) - 2023 (Bayne et.al., 2021), which is declared as the use of digital technologies in education. The works mentioned above demonstrate a trend towards adjustment of national statistics in order to meet the challenges of bringing the school in line with the needs of the digital society.

But at the same time, the authors operate on the level of the education system, without taking into account the differences between schools (Munoz, Weikert Garcia, & Herreno, 2021), which loses the universality of using the proposed approaches.

2. There are models and specific indicators proposals built on the secondary data: for example, on the data of the Croatian FDMS tool (Begicevic Redjep et al., 2021), the European SELFIE tool (Castaño Muñoz et al., 2021, Castaño Muñoz et al., 2021, Costa et al., 2021), based on data from the Estonian digital transformation self-assessment and planning tool DigiPoore (Pata et al., 2021). Analyzing psychometric (Costa et al., 2021), or discriminative (Begicevic Redjep et al., 2021, Pata et al., 2021) features of data collection tools, the authors actually set benchmarks for improving data collection tools and indicators of sub-processes of mastering digital technologies. At the same time, the mentioned studies inherit the deficiencies of the conceptual framework developed for a certain stage of solving the problems of digital renewal (Begicevic Redjep et al., 2021).

Problem statement

Thus, the **problem** of this study lies in the gap between (1) the level of need to study the processes of transformational changes in general education which are caused by the need to bring the school in line with digital society capabilities (and for which it is necessary to observe and evaluate the current state of educational institutions and their progress in direction of the digital transformation phase, using indicators of qualitative changes at the macro level), and (2) the deficit of theoretical frameworks and ways to assess qualitative changes that take place in schools during their use of digital technologies.

Research Issues, Goals and Objectives of the Research

Following research questions are formulated:

1. What are current ideas and macro-level models about the use and mastering of digital technologies in general education?
2. What theoretical model and methods, will allow us to assess the changes, including qualitative changes, that occur during the development of digital technologies by the school?

3. What tool can be used to assess key changes in the school in the context of the introduction of digital technologies?
4. What is the current state of mastering digital technologies by the school in Russian context, assessed using the developed process assessment?

The goal of the study – to develop theoretical framework and methods for assessing changes, including qualitative ones, that are taking place at school in connection with the mastering of digital technologies.

Achieving this goal involves the following **tasks**:

1. To analyse modern ideas about the theoretical frameworks and methods for assessing changes, including qualitative changes, occurring in the context of the mastering of digital technologies by the school.
2. To propose a theoretical model and methods for assessing changes, including qualitative ones, occurring in the course of assessing the mastering of digital technologies by a school
3. To develop a tool for assessing changes, including qualitative ones, occurring in the course of assessing the adoption of digital technologies by the school
4. To test the applicability of the approach to the use and mastering of digital technologies by the school.

Methods and empirical base of the study

The research methods used in the dissertation work include: review and analysis of structured descriptions of models of digital renewal, expert interviews, and statistical data analysis. The factual and information base of the dissertation research was made up of: monographs, articles, materials of reports by Russian and foreign authors on issues of digital renewal, reports of supra-governmental organizations, publications in the media, data from sociological surveys (a survey of Russian UNESCO Associated Schools, conducted in 2017/18 academic year), survey of schools as part of the Monitoring of the Digital Transformation of Educational Organizations, conducted in the 2020/21 academic year).

Theoretical framework

The first task of the study required an analysis of the literature where various issues of mastering digital technologies are considered, including in the broader context of school changes.

First of all, the works devoted to the renewal of the school were analysed (for example, Cuban, 1990, 2000; Fullan, 2011a; Kuzminov, Frumin, Zakharov, 2011; Lebedev, 2017; Frumin, 1999) including works where problems of the digital society are discussed (Fullan, 2011b; Laurillard, 2008; Selwyn, 2016; Selwyn, Hillman, Rensfeldt, & Perrotta, 2021; Lyubomov L.L., 2020; Semenov, 2005, 2020a).

The list of works where the use of digital technologies in schools is discussed includes thousands of titles. The author relied primarily on the work of A.Yu. Uvarov, G.M. Vodopyan, A.L. Semenov, E. Bulin-Sokolova, R. Kozma, W. Pelgrum, N. Law, P. Kampylis L. Cuban. Authors mentioned consider the introduction and development of digital technologies primarily as a pedagogical and social phenomenon. This makes it possible to discuss not just quantitative changes in the digital environment of the school, but also changes in the attitudes and perceptions of teachers, school leaders, students, and parents, which is important for processes assessment.

Pedagogical focus is also placed at first place in works devoted to the tools for studying, describing and managing digital renewal at the macro- level (descriptions/models of digital renewal): these are the works of A.Yu. Uvarov, P. Kampylis, C. Clarks, N. Begicevic Redjep, I. Balaban and others.

The theoretical framework of diagnostic tools for assessing the transition to the digital transformation is based on two sets of work: first, these are works devoted to the diffusion of innovations (including the introduction and development of innovations, supported by digital technologies), which are disclosed by M.V. Klarin, E.M. Rogers, P. Kampylis, P. Puentedura, A.Yu. Uvarov and others. Authors clearly substantiate the qualitative nature of transformational changes. Secondly, these are works devoted to the methodological aspect of constructing qualitative scales based on quantitative assessments of processes, which are explored by N. Begicevic Redjep and I. Balaban (Balaban, Redjep, & Čalopa, 2018; Begicevic Redjep et.al., 2021; Ređep, Balaban, Žugec, Čalopa, & Blaženka Divjak, 2017), D. Proença (Proença, 2016; Proença & Borbinha, 2016), M. Nussbaum and

colleagues (Rodríguez, Nussbaum, & Dombrovskaja, 2012; Rodríguez, Nussbaum, López, & Sepúlveda, 2010).

Methodology of the work

We start with discussion on digital technologies dissemination in general education and its stages. To do so we introduce the concept of digital renewal which is a key concept⁷ to understand changes provoked by digital technologies in education⁸. We consider that digital renewal is a process of adjustment of education results, content and curriculum, teaching and learning. Digital renewal touches all key elements of school and uses potential of digital environment. The use of the concept allows us to assess meaningfully the status with digital technologies at the macro level. We can use temporal and spatial dimensions of this process for analysis at school/education system levels.

The concept of digital renewal helps to model this process. The model allows to differ schools and regional school systems depending on their use of digital technologies, evaluating wide range of it from computerization to transformational changes. Stages of changes distinguished correlate well with levels of ICT use described in SAMR (Puentedura, 2008). Computerization stage identified with the use of ICT at substitution level, when traditional paper is replaced with digital tools. Early informatization is characterized by replacement of traditional tools by digital one where features are improved (Augmentation). Mature informatization stage is identified with replacement of traditional tool by digital one where features and functions are extended significantly (Modification). At digital transformation stage traditional tools are replaced by digital with transformed features (Redefinition) as learning outcomes and lessons' design are previously inconceivable or likely to be organized by great number of resources.

Applying a theory of innovations in education to the digital renewal we can see that there is consistency between stages of digital renewal and types of innovative approaches to the learning (Klarin, 2016): while there are modernizations, when the traditional model of

⁷ Digital renewal is considered as a concept according to which there are a group of main features that characterize changes in the goals, content, organizational forms and methods of teaching and learning.

⁸ Uvarov A. Yu., Vikhrev V. V., Vodopyan G. M., Dvoretckaya I. V., Kochak E., Levin I. Schools in an evolving digital environment: digital renewal and its maturity // Informatics and Education, No. 7 , 2021.

school does not change significantly, but only improves, correspond to the stages of computerization and early informatization; innovation-transformations aimed at a qualitative change in the educational outcomes, during which the beliefs and attitudes of educational actors are shifted, correspond to the stages of mature informatization and digital transformation. This aspect of considering the spread of digital technologies in the school is consistent with the works that study alternative modernization scenarios for updating the education system (Kuzminov, Frumin, Zakharov, 2011; Uvarov, 2020) and allows us to consider systemic changes in education due to the active participation of actors (Laurillard, 2008; Somekh, 2007; Uvarov, 2011).

The analysis conducted (Dvoretzkaya, Uvarov, Vikhrev, 2020) shows that there are more than a thousand works dedicated to the introducing and mastering digital technologies at school and to its indicators. Among them, one can single out works on the development of model of the process. These are structured descriptions of key indicators that allow to see the changes taking place in schools and guide them. Schools receive comparative information about their digital capacity.

In models the possible benchmark is fixed against certain standard, or as a target state. The stages of maturity contained in some of the analysed models indicate how close the processes are to their benchmarks. This approach is borrowed from operation research and business process management. It allows to identify how the process is manageable, predictable, controllable and measurable (Baldrige & Burnham, 1975) , being aimed at achieving a specific result. Another conclusion arising from the analysis of both digital renewal and its individual stages is that, speaking about the digital renewal of the school, it is necessary to consider two levels for its assessment: the level of macro-stages and the level/state of renewal within each stage. While digital technologies are presenting into all spheres of human activity, the tasks of planning, managing and predicting this process, determining its effects and consequences, began to arise. The mass informatization of organizations led to the need to develop a model for describing this process (Nolan, 1973) in which quantitative characteristics (for example, the organization's costs of computer resources) would be assessed through the qualitative characteristics of their use. The main hypothesis for building the model was that the organization as a system goes through ordered typical states - stages that can be described (Nolan, 1973).

Model representations' developers use the hypothesis that there is a target state of mastering digital technologies in education and the path to it can be described: 1. explicitly through the evolutionary stages, 2. subjective assessments of proximity to the target state. The analysis of model representations was carried in two steps. Firstly, the key features of models were examined in order to identify the extent to which they reflect and detail the features of the stages of digital renewal and to evaluate approaches to the introduction of qualitative change scales. Secondly, through the analysis of the content of the models in relation to the generally accepted understanding of digital renewal processes, process indicators were identified. So under the process we define the changes taking place in the adoption of digital technologies by the school through a sequential series of changes that unfold over time and occur at several system levels (usually talk about the level of individuals, the level of organization, the level of the system) (vom Brocke et.al., 2021). Thus, we can talk about a process assessment, carried out both integrally and on the basis of an assessment of the constituent subprocesses, which is fulfilled through the current state mapping with the target set of characteristics. Such an assessment is given primarily based on data on the activities of education actors.

To increase the assessment reliability, several data sources can be used including expert assessments, sociological data (including survey data). The revision of literature shows that the assessments given by members of school community regarding various aspects of the digital technologies use reflect their attitudes and ideas, which makes it possible to get an idea of the ongoing changes in practice (W. Pelgrum, N. Law, P. Kampylis L. Cuban). Despite the fact that most model representations are not accompanied by empirical tools, it was found that the distribution of schools by macro-stages of digital renewal can be refined and detailed by building scales for separate aspects. This explanation deepens the theory of digital renewal.

The most promising way to determine the state of the school/education system is to describe a state as a combination of individual sub-processes of digital renewal (Mominó & Carrere, 2016; Scheuermann & Pedro, 2010; Uvarov, 2011). The first step is to build maturity scales - integral assessments that allow to identify meanings of school digital renewal indicators.

Deficiencies of maturity self-assessment tools identified through literature review highlight the approach based on survey answers. It is based on the assumption that answers of the survey participants are determined by the systematic shifts in teaching and learning practices.

Two key indicators identified for digital renewal assessment: (1) the formation of a shared vision for the use of digital technologies in teaching and learning and (2) the use of innovative ICT supported teaching and learning. Scales were proposed for both indicators. We used a data-driven strategy (Maass, Parsons, Purao, Storey, & Woo, 2018; Weichselbraun et al., 2021). The focus of the strategy is to rethink the previously collected data from sociological surveys through the construction of process indicators of digital renewal, for which the methods of mathematical statistics and qualitative interpretation of the findings are used. Such a strategy, on the one hand, makes it possible to diagnose the situation in territorial education system, by giving meaningful assessments of key processes, and on the other hand, it allows the use of questionnaire data on the use of digital transformation in educational organizations collected during monitoring surveys. The chosen strategy was justified in view of the lack of relevant research in the Russian context. Indicators, scales and calculation approaches are given below (Table. 1):

Table 1 – The list of indicators, scales and calculation approaches

Key indicator of digital renewal	Assessment scale	Calculation approach
The formation of shared vision on ICT in teaching and learning	Dichotomous scale adapted from ICTE-MM scale (Solar et.al., 2016)	Classification approach with propositional logic-based rules.
Innovative ICT-supported teaching and learning	The scale of innovative work adapted from RISC (DeLorenzo, 2009)	Combined cluster-based methodology, that includes cluster structure mapping against RISC scale of innovative work

Computational procedures were developed as follows.

As a first step, a classification-based calculation scheme was developed the indicator “Formation of a common vision for the use of digital transformation in teaching and learning”. The idea behind it is that by comparing answers of three groups of respondents (school leaders, teachers, students), one could draw a meaningful conclusion about the state of this key digital renewal indicator on a dichotomous scale built on the basis of the ICTE-MM scale. For this, a conceptual indicator model was developed, according to which a feature vector of length 2 (V_d, V_e) was proposed. V_d is a binary categorical feature that characterizes how the DT is discussed in a school (a sample of schools), V_e – is a binary categorical feature that characterizes the extent to which the respondents’ opinions are aligned with the statement that digital technologies increase the effectiveness of teaching and learning.

In order to interpret the values of the feature vector, the rules for classification were developed. Then, the statistical procedures needed to construct the feature vector were assigned.

A schematic description of the proposed computational procedure is given below (Figure 1), it includes three steps.

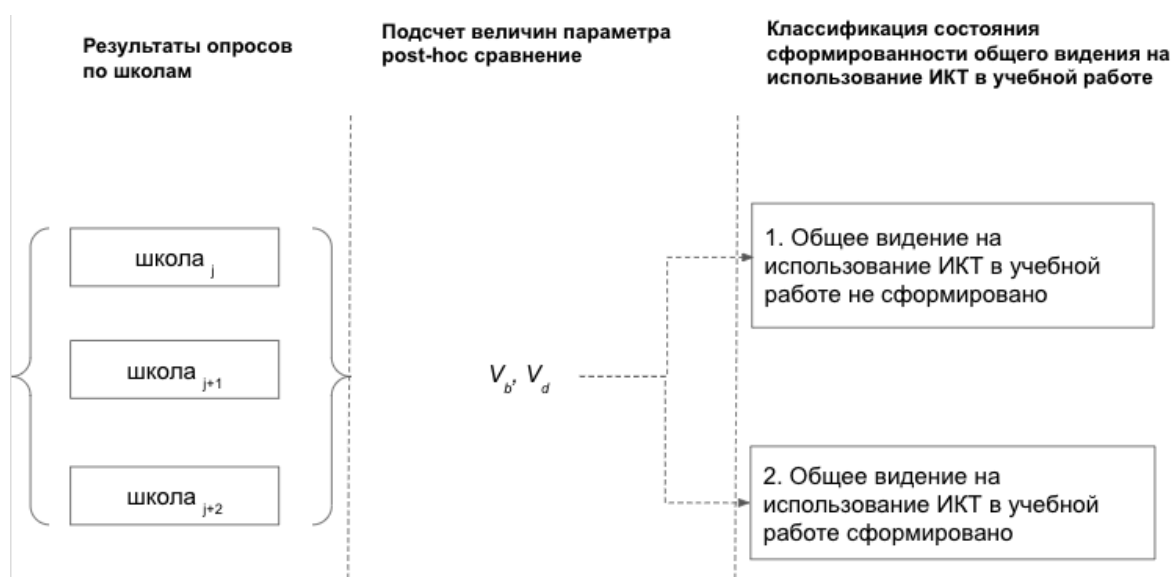


Figure 1. Procedure for assessing the formation of a common vision for the use of digital transformation in teaching and learning

At the first stage of the work, it became possible to test the possibility to apply a combined approach to the qualitative analysis of survey data. At the next stage, it was decided to construct a computational procedure where conclusions could be drawn for each school

who took part in the survey. At the second stage, a combined methodology was developed, based on clustering and mapping the resulting cluster structure onto the maturity scale of innovative work at school.

Table 2. Levels of innovative work according to RISC and capabilities to use survey data for scale labels assignment

Maturity level	Short description	Capabilities to use survey data for scale labels assignment
Traditional	Nothing is being done	Survey data solely are applicable to the measurement
Awareness	Individual teachers and school leaders can update their practice	
Understanding	There is a group of school leaders/teachers who update their practice	
First implementation	Most leaders/teachers do something along their practice update	
Usage	The same as in „First implementation” + regular performance evaluation	There is a need to update survey data with additional data
Elaboration	The same as in „Usage” + regular performance evaluation update and improvement	
Dissemination	The same as in „Elaboration” + dissemination and best practices share among other schools	

The key idea of this technique is to formalize a meaningful interpretation of quantitative data obtained as a result of a survey (on the example of teachers and school leaders).

The technique is based on the idea of school clustering used in the development of the K-model (Uvarov, 2006) and the concept of development stages (maturity of the process) underlying the Linear description of the school informatization process. For this purpose, a conceptual model of the indicator "Innovative ICT-supported ways of teaching" was developed, operationalized through a coordination and consistency of efforts of school leaders and teachers to use innovative ICT-supported new ways of teaching at the school level (Shear, Gallagher, Patel, & Fullan, 2011). Consensus in this case refers to the achievement of agreement among teachers or leaders regarding the use of innovative ICT-supported new ways of teaching in school, expressed in the proportion of respondents who believe that the school regularly works on the use of new ways of teaching. Coherence in this case refers to the similarity in what teachers and supervisors do in the direction of using innovative ICT-supported ways of teaching.

We propose a feature vector that is calculated for each school:

$$SL_{consensus}, SL_{coherence}, T_{consensus}, T_{coherence} \quad (1)$$

Details of each element of the vector and their possible values are given in Table 3.

Variables of **consensus** $SL_{consensus}$ and $T_{consensus}$ are calculated as the shares of positive answers ("agree" and "strongly agree") in each group of respondents by school.

Variables of **coherence** $SL_{coherence}$ and $T_{coherence}$ for each group of respondents are calculated through a measure of variability.

Table 3. Element of vector and calculation approach

Vector element	Description	Qualitative variable's value	Binary variable's value
$SL_{consensus}$	How aligned are school leaders' efforts to promote innovative ICT-supported teaching and learning at the school level	$\geq 60\%$	1
		$< 60\%$	0
		low	1

<i>SL_{coherence}</i>	How consistent are school leaders' efforts to use innovative ICT-supported teaching and learning at the school level	high	0
<i>T_{consensus}</i>	How aligned are teachers' efforts to promote innovative ICT-supported teaching and learning at the school level	≥60%	1
		< 60%	0
<i>T_{coherence}</i>	How consistent are teachers' efforts to use innovative ICT-supported teaching and learning at the school level	low	1
		high	0

A description of the proposed combined methodology, where quantitative assessment accompanied with qualitative interpretations, is given below (Figure 2). It includes four steps.

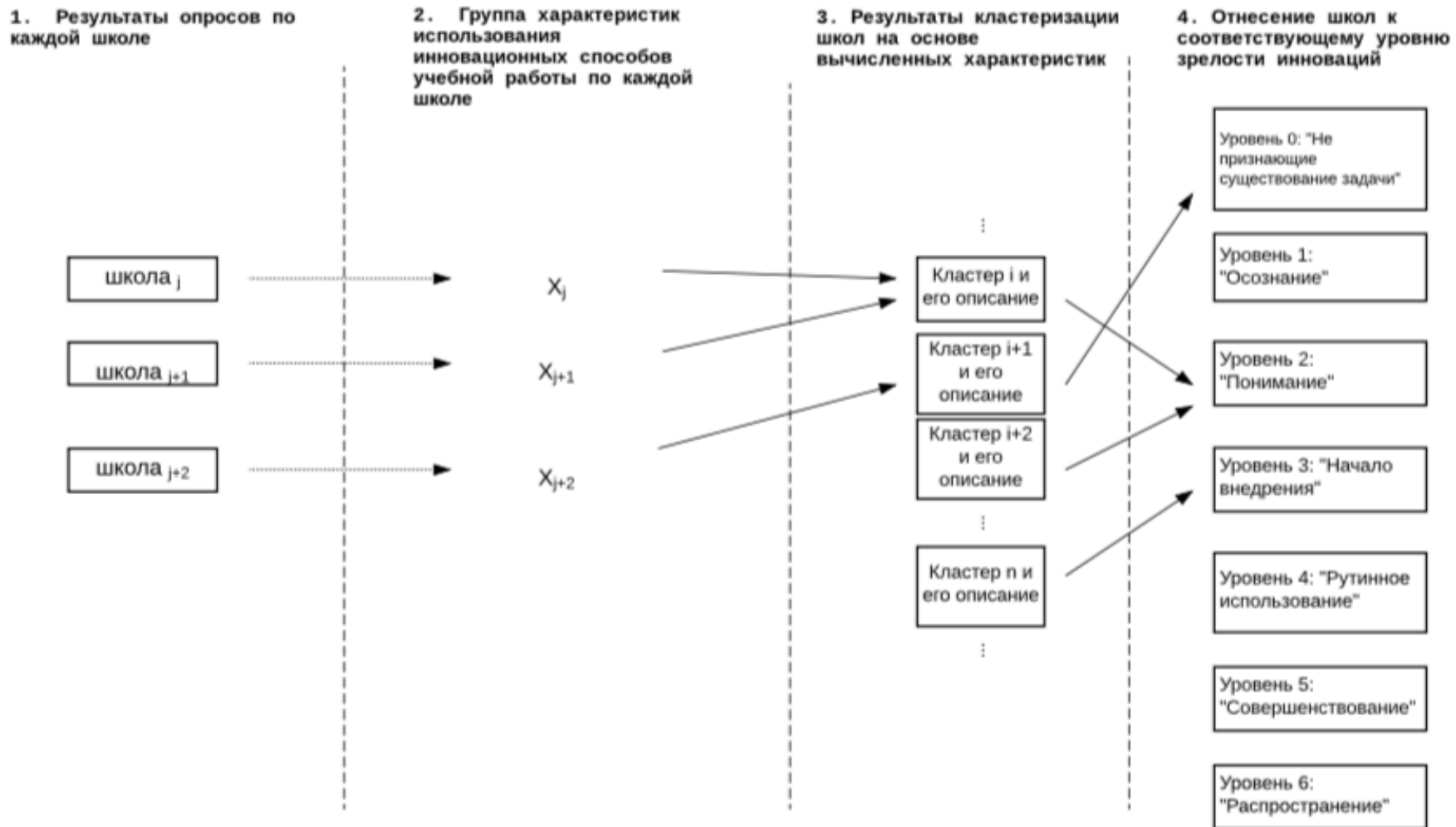


Figure 2. Procedure for evaluating the use of innovative DT-supported ways of learning

Main results

1. Research question 1: « What are current ideas and macro-level models about the use and mastering of digital technologies in general education?»

The analysis of 46 models and frameworks of ICT in school has been conducted. It is concluded that the diagnostic potential of the existing developments is limited. Firstly, the key features of digital transformation are poorly represented due to time reasons. Secondly, the proposed single-dimensional scales of the digital renewal in a number of models do not have sufficient distinguishing capabilities. Thirdly, there is no transparent and clear methodology for assessing and diagnosing the status of the territorial education system even in those tools where qualitative indicators are proposed. Quantitative data-based approaches are extremely few in number.

Research question 2: « What theoretical model and methods, will allow us to assess the changes, including qualitative changes, that occur during the development of digital technologies by the school?»

A concept of digital renewal has been introduced. This concept describes the evolving process of changes in process of adjustment of students' academic outcomes, content and curriculum, teaching and learning, relationships between individual actors of education. Digital renewal touches all key elements of school and uses potential of digital environment.

A qualitative scale to assess mastering of digital technologies by schools has been proposed. This scale incorporates the stage of digital technologies and exploits attitudes and beliefs of main actors of educational process regarding digital technologies use.

Key indicators of mastering of digital technologies are identified: formation of shared vision on ICT use in teaching and learning and innovative ICT-supported teaching and learning. Their representation in models and qualitative scales has been analysed

Research question 3: « What tool can be used to assess key changes in the school in the context of the introduction of digital technologies?»

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A method of process assessment of digital technologies mastering has been developed. This method allows to assess education system based on previously collected survey data. Based on literature review we identified that multivariate approach is reasonable for diagnostic purposes of digital renewal. We implemented this approach by calculating levels of indicators and tested is experimentally on survey data. It confirmed the possibility to distribute schools at maturity scale.

Table 4 – Computed values on scales of digital renewal key indicators with its mapping with stages of digital renewal

Stage of digital renewal	Scale «Formation of shared vision on ICT use in teaching and learning»	«Innovative ICT-supported teaching and learning»
Computerization	Vision is not formed	Traditional
Early informatization		Awareness
		Understanding
Mature informatization	Vision is formed	Implementation
Digital transformation		

Research question 4: « What is the current state of mastering digital technologies by the school in Russian context, assessed using the developed process assessment?»

Advantages of process assessment includes are presented. Firstly, the approach can be used for current state assessment of in the context of Russian school readiness to the digital transformation. Based on the results of assessment, we can conclude that the there are no significant progress towards update of teaching and learning (which is typical for the stage of mature informatization of the digital renewal) or even updating the models of teaching and learning (what is the tasks of the digital transformation).

The use of a combined survey data-based methodology makes it possible to diagnose the status of the school's digital renewal processes. In particular, the approbation of the

developed methodological approach to the formation of a common vision (which is a key aspect of digital renewal management) on the data of the SELFIE led to the conclusion that school leaders, teachers and students do not have a common vision for the use of digital technologies in teaching and learning even in schools which are known for their consistent improving academic work (the study was conducted on data collected from Russian associated schools of UNESCO).

Diagnostic tool for formation of shared vision on ICT use in teaching and learning

Findings suggest that the way school leaders place discussions on the advantages and disadvantages of ICT does not resonate with what teachers do and how students see the use of ICT in the educational process in practice (Table 5).

Table 5. The status of shared vision on ICT uses in teaching and learning

Category	Value
Formation of shared vision within discussions of benefits and lacks of ICT is in practice	0 (no such practice)
School community members have an attitude toward use of ICT in teaching and learning lead to better educational outcomes	1
<i>The value according to the classification scale of formation of a shared vision for the use of ICT in teaching and learning based on SELFIE survey</i>	There is no shared vision on ICT in teaching and learning

Diagnostic tool for innovative ICT-supported teaching and learning

The extension of the combined methodology allowed us to interpret of innovative changes in digital renewal provided by prescriptive tools. An experimental test of the methodology on data collected from UNESCO associated schools using the SELFIE showed that there is a barrier to the transition to the systematic use of innovative ICT-supported teaching (Fig. 3).

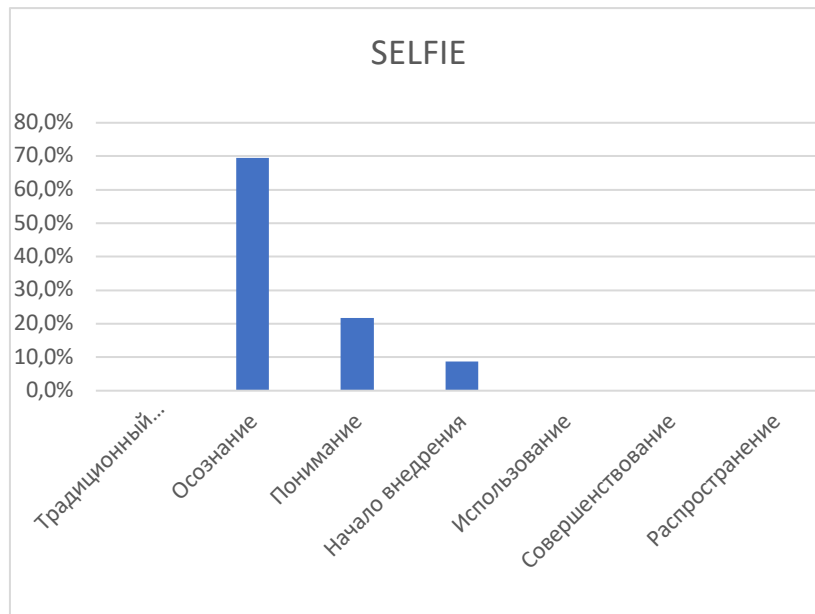


Figure 3 Evaluation of innovative ICT-supported teaching and learning use based on SELFIE data (2017-18 academic year)

An experimental test on a sample of schools participating in the federal monitoring of digital transformation showed that such a barrier remains for significant number of Russian schools (Fig. 4). Discussing the results obtained in both samples, it should be noted that comparison of the results of both samples should be done carefully: in the first case, we are talking about innovative schools interested in the development of digital technologies. In the second case, the monitoring involved schools that primarily have the technological conditions for online survey. It means that the actual status in Russia can be much more pessimistic. At the same time, it should be taken into account that despite the fact that the monitoring survey took place already in the context of a massive transition to forced distance learning, during which teachers mastered the means of digital transformation, there still remains a significant proportion of schools in which digital technologies are used for traditional teaching and learning (11.98%).

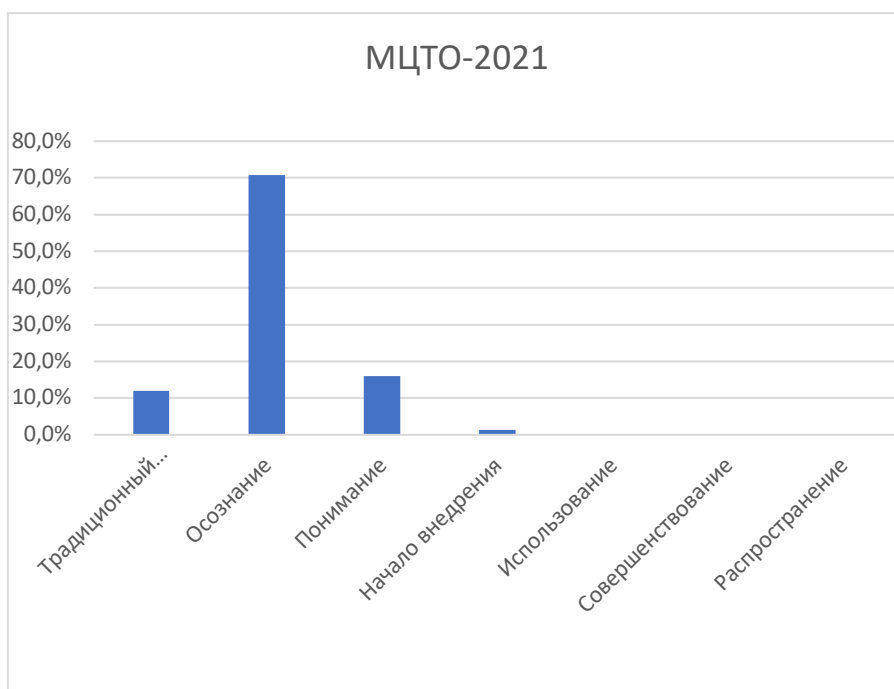


Figure 4 Evaluation of innovative ICT-supported teaching and learning use based on MoDT data (2020-21 academic year)

It is possible to conclude that at national level the number of schools with capacity to transformative changes is small. Main share of schools is situated at the stage of early informatization where active use of ICT in teaching and learning is not inquired. In these schools the teaching and learning is enhanced by ICT and it is matched with Substitution and Augmentation levels of SAMR. However there is no functional changes and school culture update.

In addition, a very weak correlation was found between the RISC scale of innovative work and such an indicator of the development of the digital infrastructure of the school in terms of the conditions for the active learning work of students in digital environment. We mean the number of mobile PCs used for educational purposes per 100 students ($r = 0.14$, $p=0.007$, $n=477$) and the number of personal computers used for educational purposes that have access to the Internet per 100 students ($r= 0.009$, $p=0.001$, $n=477$). This fact correlates well with the results of previous studies of the innovative processes in schools in the context digital technologies spread (P. Ertmer, W. Pelgrum, M. Judge, N. Law). Moreover, it is interesting to consider the discovered weak correlation in the context of the development of ICT literacy of students.

Conclusions on diagnostics

Thus, we experimentally tested the applicability of the process assessment to the mastering of digital technologies by the school. This allows us to conclude that Russian schools are characterized by the predominance of innovation-modernizations, during which the traditional model of school work does not adjust significantly, but only enhance (unlike transformations aimed at qualitatively changing the outcomes of the education). Using the process indicator " Innovative ICT-supported teaching and learning" we show that both advanced schools and a larger sample are supplanted. The empirical result obtained is in good agreement with the results of previous studies that assessed transformations in school education as a result of the development of digital technologies and learning outcomes (including the example of information and communication competence) (for example, with the ITL study). To manage the progress of schools toward the digital transformation, which implies a qualitative change in the results of school work as a radically different vision of pedagogy based on soft skills and new digital literacies, diagnostic tools are needed at the managerial level to assess the transformational changes that occur as a result of the adoption of digital technologies by the school.

Today it is becoming clear that qualitative shifts in the education system at the macro stages are impossible without achieving a certain level of information and communication competence of students (Asmolov, Semenov, & Uvarov, 2010; Vodopyan & Uvarov, 2016). A number of empirical studies already identified the situation with the use of digital technologies in the education and offer factors that impact information and communication competence (Fazekas, 2021; Ferraro, 2018; Shear et al., 2011; Tondeur, van Keer, van Braak, & Valcke, 2008). Moreover, it should be noted that often found evidence of links between the level of literacy (mathematical, information and communication, reading) and the development of the digital educational environment are not sustainable (Biagi, Loi, 2013; Hatlevik, Ottestad, Throndsen, 2015). But at the same time, there is an extremely small number of works that would not only typologize different schools, characterize the distribution of schools at the level of the district/regional education system, and evaluate the progress of schools toward mastering of digital technologies (Vodopyan & Uvarov, 2006; Uvarov,

2011), but also checked how such a movement of schools is associated with the development of the digital educational environment of the school. Preliminary data obtained on the basis of the Monitoring of the Digital Transformation of Schools and the ICC monitoring study in the Russian context allow us to judge the presence of such a connection, and this is one of the lines of continuation of this study.

This may serve as an argument that the diagnostic tool help to reveal real shifts in the work of schools at the macro level.

Scientific, theoretical and practical significance of research findings

The author obtained the following key findings summarized as follows:

- The concept of digital renewal has been introduced and theoretically substantiated. It can be used as a framework for developing an assessing tool for the degree of mastering digital technologies by a school.
- To assess the transformational changes that occur as a result of the mastering of digital technologies by the school, a diagnostic tool is proposed. It combines the use of quantitative sociological data and qualitative interpretations. A diagnostic tool is based on key indicators of the transition to solving the problems of digital transformation.

The theoretical relevance is defined its contribution to the emerging theory of school digital renewal. An approach proposed sets a new theoretical view on the situation of simultaneous existence in the education system of schools, where the use of development of digital technologies differs significantly. This provides wide opportunities for further theoretical and empirical developments in the field of transformational changes in the education (as key changes leading to a radical increase in academic outcomes), studying and describing such processes, their changes and factors.

The practical relevance of this study

The results and conclusions of the study can be used for further research dedicated to the detailed examination of the use of digital technologies at school. The research materials can be used by school teams. The diagnostic tools can help to schools to assess

their state of mastering digital technologies by key aspects, to evaluate themselves against the certain norm and against other schools, to develop and implement programs for their transformation. Diagnostic tools can also be used by responsible education authorities for targeted recommendations development and targeted educational policy elaboration.

The results can be summarized in the following provisions subject to defence:

1. The concept of "digital renewal" is a key framework concept that is necessary for understanding changes in the education associated with the use of digital technologies by the school. The use of its concept allows the most adequate disclosure of the specifics and essential features of the development of digital technologies by the school.
2. Evaluation of the use and mastering of digital technologies in schools is based on process indicators, examples of which are: (1) developing a shared vision for the use of digital technologies, (2) using innovative ways of teaching and learning supported by digital technologies. Both indicators are of a process nature, integrally describe the process of mastering digital technologies by the school and allow to assess the transition to the digital transformation.
3. The proposed framework for the process assessment of the use of digital technologies by schools allows one to see the distribution of schools on the scales of key indicators. It gives a subtle tool for assessment the readiness of schools to solve the problems of digital transformation.

The relevance of findings is confirmed in international context as well: two waves of ICILS (Fraillon, Ainley, Schultz, Friedman, & Gebhardt, 2014) show that there is an extremely small proportion of students with a high level of computer literacy remains in almost all education systems, including the Russian Federation and Moscow. The expansion of the share of students with a high level of computer literacy is one of the expected results for education, but it is not achieved systematically, due to the lack of a developed system of personalized support and management of schools on the way to their digital renewal, where different background and pace of schools are taken into account.

In order to further extend this research, a number of potential routes could be taken:

1. Development of a process multi-aspect model of digital renewal, within which key aspects and indicators of digital renewal are clarified and substantiated.
2. Development and justification for the set of key process indicators that help to measure transformational changes, their empirical verification, including the use of multi-parametric data sources for diagnostic purposes. Such a development of the study will set the theoretical and methodological frameworks for building an automated system for assessing the state of school digital renewal, including using artificial intelligence approaches, which is important for supporting decision-making related to the mastering of digital technologies by the school at different levels of the education system.
3. Comparison of the results of assessments based on a diagnostic tool with the academic outcomes of students in order to establish patterns in the use and mastering of digital technologies.
4. The conducted process assessment can be used for practical recommendations for individual schools (school leaders, school teams) on moving towards the digital transformation stage based on the measurements. Exploring and expanding on additional indicators of digital renewal will refine such targeted recommendations. Work on building an evidence-based educational policy is also associated with this direction: the development of targeted methods to support the development of schools of the territorial education system and at different stages of digital renewal can be done based on the results of a process assessment.

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