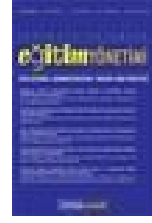





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Determination of the Digital Educational Environment Composition for a Math Teacher based on the Analysis of Research and Practical Teachers' Opinions

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<p>Article History</p> <p>Article Submission 12 November 2022</p> <p>Revised Submission 24 December 2022</p> <p>Article Accepted 28 February 2023</p>	<p style="text-align: center;">Abstract</p> <p>The use of digital technologies in the organization of the educational process takes education to a new level. The aim of the study is to examine the subject digital environment of a math teacher. The article analyzes the opinions of scientists in the field of the subject of digital educational environment component composition, which are the basis for the determination of such components as a didactic learning system. Conducting the study required the use of a whole range of methods, such as observation, survey, and compilation of the Likert scale. Two groups of respondents participated in the survey: the first group included math teachers who had completed advanced training courses on building a subject-based digital educational environment; the second group included teachers who did not take such courses. The author tested the assumption that there is no significant difference in the selection of the subject digital educational environment components by math teachers. To determine the absence of differences between the two experimental distributions, the χ-square criterion was used. Based on the results obtained, the theoretical model of the subject digital educational environment was corrected. The results of the study showed that the theoretically justified component composition of the subject digital educational environment was confirmed as a result of experimental work with practicing teachers, which confirms the relevance of the instrumental approach to the construction of the subject digital educational environment according to the model proposed.</p> <p>Keywords: Digitalization; Subject Digital Educational Environment; Digital Tool; Math Teacher</p>
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Introduction

Digitalization opens up new opportunities for education. The use of digital technologies in the organization of the educational process takes education to a new level, as digitalization makes the learning process flexible, open, mobile, and personalized. In this regard, teaching methods and educational approaches are being improved, which enable the teacher to focus on the individual development of the student and take into account his/her educational needs (Kalimullina et al., 2021). In such conditions, the learning process should promote the activity of students, the educational content should be practice-oriented, provide students with tools for learning activities, and promote their self-development and self-improvement (Lyubimova et al., 2015; Galimullina et al., 2016).

The digital learning environment should provide flexible learning in an interactive educational space and allow using a large number of sources, educational resources, and services that students can quickly and easily adapt to their educational needs (Garcia, 2021). Also, the digital educational environment (DEE) should contain a list of digital tools that ensure effective communication, teamwork, reflection, self-control, and foresight of competencies (Galimullina et al., 2017; Galimullina & Lyubimova, 2021; Öztürk, 2020). Such principles of building a modern DEE will make the learning process comfortable and personalized, and educational content open, accessible, and mobile.

The DEE of the educational process is discussed in this study, where the main participants are schoolchildren led by a teacher. The purpose of such an environment is to achieve educational results in a specific academic subject. Such an environment provides teachers with convenient tools for managing the educational activities of students. This approach gives the teacher the opportunity to build an environment according to the author's plan (Galimullina & Khuzeeva, 2021). Currently, the problem of building a model of a subject-oriented DEE focused on teachers is relevant.

The aim of the study is to identify the main components of the subject DEE for the best practical application in the work of a math teacher. The author of the article identified the following main research questions: 1. What is the component composition of a teacher's DEE? 2. Which components of a math teacher's DEE are the most significant and valuable? The scientific novelty of the research lies in the authors' determination of the DEE components that allow the math teacher to build an author's educational environment on the subject, and the assessment of the degree of the most significant DEE components for a math teacher. The justification of the obtained results was carried out using the χ -square criterion. The practical implementation of the research process was carried out in the form of an analysis of a survey conducted among math teachers using the Likert scale.

Literature Review

The concepts of a DEE and a subject DEE of the teacher

The concept of DEE is used in different contexts. Nowadays, it is known to everyone who follows and participates in the program "Digital Economy of Russia". This concept is associated with the program "Digital Educational Environment" (Galimullina & Khuzeeva, 2021), the main task of which is to create a modern and secure digital educational space.

Currently, there is no general definition of the DEE concept. The concept of a DEE has become the subject of scientific knowledge for such researchers as Shilova (2020), Lapin (2019), Prirodova et al. (2020), Khoroshikh and Kalugina (2021), Budarina and Loksha (2018), Abramsky (2019), Kurkina and Starodubtseva (2019), Biankina (2017), Weindorf-Sysoeva and Subocheva (2018), Zhigalova (2019), and many others.

For example, Lapin defines a DEE as a single information system that unites all participants in the educational process: students, teachers, parents, and the administration of educational institutions (Lapin, 2019). Prirodova et al. describe a DEE as part of the global information space, sectorized in various industries and directions: economics, management, politics, technology, healthcare, and education (Prirodova et al., 2020). The work by Shilova provides a pedagogical

interpretation of a DEE through the concept of pedagogical relations between the subjects of the educational process based on the use of digital technologies and digital educational resources in order to master culture, ways of self-realization aimed at the formation of digital behavior of modern society citizens (Shilova, 2020).

Biankina, Weindorf-Sysoeva, and Subocheva define the DEE of an educational organization as a set of methodological, technological, and technical support presented in a digital format (Biankina, 2017; Weindorf-Sysoeva & Subocheva, 2018). Abramsky defines a DEE in his research as a new technological level in the development of information educational environments and speaks about its intellectualization. In his works, a DEE is a complex of intelligent information solutions, systems, and tools aimed primarily at improving the quality and efficiency of the educational process. An important distinctive feature of a DEE, according to the author, is the ability to form an individual educational trajectory for the student, on the basis of which it is possible to analyze his/her needs with the proposal of various scenarios for further development (Abramsky, 2019; Tarman & Kilinc, 2022). It should be noted that many authors consider the digital environment as part of the educational environment that has signs of digitalization obtained as a result of the transformation of education in the process of informatization (Budarina & Loksha, 2018; Zhigalova, 2019).

The analysis of various scientific works also allows concluding that a DEE is mainly understood as a digital learning tool or some kind of technical solution for organizing educational activities. For example, the authors' team of the EDUTAINME project has developed a Digital Learning Environment Manifesto where a DEE is part of digital pedagogy and is defined as an open system designed to solve educational problems (Chebotar et al., 2018). The authors of the Manifesto (psychologists, teachers, sociologists, programmers, and pedagogical designers) describe the basic principles of designing a DEE, where a student builds his/her educational trajectory under the guidance of a teacher and is an active participant in the educational process (Erbilgin & Şahin, 2021).

An analysis of recent publications shows that the discussion of DEE problems usually takes place not only from the perspective of an educational organization but also within the framework of a specific subject. Currently, there are a number of papers devoted to discussing the general structure of the university DEE. The general structure of the DEE in the conditions of intensive education informatization was given by Zakharova (2005) and Abrosimov (2005). Atanasyan in his works built and analyzed a model of the DEE of a pedagogical university (Atanasyan, 2009). In the work by Gagarina and Henner, the highly developed DEE of the university is considered a means of forming the humanitarian component of higher education (Gagarina & Henner, 2009). A number of works investigate the relationship between the DEE and the media education system. For example, the work by Badalova et al. investigates the role of media education in the development of the digital educational system in the conditions of a digital economy society formation (Badalova et al., 2017). In the article by Fotieva and Kirilin, media education in the context of digital education is considered from the general philosophical positions (Fotieva & Kirilin, 2019). The works of Gavrilova are devoted to the training of math teachers in the system of continuous pedagogical education. In her research, the author describes the didactic system of math teacher training and identifies such components as educational and methodological, research, control and diagnostic, technological, as well as a component of the organization of network communication activities (Gavrilova, 2012).

As the review and analysis of scientific literature have shown, a DEE is mainly understood in pedagogy as the digital environment of an educational organization. Such a DEE is defined as a single educational system that allows uniting all participants in the educational process. Thus, educational institutions build their digital environment using special tools. For example, the Yelabuga Institute of Kazan Federal University, is an electronic university and an e-learning system. It should be noted that a DEE of an educational organization can be supplemented and expanded through subject-based DEEs that are created by teachers and ensure that students achieve educational results in a particular subject (Galimullina & Khuzeeva, 2021).

This study concerns the DEE of the educational process, that is, the subject DEE, the main participants in which are schoolchildren led by a teacher. The purpose of such an environment is to achieve educational results in a specific academic subject. By the subject DEE, the author

understands the totality of technical, software, and intellectual support in the form of digital tools, resources, and platforms, which provides comfortable, flexible, and personalized learning of a particular subject. Such an environment provides teachers with convenient tools for navigating the students' educational activities. This approach gives the teacher an opportunity to build an environment according to the author's plan (Galimullina & Bochkareva, 2021). The construction of a DEE implies the development of digital content with a description of communication methods corresponding to the teacher's work plan for the near future with the definition of the target purpose and necessary educational and cognitive actions of students, methods, and technologies of work for a certain time period aimed at achieving educational results and the development of certain competencies in the subject. Therefore, the author focuses on the instrumental nature of the subject DEE of the teacher.

DEE components

The author performed an analysis of Russian and foreign literature on this topic and identified the components of a teacher's DEE. Many researchers distinguish groups of information and pedagogical technologies as the main components that make up the DEE of a teacher. Digital educational resources and technological means refer to the information technologies of a teacher's DEE and a set of pedagogical technologies allows teaching using the digital environment (Magomedov, 2019; Mironenko, 2019). For example, Gorbunova in her writings describes in detail the structure of a DEE, highlighting digital tools as its main component (Gorbunova, 2015). Zhigalova considers digital technologies and resources to be the key elements of a DEE, which determine the functionality of the digital environment, its content, and its structure. The author highlights such technologies as cloud services, artificial intelligence, neurotechnology, the Internet of Things, etc. (Zhigalova, 2019).

Shutikova and Beshenkov in their works describe the model of the DEE of the university, highlighting such components as educational, scientific, extracurricular, and organizational and managerial (Shutikova & Beshenkov, 2020). Along with the above-mentioned components of the DEE in the higher education system, the authors directly or indirectly define such requirements as organizational and legal, material and technical, requirements for teacher competencies, as well as requirements for ensuring the educational process in accordance with federal state educational standards. In this DEE model, a special role is assigned to online resources, massive open online courses, and web portfolios, as well as the introduction of promising technologies such as artificial intelligence, virtual reality, blockchain, cloud technologies, and Big Data, which allow for the personification of higher education in DEE.

Mironenko defines a DEE as a set of information, digital and educational resources, and technologies of their application, providing effective and mobile assimilation of educational programs by students taking into account their capabilities and needs (Mironenko, 2019).

The most meaningful characteristic of DEE components is presented by Korotkov. The author identifies the educational, methodological, research, extracurricular, and administrative components of DEE, as well as the components of monitoring and evaluating student learning outcomes (Korotkov, 2011).

Thus, many scientists and educators present the DEE as a multi-level and multifunctional didactic system. From this point of view, the model consists of the following components: educational technologies, forms and methods of teaching, learning objectives, digital content, communication methods, digital tools, digital resources, Internet resources, online educational platforms, teacher's portfolio, and didactic materials. As the main hypothesis of the study, the following assumption is put forward that the component composition of the subject digital educational environment, determined and justified theoretically and experimentally, is approximately the same.

Methodology

Study design

The analysis and generalization of scientific works of researchers in the field of education are used to substantiate theoretical conclusions and develop the composition of the DEE of a

mathematics teacher, psychologist, and methodologist. A comparative analysis of DEE models is also carried out. In order to verify and confirm the results of the study, the following methods were used: theoretical - analysis and generalization of the most relevant works on the problem under study; empirical - questionnaire, survey; mathematical and statistical processing of study results. Structurally, the study consists of three stages. A detailed description of the time interval, the types of activities of researchers at each stage, as well as the results of the research stages, are presented in Table 1.

Table 1. Description of the research stages

Stage No.	Time interval	Types of activities	Result
1	May-July, 2021	Analysis of the works by Russian and foreign scientists on the problem under study	Theoretical model of the subject DEE based on the didactic system
2	August-September, 2021	Organizing and conducting a survey of practicing teachers	Subject DEE model of an instrumental nature
	October, 2021	Definition of the content and types of activities of advanced training courses trainees	Program of advanced training courses for math teachers: "The practice of using digital tools by a math teacher in the construction of a subject DEE"
	March, 2022	Conducting advanced training courses for math teachers according to the developed program	A questionnaire that allows forming the opinion of math teachers about the composition and structure of the subject DEE
3	April, 2022	Conducting a survey of respondents within the developed list of questions, summarizing and analyzing the identified results, formulating conclusions	The components of the math teacher's subject DEE, defined and substantiated theoretically and experimentally

The content of the first stage is aimed at forming the composition of the subject DEE of a modern teacher based on the works by Russian and foreign scientists in the field of subject education (May-July, 2021). Work in this stage was carried out according to the following algorithm: sequential search for publications, selection, evaluation, and inclusion in the analysis. As a result, the most significant DEE models on the subject were selected and analyzed to determine the conceptual field of this study. The time interval of these models ranges from 2011 to 2018. Thus, the authors have determined the composition of the DEE, which is based on a didactic learning system.

The methodological block of the second stage of the study is implemented by organizing and conducting a survey of practicing teachers

(participants in the International Festival of School Teachers) to determine the most significant components of a DEE from their point of view. Statistical analysis was carried out at this stage (August, 2021). The results of this analysis were included in the next step of the work, which was to determine the composition of a DEE from an instrumental point of view. Further work of the author was to determine (on the basis of a survey) the content and types of activities for students of advanced training courses (September-October, 2021), and then implement these courses in March 2022. Thus, advanced training courses on the problems of creating a DEE for math teachers were held in March-April 2022; the group of students consisted of 38 people. At this stage, the researcher concluded that it was necessary to move to substantiate the instrumental approach to DEE design, which led to an updated vision of the subject DEE structure. To substantiate the new component composition of a DEE, the authors evaluated the attitude of teachers toward the problem under study using the Likert method. The developed questionnaire

was offered both to teachers participating in these advanced training courses and to other teachers. The research consists in conducting a survey of practicing teachers in order to identify the most relevant and in-demand components of DEE. The results obtained at the second stage are confirmed by the method of statistical verification of hypotheses based on the χ -square criterion. In this study, the χ -square criterion is used to determine whether there is a statistically significant difference between the expected frequencies and the observed ones. This criterion is also used to compare the survey results of teachers who completed advanced training courses under the program "Practice of using digital tools by a math teacher in the construction of a subject DEE" with the results of those teachers who did not participate in the courses.

Research instruments

The research described in this article includes several stages. At each of these stages, research tools corresponding to the objectives of the stage were used. Let us analyze these tools in the order corresponding to the logic shown in Figure 1.

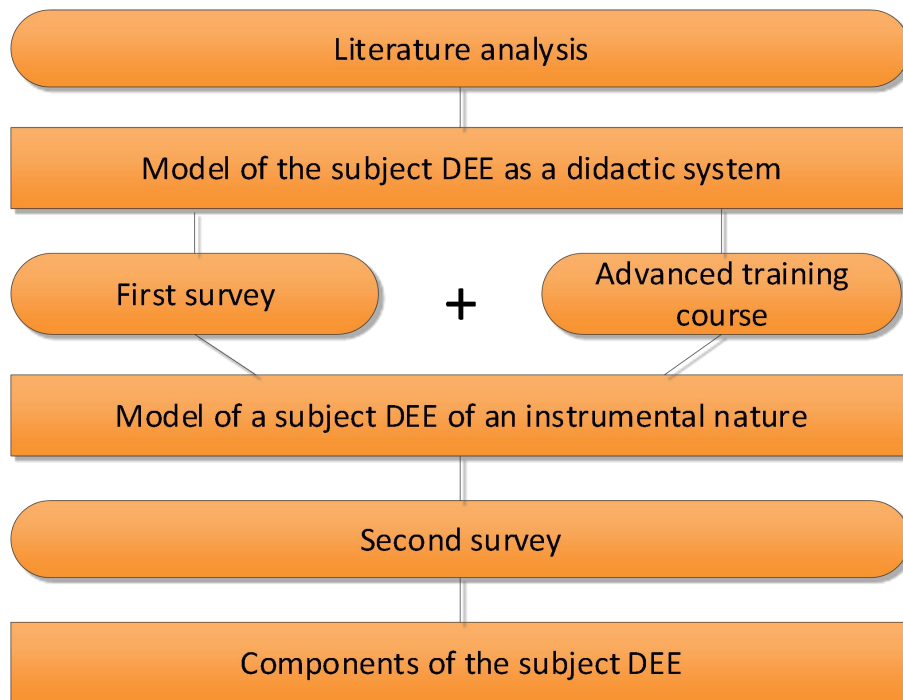


Figure 1. Research logic

So, Figure 1 schematically shows the logic of this research. The diagram shows the stages in the form of rounded rectangles. The result of each stage is in the rectangle below it.

The author offers a model of the subject DEE of the teacher and determines its component composition based on the analysis of scientists' publications in the field of the DEE composition and structure. This model is constructed as a didactic learning system. The author conducted a survey of practicing math teachers using the Likert method in order to compare the component composition of the author's theoretical model and teacher preferences, on the basis of which the technology of creating such an environment by a teacher in practice will be built in the future. Respondents were asked to indicate the degree of their agreement or disagreement with a certain statement ("fully agree", "agree", "partially agree", "partially disagree", or "completely disagree") on the following statements, which are based on the main component of the teacher's subject DEE:

1. The math teacher's DEE will be effective if the teacher uses learning management systems (LMSs) (Classroom, Moodle, iSpring, etc.).
2. The use of specialized mathematical digital tools significantly increases the efficiency of the mathematics teaching process.
3. Specialized mathematical tools will allow each math teacher to build a unique digital

environment taking into account the features of his/her methodological system.

4. It is advisable to start building a DEE for a math teacher by introducing digital elements that provide an educational result into the existing Calendar and Thematic Planning.

5. The use of messengers, video communication tools, social networks, and quick feedback tools will improve the communicative capabilities of the educational environment.

6. The electronic form of the textbook is a mandatory part of the DEE for a math teacher.

To conduct the survey, the authors used the Microsoft Forms service, as well as the capabilities of Microsoft Excel for the statistical processing of the study results.

The study was conducted in March-April 2022. Two categories of practicing math teachers participated in a survey conducted in mid-April 2022. The first category included teachers who had completed advanced training courses under the program "Practice of using digital tools by a math teacher in the construction of a subject DEE" featured by the author of this study. Within the courses, teachers studied the concept of a DEE, mastered digital tools previously unknown to them, participated in collective work on determining the composition of DEE in mathematics, and designed the educational process using digital tools and resources. The second category included teachers who had not taken these courses.

The presence of both types of teachers (those who have completed advanced training courses and those who have not) as respondents makes it possible to reasonably determine the composition of the DEE and draw conclusions about the preferences of certain components by representatives of various categories.

The authors used the χ -square criterion to calculate the homogeneity of two independent experimental samples. In this case, the hypothesis H_0 (there are no differences between the two experimental distributions) was tested. The authors tested the assumption that there is no significant difference in the selection of the subject DEE components by math teachers.

Data collection

The selection and analysis of theoretical data were carried out throughout the study.

The collection of empirical data was carried out by the researcher at two stages of work: the second and fifth steps of the described study.

Then we prepared a questionnaire to determine the component composition of a DEE. At this stage, the Google Forms functionality was used. This tool, due to its integration with Google Sheets, makes it possible to create a questionnaire online, distribute it quickly, and process it efficiently. The survey was conducted without fixing the respondent's name; the questionnaire consisted of 5 questions. Participation in the survey was voluntary. Active teachers who came to Yelabuga in August 2021 to participate in the International Festival of School Teachers were invited to the questionnaire; 194 teachers passed the questionnaire. After the survey, the data was uploaded to Google Sheets, then analyzed and mathematically processed.

A questionnaire containing six statements was developed using the Likert method. The survey was conducted online, by distributing a link to the questionnaire to the heads of advanced training courses for math teachers. The survey contained a question about taking advanced training courses under the program "Practice of using digital tools by a mathematics teacher in the construction of a subject DEE", which made it possible to process separately the data of both groups of teachers: who completed an advanced training course and those ones who did not participate in it. The justification of the obtained results was carried out using the χ -square criterion.

Results

At the second stage of the study, a survey of teachers was conducted in August 2021. Teachers received access to the questionnaire using QR codes, which they got with handouts of the International Festival of School Teachers participants.

One hundred ninety-four teachers participated in the survey, of which 77% were from

Tatarstan, the remaining 33% were from other regions of Russia, and 13% of the total number of respondents were rural teachers.

Almost half of the respondents were experienced teachers with at least 20 years of experience. All respondents were active participants in the Teachers' Festival. This fact leads to the conclusion that they strived to develop and were involved in the innovative processes of Russian education. Respondents' work experience: from 20 years and more - 47%; from 5 to 20 years - 35%; up to 5 years - 18%. The third stage of the study was conducted in April 2022. There were 54 participants in the survey. All respondents were math teachers. Let us introduce a symbol for groups of teachers: teachers who had taken advanced training courses under the program "Practice of using digital tools by a mathematics teacher in the construction of a subject DEE" were in Group A. Those teachers who had not taken such courses were in Group B. Group A included 30 teachers and Group B included 24 respondents. The survey participants were teachers of the Republic of Tatarstan. The survey was conducted using Microsoft Forms.

Since researchers use the method of Likert scale to measure the attitude of teachers toward certain components according to the degree of need to include them in the DEE, the χ -square criterion is very convenient to prove the correctness of the results obtained and their correct interpretation.

The χ -square criterion is one of the most frequently used criteria in various studies. It allows for solving a large number of different tasks, the initial data for which are obtained on any scale. The criterion is constructed in such a way that when two experimental distributions completely coincide, the empirical value of χ -square is zero, and the greater the discrepancy between the compared distributions, the greater the value of the empirical value of χ -square.

In this study, the χ -square criterion was used to compare two experimental distributions: Group A and Group B. In this case, using the χ -square criterion, the homogeneity of two samples is evaluated and the hypothesis that there are no differences in the selection of components of the subject DEE by math teachers is tested.

Participants

The survey was conducted twice with different target audiences. For the first time, 194 teachers from different regions of Russia participated in the survey. Such wide geography was achieved due to the International Festival of School Teachers in August 2021 held at the Yelabuga Institute of Kazan Federal University (Republic of Tatarstan, Russia). The survey participants were teachers of various ages and qualification categories. This survey was conducted in order to clarify which components of the subject DEE are considered by practicing teachers to be the most significant. Thus, the didactic model of the subject DEE has received an instrumental character.

Two groups of 54 teachers participated in the second survey in April 2022: Group No. 1 included teachers who had just completed advanced training courses at the Yelabuga Institute of Kazan Federal University, including a module on building a DEE for math teachers; Group No. 2 included teachers who had not passed these advanced training courses. In the first category, 30 people were interviewed, and in the second one - 24. A total of 54 respondents took part in the second survey. This survey was conducted for the purpose of experimental confirmation of the received instrumental model composition, as well as for the purpose of further technology development for creating a subject DEE by a teacher (by the example of a math teacher).

Teachers were offered a choice of several DEE definitions. The results of the answers to this question are placed in Table 2.

Table 2. The results of respondents' opinions on the choice of DEE definition.

DEE definitions	Percentage of teachers who agreed with the statement
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DEE definitions	Percentage of teachers who agreed with the statement
1. A subject DEE is understood as a single information system that will unite all participants in the educational process: students, teachers, parents, and the administration of educational institutions.	18.6%
2. A subject DEE is a part of the global information space, sectorized in various industries and directions: economics, management, politics, industry, healthcare, and education.	0.5%
3. A subject DEE is understood as a complex of information educational resources, a set of technological means of information and communication technologies, communication channels, and a system of modern pedagogical technologies that provide training in modern conditions of education digitalization.	32.5%
4. A subject DEE is understood as a totality of technical, software, and intellectual support in the form of digital tools, resources, and platforms, which provides comfortable, flexible, and personalized learning of a particular subject.	12.9%
5. A subject DEE is a set of software and hardware, educational content necessary for the implementation of educational programs, including the use of e-learning, distance learning technologies, and providing access to educational services and services in electronic form.	35.6%

The smallest number of votes (0.5%) was given to definition number 2, which underlines the fact that this definition does not fit the subject DEE. Definitions number 3 and number 5 received the largest and almost the same number of votes, which indicates that respondents understand the complex nature of the DEE essence. However, it also indicates that many teachers do not see a significant difference between the organization's DEE and the subject's DEE.

To determine the composition of DEE, teachers were asked to select from the list the components they thought were necessary. After analyzing the components of DEE selected by the respondents, the author identified only those that scored more than 50% of the votes. As a result, the list has decreased; here is this list (Table 3).

Table 3. The results of a survey to choose from the list of subject DEE components necessary in the opinion of teachers.

List of components offered to teachers to choose from	List of components selected by teachers
Educational technologies Forms and methods of training Learning objectives Digital content Communication methods Digital tools Digital resources Internet resources Didactic materials	Educational technologies - 66% Digital content - 60% Digital tools - 57% Digital resources - 68% Internet resources - 59% Online educational platforms - 66%

Thus, components that are present in the DEE, but do not explicitly affect the digital aspect, were removed from the list (highlighted in gray). They characterize the DEE mainly as a didactic system. It leads to the conclusion that practical teachers focus on DEE resources and tools. The researcher believes that teachers need an instrumental approach to building a DEE. It is obvious that such an approach will make it possible not only to build a model that is understandable and close to teachers but also to create the basis for the development of technology for creating a subject-based DEE by a teacher.

The following results were obtained from teachers in response to a question about the features of the subject DEE (Table 4).

Table 4. Results of answers to the question about the features of the subject DEE

Option to choose from	Percentage of teachers who agreed with the statement
1. Provides effective training for a group of students on an educational trajectory	46.40%
2. Developed by a teacher	19.10%
3. Provides monitoring and recording of the progress and results of the educational process	41.80%
4. Provides remote interaction of an educational institution with other social organizations	45.40%
5. Allows expanding the possibilities of building an educational trajectory for students	47.90%
6. Provides information and methodological support for the educational process on the subject	56.20%

Questions 1 and 3-6 received a fairly large percentage in the range from (41.80%) to (56.20%). This suggests that teachers tend to think that DEE allows for organizing an effective educational process with the provision of individual trajectories of students. However, only 19.10% of respondents chose the answer option about creating a DEE by a teacher. Therefore, the authors concluded that there is a misunderstanding of the subject of DEE essence. It is obvious that the subject DEE is built by the teacher from both ready-to-use digital solutions and resources and fragments created by the teacher (including those created together with students). In this case, teachers understand the DEE in the subject as a kind of educational platform with ready-made content. Such platforms of Russian school education include Russian Electronic School (RESH), Ya.Klass, Mobile e-Learning, Uchi.ru, Ya.Textbook, Foxford, 1C: School, Sber.Class, InternetUrok.ru, Moscow Electronic School (MES), etc.

According to the author, the subject DEE should be based on the need for the teacher to carry out those types of activities that will ensure the achievement of an educational result. That is why the questionnaire included a question about the actions that a teacher should perform in a digital environment (Table 5).

Table 5. The results of the answers to the question about the actions of the teacher in DEE

Option to choose from	Percentage of teachers who agreed with the statement
1. Fill the environment with content	34.00%
2. Monitor the activities of students	75.30%
3. Manage communication between DEE participants	72.20%
4. Send reports to the school administration	18.60%
5. Interact with colleagues	28.90%
6. Provide access to the resources of the school library	21.60%

It is important that teachers understand the need to manage students' activities in a digital environment. When answering the question about the actions that the teacher should carry out in the subject DEE, quite high percentages gained such positions as controlling the activities of students and managing communication between participants in the subject DEE. Only (34%) of respondents expressed a desire to fill the environment with content, which confirms the idea expressed earlier about the orientation of teachers to act in a ready-made system filled with content.

The analysis made allows modifying the model of the subject DEE with a didactic character,

which was obtained as a result of sources analysis at the theoretical stage, into a practice-oriented subject DEE based on an instrumental approach.

So, based on the results of the survey and their interpretation, the author proposes a model of the subject DEE. It should be noted that the presented model is instrumental in nature and is designed to ensure that teachers understand not only the composition and structure of the DEE on the subject but also the way to create it. The practice-oriented nature of the model will allow teachers to decide on a set of digital tools and their purpose and, as a result, prepare teachers to build their own DEE.

The composition and logic of building a DEE on the subject (Figure 2). The teacher is in the center of the diagram. Since the teacher works in accordance with the calendar-thematic planning, that is, the work program, which corresponds to a certain educational and methodological complex, the textbook should be the basis for building a digital environment (obviously, it should be an electronic version of the textbook). The electronic form of the textbook can be used by the teacher both in front-line work in the classroom, and when organizing individual work. A good electronic form not only repeats the printed version but also is multimedia, interactive, contains links to additional sources, interactive tasks of various levels, etc.

As mentioned above, the author's model is instrumental in nature; it demonstrates the role of certain digital resources, tools, platforms, etc. The DEE should be built on a single digital platform. That is the reason why at the present moment, it makes sense to deploy a DEE based on an LMS. The most common LMSs are Google Classroom, Moodle, iSpring, etc. In such an environment, a teacher can freely combine the use of platforms with ready-made educational content, as well as use digital tools for creating the author's content, taking into account the characteristics of each of them.

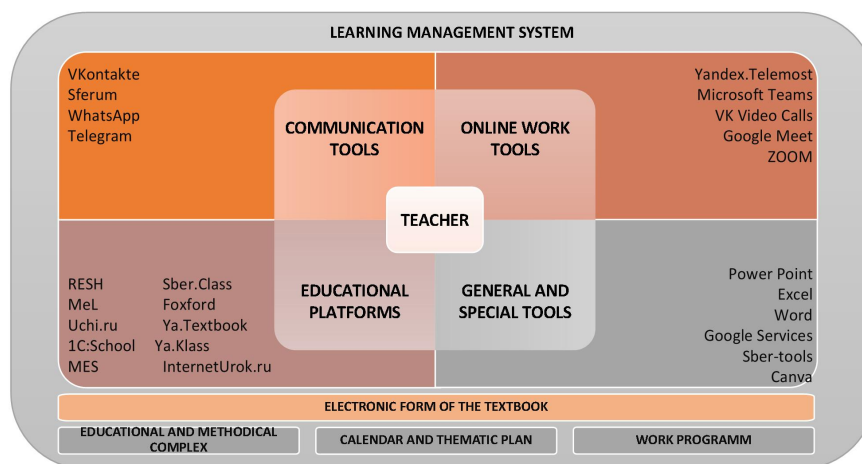


Figure 2. Schematic representation of the subject DEE model

Note that the groups of tools presented in the model allow the teacher to solve certain pedagogical tasks that arise during the organization of the educational process. The author identified the following elements of the subject DEE: educational platforms, communication tools, tools for organizing online classes, and general and special tools of the teacher. The tools of communication organization include social networks, which not only have excellent opportunities for use in the educational process but also allow for the possibility of constant communication, both with an individual student and with a group of students. The need to include such DEE elements is indicated by the emergence of a special social network for the school - Sferum. Messengers can also be attributed to this group. As practice shows, most teachers, parents, and children cannot imagine the educational process without their use. The usefulness of messengers in practice is sometimes doubtful but the fact of their use in building a learning environment cannot be denied. When working in mixed learning mode, videoconferencing tools are not included in the list of mandatory components, but they allow for online participation in the

educational process of those students who do not have the opportunity to attend school. There are quite a lot of options for using the possibilities of online conferences to solve the current tasks of a teacher. General-purpose digital tools and subject-specific tools play a key role in the proposed model. It is these groups of tools that enable the teacher to build a DEE taking into account the peculiarities of the subject being taught. The use of specific tools in the educational process allows the teacher to achieve educational results in his/her subject.

Since the subject DEE is considered, it is obvious that it should contain subject digital tools. In this case, these are mathematical tools. The author conducted a review and analysis of the digital tools of the teacher for constructing the subject DEE. In particular, specific digital tools were selected and analyzed for their application by math teachers in practice when building a subject DEE. As a result of such work, classifications of digital educational tools for a teacher, including for a math teacher, were identified. The developed author's classification of digital tools is based on the approach of distributing tools into categories depending on their application in solving pedagogical and mathematical problems, respectively. Six categories of digital tools for building a subject-based DEE were identified in the classification of a teacher's digital tools.

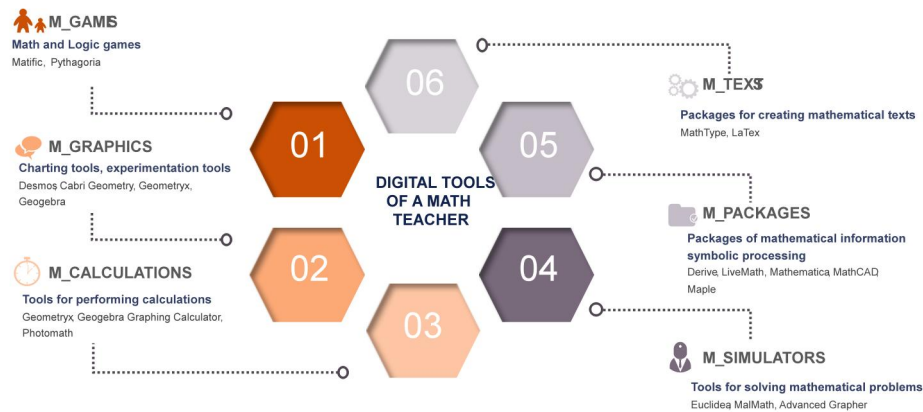


Figure 3. Digital tools of a math teacher for building a subject DEE

The authors attributed the following tools to the specific tools for constructing the subject DEE of a math teacher: tools for creating mathematical and logic games (Matific, Pythagoria); charting tools, experimentation tools (Desmos, Cabri Geometry, Geometryx, Geogebra); tools for performing calculations (Geometryx, Geogebra Graphing Calculator, Photomath); packages for creating mathematical texts (MathType, LaTeX); packages of mathematical information symbolic processing (Derive, LiveMath, Mathematica, MathCAD, Maple); tools for solving mathematical problems (Euclidea, MalMath, Advanced Grapher).

The component composition of the mathematics teacher's subject DEE, which is determined and justified theoretically and experimentally, served as the basis for the second survey in order to identify the respondents' preferences. Within the framework of this survey, a list of questions was developed, the results obtained were summarized and analyzed, and conclusions were formulated on their basis (Table 6).

The survey contains the following questions:

Q1: Have you mastered the module «DEE of math teacher» in March 2022 at the advanced training courses at the Yelabuga Institute of Kazan Federal University?

Q2: The math teacher's DSP will be effective if the teacher uses learning management systems (Classroom, Moodle, iSpring, etc.).

Q3: The use of specialized mathematical digital tools significantly increases the efficiency of the process of teaching mathematics.

Q4: Specialized mathematical tools will allow each mathematics teacher to build a unique digital environment taking into account the features of his methodological system.

Q5: It is advisable to start building a digital educational environment for a mathematics teacher with the introduction of digital elements into the existing KTP that provide an educational result.

Q6: The use of messengers, video communication tools, social networks, and quick feedback tools will improve the communicative capabilities of the educational environment.

Q7: The electronic form of the textbook is a mandatory part of the digital educational environment of a mathematics teacher.

Table 6. Results of teachers' survey on preferences regarding DEE components

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	Yes	Completely agree	Completely agree	Completely agree	Completely agree	Completely agree	Agree
2	No	Agree	Agree	Partially agree	Partially agree	Agree	Partially disagree
3	No	Agree	Agree	Agree	Agree	Agree	Partially agree
4	Yes	Agree	Agree	Agree	Agree	Agree	Partially disagree
5	Yes	Partially agree	Completely agree	Agree	Agree	Agree	Partially agree
6	Yes	Partially agree	Agree	Completely agree	Agree	Completely agree	Partially agree
7	No	Completely agree	Completely agree	Completely agree	Completely agree	Completely agree	Completely agree
...
49	No	Partially disagree	Partially disagree	Partially agree	Partially agree	Partially agree	Partially agree
50	No	Partially disagree	Agree	Agree	Agree	Partially agree	Agree
51	No	Agree	Partially agree	Partially agree	Agree	Agree	Completely agree
52	Yes	Partially agree	Partially agree	Partially agree	Partially agree	Partially agree	Partially agree
53	Yes	Agree	Agree	Agree	Agree	Partially agree	Partially disagree
54	Yes	Partially agree	Partially agree	Partially disagree	Partially agree	Partially agree	Partially agree

The next stage was the statistical processing of the results and the calculation of the χ -square experimental value for each statement. Table 7 shows the results of the survey on Statement 1: "The math teacher's DEE will be effective if the teacher uses LMSs (Classroom, Moodle, iSpring, etc.)". The cells indicate the number of responses according to the degree of agreement or disagreement with a certain statement, which are based on the main component of the teacher's subject DEE.

Table 7. Statistical processing of results

	Completely agree	Agree	Partially agree	Partially disagree	Disagree	Total
Group A	O11=6	O12=12	O13= 12	O14= 0	O15= 0	n1=30
Group B	O21=4	O22= 12	O23= 4	O24= 4	O24= 0	n2=24

Total	10	24	16	4	0	54
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Figure 4 shows a general formula for calculating the empirical value of χ -square for comparing two experimental distributions. Figure 5 shows the calculation of the empirical value of χ -square for Statement 1, the results of the survey which are shown in Table 6.

$$\chi_{\text{emp}}^2 = \frac{1}{n_1 \cdot n_2} \cdot \sum \frac{(n_1 \cdot O_{2i} - n_2 \cdot O_{1i})^2}{O_{1i} + O_{2i}}$$

Figure 4. A general formula for calculating the empirical value of χ -square for comparing two experimental distributions

$$\chi_{\text{emp}}^2 = \frac{1}{30 \cdot 24} \cdot \left[\frac{(30 \cdot 4 - 24 \cdot 6)^2}{6 + 4} + \frac{(30 \cdot 12 - 24 \cdot 12)^2}{12 + 12} + \frac{(30 \cdot 4 - 24 \cdot 12)^2}{12 + 4} + \frac{(30 \cdot 4 - 24 \cdot 0)^2}{0 + 4} + \frac{(30 \cdot 0 - 24 \cdot 0)^2}{0 + 0} \right] = 7,83$$

Figure 5. Calculation of the empirical value of χ -square for Statement 1

The indicators of the linked tables are calculated according to Statements 2-6 in the same way. Table 8 shows the values of χ -square empirical for all Statements of the analyzed survey.

Table 8. Empirical values of χ -square for each Statement

Statement	Empirical value of χ -square
1. The math teacher's DEE will be effective, if the teacher uses learning management systems (Classroom, Moodle, iSpring, etc.)	7.83
2. The use of specialized mathematical digital tools significantly increases the efficiency of the mathematics teaching process	8.24
3. Specialized mathematical tools will allow each math teacher to build a unique digital environment taking into account the features of the methodological system	5.90
4. It makes sense to start building a math teacher's DEE with the introduction of digital elements that have an educational result in the existing calendar and thematic planning	1.23
5. The use of messengers, video communication tools, social networks, and quick feedback tools will improve the communicative capabilities of the educational environment	17.39
6. The electronic form of the textbook is a mandatory part of a math teacher's DEE	8.48

The number of degrees in the considered case is $v=(k-1)(c-1)=(2-1)(5-1)=4$. Then the critical values of the χ -square criterion for the degree of freedom $v=4$ will be as follows (Figure 6).

$$\chi_{\text{cr}}^2 = \begin{cases} 9,488 & \text{for } P \leq 0,05 \\ 13,277 & \text{for } P \leq 0,01 \end{cases}$$

Figure 6. Critical values of the χ -square criterion at the degree of freedom $v=4$

Therefore, one can now interpret the results of the survey.

As can be seen from Table 8, the values of χ -square empirical for Statements S1-S4 and S6 are in the zone of insignificance, since they are less than 5% of the significance level, and the value for Statement S5 is in the significance zone since it is greater than 1% of the significance level. In other words, for S1-S4 and S6, hypothesis H_0 should be accepted that there are no differences between the two empirical distributions. Thus, the preferences of teachers who have passed and have not passed these advanced training courses do not have significant differences. In contrast, the value

of χ -square empirical for Statement S5 is in the zone of significance; therefore, for this statement, the alternative hypothesis should be accepted that the distributions of preferences in two unequal samples differ statistically significantly from each other.

The analysis of the survey allowed answering the first question posed in the study about the component composition of a DEE. Teachers agree that LMSs, digital tools, including specific ones (in mathematics), and electronic forms of textbooks should become mandatory components of the subject DEE, and it is necessary to start building a subject DEE with the development of a calendar and thematic planning. As for the fifth statement, teachers' opinions are divided: teachers who have completed advanced training courses are more likely to agree that the use of messengers, video communication tools, social networks, and quick feedback tools will improve the communicative capabilities of the educational environment. Thus, 47% of teachers from Group A gave the answer "Completely agree" to the fifth question, while from Group B there were 0%. Experience shows that this is due to the fact that teachers usually believe that social media distract children from their studies, children spend a lot of time on the phone, and online communication often does not relate to learning.

Math teachers identify digital mathematical tools and LMSs as the most significant components of the digital educational environment. At the same time, teachers note that specialized digital tools will allow the teacher to build a DEE according to the author's plan, taking into account the methodological system. The significance of specialized digital tools as the main component of the subject DEE is indicated by the largest number of responses for the highest degree of agreement ("Completely agree") in Statement 2. Note that the maximum number of "Completely agree" responses in respect of Statement 2 were received in both categories of respondents. This is due to the fact that this component is the most familiar and understandable for a wide range of teachers, which is repeatedly confirmed by the conclusions of the survey conducted at the second stage of this study. Also, practicing teachers noted the need to include the LMS as a significant component of the subject DEE, since the teacher should have a digital space where the educational process with the students can be organized. Less preference was given to positions concerning electronic forms of textbooks and communication systems: messengers, video communication tools, social networks, and quick feedback tools.

Discussion

The problem of the subject DEE composition is quite acute. Researchers describe the characteristics of such an environment, indicating the types of activities of its participants. Much less attention is paid in research to the instrumental nature of the digital learning environment. This approach is more often used in the study of higher school DEEs than in the study of the subject DEE of secondary education. Let us consider some results of studying the composition of the subject DEE.

In the New Education Architecture section of the Digital Learning Environment Manifesto, the authors note its components such as LMS, learning content management system, non-interactive sources, tool environments, and data storage. Teacher-scientists contrast an electronic textbook with a DEE, thus proving that an electronic textbook should become part of DEE (Chebotar et al., 2016). It can be seen that in such positions as the LMS, tool environments, and an electronic textbook, the researchers' opinion coincides with the components of the DEE identified in this article.

Solovov and Menshikova, exploring the DEE model of the university, describe a didactic model of a digital educational resources complex, which is based on the instrumental software (author's systems, LMS, online learning platforms, artificial intelligence systems, VR, AR, etc.) and coincides with the model described by the author, precisely the LMS and digital tools (Solovov & Menshikova, 2021). Also, a typical complex of a digital educational resource is placed in the DEE scheme of the university, which practically corresponds to the composition of the teacher's subject DEE model (this article) in terms of educational platforms, messengers, video communication systems, and ready-made digital resources.

Zhiyasheva et al. studied the views of teachers on the use of information and communication

technologies in the educational environment. A total of 58 teachers participated in the survey under consideration. According to the results of the study, 82% of teachers stated that they understood new concepts related to the information and educational environment, although they did not often use them. Only 28% of respondents understood the meaning of the terms "educational information environment" and "educational media environment". Electronic libraries and electronic textbooks were known to many teachers but only 47% of them fully understood their value. These facts lead to the conclusion that it is important for teachers to understand the essence of the digital learning environment (Zhiyasheva et al., 2021). The author's research also showed that teachers believed they knew the concept of DEE, but found it difficult to formulate it correctly.

Investigating the effectiveness of digital learning introduction into educational policy in conditions of self-isolation during the pandemic, Pratiwi et al. concluded that teachers preferred to use Zoom, WhatsApp, and Google Classroom as platforms for organizing digital learning (Pratiwi, 2020). Thus, it can be concluded that faced with the need to conduct training remotely, teachers chose an LMS from many applications as the basis for creating a digital learning environment, a means for video communication and establishing online contact, and a messenger for operational feedback. These components are also part of the model proposed in this article.

A significant similarity in some parts of the models under consideration was revealed when comparing the composition of the personal e-learning environment of a higher school math teacher (Vlasenko et al., 2020) with the components of the subject DEE of a math teacher proposed by the author of this article. Vlasenko et al. determine the composition of the personal e-learning environment of a higher school math teacher (Vlasenko et al., 2020) by analyzing the types of activities. Among other elements, scientists consider important such components as LMSs, tools for organizing communication and collaboration, and cloud services (as universal tools of a teacher). Taking into account the peculiarities of the taught subject (in this case mathematics), the authors included specialized mathematical tools in the model, which are divided into two categories: packages for symbolic processing of mathematical information and tools for statistical processing of information. The listed components are also present in the model of the subject DEE of a math teacher proposed by the author of this article. The author describes an instrumental approach to constructing a model of the subject DEE, while highlighting groups of both universal and mathematical tools that allow the teacher to solve various pedagogical tasks. Both studies use an activity-based approach, which is currently very relevant for both higher and secondary schools.

The issues of designing the infrastructure that makes up the intellectual educational environment are given a significant place in the scientific literature, so this study occupies its own specific methodological niche. All said in the Discussion section leads to the conclusion that the model proposed by the author on the one hand does not contradict similar studies and is even confirmed by them, and on the other hand emphasizes its uniqueness and orientation to the secondary school.

Conclusion

The study conclude that the theoretically justified component composition of the subject digital educational environment was confirmed as a result of experimental work with practicing teachers, which confirms the relevance of the instrumental approach to the construction of the subject digital educational environment according to the model proposed by the author.

The ability to build a subject-based DEE is the most important component of any teacher's (in particular, a math teacher's) readiness to make the learning process comfortable and personalized, educational content open, accessible, and mobile, and educational results achievable. Determining the component composition of the subject DEE is quite a difficult task and requires comprehensive study since it is a multi-level and multifunctional didactic system. At the same time, teachers need recommendations on how to build such a subject environment, so it is important to find such approaches to DEE design that will allow the developing of a technology for creating a subject DEE. This study made it possible to identify and experimentally verify the component composition of a DEE based on an instrumental approach. According to the author, the subject digital educational environment should contain such mandatory components as digital

tools, resources, and services, means of communication of all participants in the educational process, as well as provide them with the possibility of a single entry into the digital environment. The author does not exclude the possibility of identifying other components of the subject DEE. End-to-end technologies that are increasingly penetrating education can also be used to build a model of the subject DEE. This research can be continued in the direction of exploring the possibility of including other digital solutions and formulating new models of a subject DEE. Conducting a study according to this step-by-step logic and analyzing the data of teacher surveys conducted according to the described methodology allows determining the composition of the subject DEE, which is instrumental in nature, that is, in turn, gives an opportunity to further development of DEE construction technology which is easy to understand for teachers. The model of a subject DEE described in the article will allow teachers to expand their understanding of a subject DEE, expand the component composition of their author's digital environment, and teachers of higher educational institutions conducting advanced training courses for teachers in the field of digitalization of education will be able to fill them with relevant content.

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