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Research Article

Web-technologies in Knowledge Integration as a Means of Mathematical Literacy Forming of School Students

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Astract: Digitalizing of social relations and new dominants of the younger generation entails a change in the requirements for mathematics teacher's professional activity. A modern teacher should not only have the fundamental knowledge concerning with mathematics, but also possess the modern Web-technologies as a means and component of information and educational environment organizing and managing of functional literacy development of school students. The article deals with the components and techniques of mathematical literacy integration and information competence and procedures development in teaching mathematics on the basis of complex knowledge mastering in network educational community; the content and mechanisms for such integration, based on modern achievements in science adapting (fractal geometry, fuzzy sets and fuzzy logic, theory of coding and data encryption, etc.) to school mathematics is also revealed. Problems solving of universal educational actions and mathematical literacy development of school students as a structural phenomenon of an innovative educational environment organizing for managing the school student's cognitive activity in the network educational community is consistently reflected. The cognitive and activity-based aspects of the introduction of Web-technologies and information environments in the integration of mathematical literacy and information competence as well as school student's cognitive activities are identified.

Keywords: Teaching Mathematics, Network Educational Communities, Knowledge, Fundamentalization of Mathematical Education, Technification.

1. Introduction

Mathematical education in Russia and around the world has undergone significant changes in recent decades, if not crisis phenomena of both objective and subjective nature. The emphasis of Western pedagogy on practice-oriented methods and results of education, which also affected Russian school, leads to better socialization of an individual, a greater opportunity to use the mathematical knowledge in real life (Povidaychyk 2020). However, the intellectual operations of thinking (understanding, concretization, abstraction, generalization, modeling, analogy, associations, etc.) being the basis of universal educational actions development of school students and their functional literacy, for various objective and subjective reasons, have ceased to develop the effectively in school education. As well as the loss of reference points in fundamentalization of mathematical education, both in Russia and in the world, leads to a shortage of qualified staffs concerning to the development and implementation of modern technologies, loss of flexibility, criticality and creativity of school student's thinking, leads to the loss of the ability to occupy the modern areas of productive forces. Russian mathematical education has always been advanced in terms of its fundamentalization – the methodology and technology of P.Ya. Galperin, V.V. Davydov, L.N. Zankov, V A. Krutetsky, N F. Talyzina, V D. Shadrikov and others created a solid foundation for effective personal development. However, in recent decades the school student has changed: the possibilities of the information environment, the priorities concerning with personal development, changes in social tasks before the school, the growth of personal preferences lead to negative consequences in the traditional development of mathematics. Moreover, the digitalization of schools and universities has been declared the main trend in Russian education is intended to provide the answers to the "explosive" emergence of new

competencies, changes in the labor market and the openness of global information space (Povidaichyk 2019). However, the results of Russian school students in International Mathematical Olympiads leave much to be desired (over the past 10 years, Russia has fallen to the 11th place in the world), the international PISA test that assesses school students' functional literacy in different countries and the ability to apply the knowledge in practice (takes place every three years; the test involves teenagers aged 15 years), gives the following results (Figure 1):

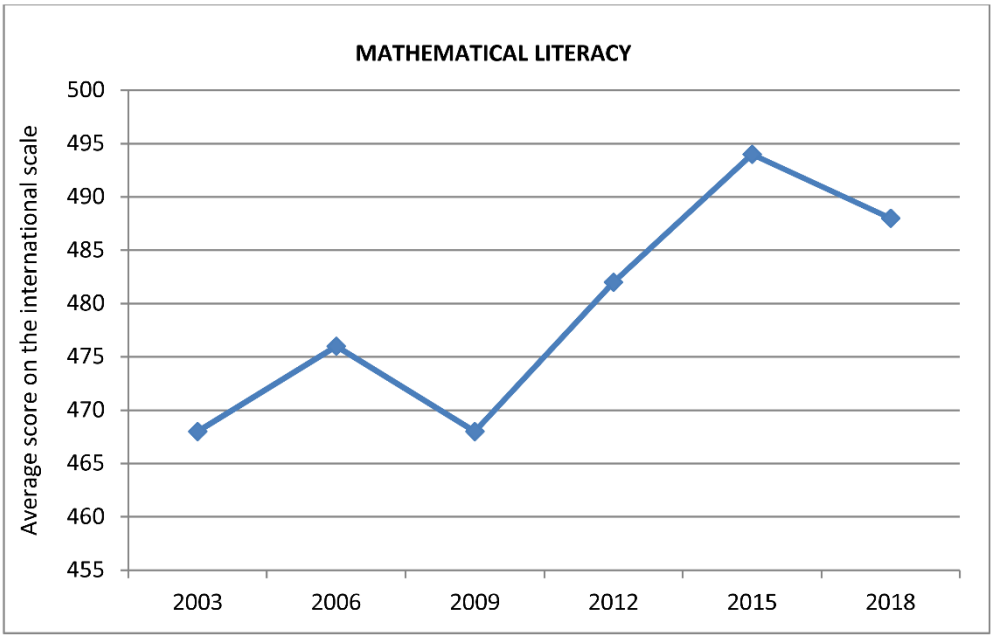

Figure 1: Results of PISA testing in Russia

The 2018 results show that about one fifth of primary school graduates do not reach the threshold level of functional literacy (for each area – mathematical, natural science and reading) and about a third of students in one of the areas. Russia takes 27-35 places in the world ranking. The main difficulties in performing the tasks of functional literacy monitoring are identified:

- understanding the situation and translating it into the language of subject area, finding a solution;
- working with information presented in different forms (figure, text, table, diagram);
- working with real data, values and units of measurement;
- interpreting the results taking into account the proposed situation;
- using educational and life experience.

One of the ways of problems solving of forming functional (mathematical) literacy of school students can be the integration of mathematical, natural science, informational and humanitarian knowledge as well as activities by means of saturated informational and educational environment creating and functioning (Fezchenko 2019). Modern trends in the development of education (open education, distance learning, the emergence of a significant number of educational websites) actualize the problem of the necessity for a mathematics teacher to master the new content and nature of professional activity in the conditions of society digitalization. The existing system of professional training and activities of mathematics teacher in Russia, which took shape in the industrial era, is notable for its considerable conservatism and is focused, first of all, on the formation of educational activities of reproductive type (Zinchenko et al. 2020). Traditional methods of teaching mathematics in school are characterized by informational nature of classes, definition of the goals of homework in terms of subject-based mathematical education – "prove...", " solve...", " learn...", etc.; applied orientation is reduced to general phrases about the necessity of mathematical competence for socialization in real life and a small number of practice-oriented tasks. The knowledge of many graduate-mathematicians of pedagogical university is formal and not professionally oriented: there is no clear and complete understanding of the existing intersubjective communications of mathematical disciplines and their role in the building of mathematical literacy of school students; poorly developed professional skills associated with the use of ICT tools in professional activities, including distance learning technologies; insufficiently formed information culture in terms of skills mastering of finding information and its using in professional activities [1].

In solving these problems a significant role is played by the introduction of Web-technologies in teaching mathematics at secondary school. Web-technologies are modern and effective means of integrating mathematical and information knowledge and activities of school students in new era of science computerization and society digitalization, i.e. the process of mathematical ideas and methods penetration in various areas of life, modern technologies and industries, achievements of natural science and humanities [2]. By integration we understand the process of combining any elements into a whole, as a result of which the new properties arise that are not inherent in the individual elements earlier. In modern science and the needs of technology development, production and explanation of situations in social processes, there is also a strengthening of the integrating role of mathematics as a universal phenomenon of opening and controlling the laws of functioning and development. Indeed, the mathematical apparatus and mathematical methods can be used in studying the qualitatively different fragments of reality (Romashkina and Khuziakhmetov 2020). This is possible, first of all, because objectively there is a commonality, connection and unity between different areas of the real world, which can be described using the same models, sign-symbolic forms and quantitative ratios. The fact that the same mathematical theory can be interpreted on objects of qualitatively different nature shows the commonality of these objects in terms of internal mechanisms of genesis and development, including in quantitative terms. Wide and unlimited in principle of mathematics using in the modern world confirm the commonality of nature corresponding areas, contributes to the disclosure of their unity, and thereby indicates new ways of knowledge integrating (Sydykhov et al. 2017).

Speaking about the integrating role of mathematics in modern science, one crucial point should be made. Any object of activity has both qualitative and quantitative characteristics. The qualitative and quantitative certainty of the object is in unity within the framework of specific measure: with a change in quality, quantitative certainty changes, and a change in quantitative certainty inevitably leads to qualitative changes – one measure succeeds another. Certainty in the change of measures is fixed in the form of a law, so any law always assumes both qualitative and quantitative characteristics. The modern stage of science development is characterized by the strengthening and deepening the interaction between its individual branches, the development of new forms and means of research, including the mathematization and computerization of cognitive processes (Sapazhanov et al. 2020). The spread of mathematics concepts and principles in various fields of scientific knowledge has a significant impact on the effectiveness of special research, as well as on the mathematics development itself. As for the mathematics process of reality cognition is playing an increasingly important role. Today there is no field of knowledge where mathematical concepts and methods are not used to some extent (Zhanysova et al. 2014). Problems that were previously considered are impossible successfully solved through the mathematics using, thereby expanding the possibilities of scientific knowledge. Modern mathematics combines very different fields of knowledge into a single system. The heuristic interaction of qualitative and quantitative, meaningful and formal research methods forms the objective basis for the mathematization of scientific knowledge. The actualization of these integration processes gives mathematical science a holistic character and internal unity of ideas, methods, concepts and theorems, algorithms and procedures.

2. Web-technologies and Mathematical Literacy of School Students: Deep Analysis

We will also consider the integration of mathematical and information knowledge, carried out on the basis of Web-technologies using through the interpenetration of generalized mathematical knowledge and information skills in the development of complex knowledge of modern achievements in science. Under the conditions of a multiplying flow of scientific information, Web-technologies have become the main technology for information support concerning research in many sciences, in addition, Web-technologies have become intensively used in the information support of mathematical modeling in zoology, botany, and physiology as well as in law, linguistics, physical education and even in art. As we can see, Web-technologies begin to play a fundamental role in the information support of mathematical research in all sciences, the names of which are reflected in the list of relevant subjects in secondary school.

Thus, a modern teacher should not only have a basic competence in mathematics, but also possess modern Web-technologies, especially in the conditions of mode operation changing of educational institutions, namely, the transition to a distance learning format. The traditional scheme of passive transferring of educational information to students gives a minimal effect. Therefore, the pedagogical advantages of Web-technologies using in learning process are due to the sharply increased volume and speed of obtaining educational information, a variety of its presentation forms and the ability to individualize the learning process (Abdullina et al. 2013).

The research of various kinds of disproportions between technification, foundation, differentiation, integration, competence approach and other trends in modern education gives grounds to assert that the modern cultural approach is beginning to play a fundamental role in the methodology of introducing Web-technologies

into training a future teacher. This approach is based on the principle of cultural conformity. The analysis of the essence of the principle of cultural conformity in relation to the mathematical training of teachers shows that the stage of the modern "universal" mathematical culture, that we are at this time, requires us to act in accordance with it, if we only want to achieve positive results from the introduction of Web-technologies in this important type of training, especially – teachers of mathematics (Baimanova et al. 2019).

The historical and philosophical analysis of mathematics problems development shows that decisive role in the methodology for introducing Web-technologies into the methodological and mathematical teacher's activity is played by the study of the characteristic features of the process of mathematization of sciences, which reflects the formation at the turn of the century of a modern culture of mathematical applications in various fields of knowledge. The most striking manifestations of this new stage of "all-human" culture, having the greatest impact on education, are mathematical modeling, discrete mathematics and computational processes, being the basis of the methodology for implementing the cultural approach to the modernization of mathematical education, helping to overcome various disproportions between technification, fundamentalization and other trends in modern education [3]. Therefore, mathematical modeling, discrete mathematics and the theory of computational processes are the cultural basis for implementing Web-technologies in forming school student's mathematical literacy [4].

The basic concepts of the language of these areas of mathematics are particularly important in the new emerging culture of searching, processing and analyzing information in the process of implementing the stages of mathematical modeling using a computer and computational processes in various fields of science and industry. Ideas and methods of modern discrete mathematics (also known as discrete analysis, computer and concrete mathematics) play a particularly important role in the correct information possessing. Therefore, it is true that mathematical modeling, discrete mathematics and computational processes form the terminological basis for using the broad capabilities of Web-technologies in the search, processing, analysis and use of mathematical information on the Internet. Thanks to these most striking manifestations of the modern mathematical culture of research using unique computer capabilities, Web-technologies have become the basis of "information support for mathematical research" [5; 6].

Thus, mathematical modeling, discrete mathematics and computational processes are an integral part of the terminological foundations of correct information support for new types of educational activities implemented in the process of forming mathematical literacy of school students, for example, in implementing various educational network projects in the process of teaching mathematics of complex knowledge based on language of mathematical structures using. The language of mathematical structures and schemes (in the general scientific terminology – tools and methods concerning mathematical knowledge) are being dominant in mathematical modeling, discrete mathematics and the theory of computational processes and playing a particularly important role in the acquiring of mathematical thesaurus by school students.

Firstly, it should be assumed that these structures and schemes language plays a fundamental role in the qualitative analysis of problems in a particular subject area, in the systematization of information interest on the problem in the Internet, its structuring, and the presentation of available knowledge in a form convenient for subsequent problem solving.

Secondly, these structures and schemes language plays an important role in the foundation of mathematical activity of school students, which implies the priority of fundamental knowledge and giving this knowledge the value of the basis or core for lot of knowledge accumulating [7]. Therefore, it is true that the language of these structures and schemes is necessary for the unification and standardization of Web-technologies introduction in mathematical literacy developing of school students. Ignoring this leads to information primitivism by using of Web-technologies, characterized by the assimilation of mainly information components of knowledge. Information primitivism in the language using of these structures and schemes generates the most persistent errors concerning mathematical modeling, which remain unnoticed during the final analysis and testing of modeling results and reach the stage of implementation of its results. First of all, these are errors in the omitted logic of reasoning, i.e. errors in the correct use of the necessary terms of mathematical language.

3. Functional (Mathematical) Literacy of School Student

As follows from the above, there is an important problem of forming student's mathematical literacy in using Web-technologies, based on the thesaurus (lexicon) of the most striking manifestations of modern achievements in science, elements of mathematical culture such as mathematical modeling, discrete mathematics, computational processes in the development of fractal geometry, fuzzy sets and fuzzy logic, the theory of

encoding and encryption of information, etc. The mathematical literacy in using Web-technologies should be understood as follows:

- correct formulation of information necessity that make it possible to determine the most preferred mathematical Web-resources for new types of educational activities;
- application of the optimal and correct set of information resources in mathematics;
- efficient construction of search queries based on correct indexing of mathematical texts and query language;
- adequate assessment of the reliability of mathematical information, as well as the quality of electronic teaching resources in mathematics.

Speaking about the mathematical literacy of school students in using Web-technologies, it is also important to note that a mathematics teacher should know almost all topics of computer science, use technical means at the qualified user level in order to be able to transfer the knowledge and skills to others. Therefore, due to the expansion of the subject area Information Sciences as "the fundamental science and educational discipline" increases the value of "subject" information sciences and the resulting "subject" information technologies play a fundamental role in the information support of learning process in terms of sciences mathematization [8]. While implementing Web-technologies in the processes of forming mathematical literacy, it should also be assumed that Web-technologies play a leading role in the information environment developing of modern achievements in mathematical science (information and knowledge that are the content of databases; distributed information processing; dissemination of scientific information) and mathematical culture (electronic libraries, search engines, materials of conferences, symposiums, seminars, virtual mathematical communities, Web-services for automating various research, specialized sites, etc.).

Social services (Web 2.0-technologies), based on the active participation of users in developing the content, form the basis of modern concept of Internet development. The feasibility of using Web 2.0 services in education was pointed out by [9-16]. Let's present the model of mathematical and information knowledge integration and activities of school students based on Web 2.0-technologies (Figure 2):

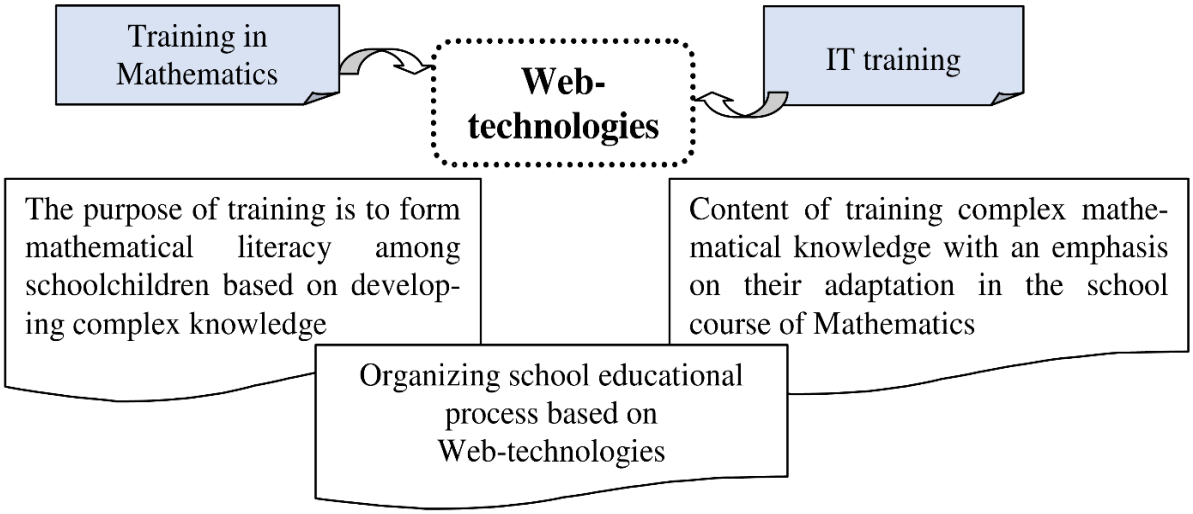

Figure 2: Model of integrating mathematical and information knowledge and activities based on Web 2.0-technologies

Taking into account the didactic possibilities of Web-technologies using in developing mathematical literacy of school students, the Table 1 shows the components of mathematical and information knowledge and activities integration [17].

Table 1: Integration components of mathematical and information knowledge and activity based on Web-technologies and using information environments

Integration components	**Mathematical activity in the assimilation of complex knowledge**	**Integration toolkit and technologies**	**Universal learning actions of formed mathematical literacy**
Assimilating the	1) implementing the	Cross-	1) setting goals

ways of knowledge replenishment and orientation in an extensive knowledge system	educational network interdisciplinary projects on mathematics on the base of complex knowledge adaptation; 2) updating and selecting mathematical knowledge and procedures based on implementing the stages of complex knowledge adaptation;	platform environment Creator Web 2.0 – technologies Computer algebra systems	independently and consciously; 2) structuring and presenting information; 3) planning, organizing and managing personal activities; 4) identifying, generalizing and consciously using mathematical knowledge in educational and cognitive activities
Defining the structure of an object, all its elements and the relationships between them	3) establishing links between various mathematical concepts and procedures; 4) constructing and computer designing of structural logic circuits;		5) conceptual modeling; 6) purposefully extracting and generating subjectively new knowledge;
Designing and integrating the knowledge by school students themselves	5) showing standards and solving PISA-like interdisciplinary practice-oriented and constructive tasks (thinking up, composing, etc.) in mathematics; 6) performing a research Web-quest in mathematics;		7) mathematical and computer modeling activities for achieving the set goals; 8) performing self-checking and self-monitoring;
Transferring knowledge and skills to a new situation independently	7) generating new tasks and encoding educational material using reference signals and encoding tables;		9) interpreting conditions and methods for solving tasks; 10) structuring and presenting information;
Communication and open dialogue between participants of educational process, forming non-linear direct and feedback	8) exchanging mathematical information, conducting mathematical discussion, interaction in a network social environment.		11) transmitting mathematical facts; 12) conducting a verbal exchange of information; 13) carrying out collective activity.

The methodological basis for creating any methodological system is represented by the didactic principles of teaching. In this case we are not speaking about replacing the existing traditional didactic principles with new ones, but about revising and filling them with content that makes it possible to use them constructively under the conditions of society and education digitalization. In accordance to well-known position that the principles of teaching combine the theoretical concepts and pedagogical practice, forward the teacher's activities in the right direction, implement the normative function of didactics, we will consider the new interpretations of principles: scientific nature, fundamental nature, the relationship between theory and practice and the founding of personal experience.

A new interpretation of the principle of science nature (the connection between science and education) is presented by expanding the traditional interpretation, implying the development of school student's ability to distinguish true scientific knowledge from pseudo-scientific (including the development of the quantitative literacy). Namely, the range of personal experience is enriched by the content of modern achievements in science (fractal geometry, the theory of encoding and encryption of information, fuzzy sets and fuzzy logic, non-Euclidean geometries, etc.) and their adaptation to school mathematics based on mathematical and computer modeling [17].

The interpretation of the fundamental nature's principle as a principle that increases the priority of the thesaurus of mathematical structures and schemes, which should be at the first place of any mathematics teaching based on theoretical generalization, is changing. According to the innovative principle of founding of personal experience [1], since the diagnostics of the condition of the breadth of experience of the individual, through realization of layer-by-layer continuity of knowledge and ways of activity in the study of complex knowledge in mathematics (including research) and dissemination activities, the amount of, the content and structure of mathematical and information competence of school students in assimilating and knowledge the essence of mathematical constructs should undergo significant changes leading to understanding [18]. The founding principle is an original synthesis of general didactic principles: integrity and consistency, natural consistency, individualization, self-development and personal priorities.

The principle of theory and practice relationship in the context of saturated new educational environment implementation involves the organizing practice-oriented mathematical activities of students on the basis of mathematical and computer modeling and case studies of real-life situations, applied aspects of developing natural sciences and humanities, leading to the development of interest, self-determination and creative activity of personality. The following cognitive and activity aspects of the implementation of Web-technologies and information environment in the integration of mathematical and information knowledge and activities of school students (Table 2) should be highlighted:

Table 2: School student's cognitive activity components on the Internet

Traditional teaching forms	**School student's cognitive activity components on the Internet**
Practice and laboratory lessons	1) performing tasks to determine the validity and reliability of Web-resources concerning mathematical disciplines; 2) performing tasks to find essentially new information in mathematics, comparing it with the known; 3) performing tasks for comparing properties of various mathematical objects, establishing relationships between them, compiling and filling databases of basic mathematical concepts; 4) creating a situation that initiates communication and dialogue of cultures on the basis of setting, solving, researching and interpreting the conditions of practice-oriented tasks, searching for new mathematical information, comparing it with the known
Control (input, current, total)	public defense of educational network projects with presentation of one's own activities, conducting Web-quests, computational procedures for laboratory and multi-stage mathematical and information tasks
Independent work	1) developing a training network project based on solving and researching PISA-like tasks; 2) preparing a thematic Web-summary on integrating mathematical knowledge and procedures based on the interpretation of practice-oriented tasks; 3) developing an electronic encyclopedia of practice-oriented and PISA-like tasks for mathematical literacy; 4) compiling an annotated list of Web-resources on the problem of mathematical literacy; 5) selecting, solving, researching and interpreting practice-oriented tasks in mathematical disciplines based on computer modeling; 6) performing tasks in preparation of abstracts, annotations, messages in mathematics

Thus, each of the above-mentioned traditional forms in the process of teaching school students mathematical disciplines can be combined on the basis of network educational community into a single technology for teaching mathematics of complex knowledge.

4. Conclusions

The research shows that mathematical modeling, discrete mathematics and the theory of computational processes are the cultural basis for the implementing Web-technologies in forming mathematical literacy of school students in teaching mathematics of complex knowledge based on using the language of mathematical

structures. At the same time, the developed content and mechanisms of modern achievements adaptation in science (mathematical modeling, discrete mathematics, numerical processes in the development of fractal geometry, fuzzy sets and fuzzy logic, the theory of encoding and encryption of information, etc.) to school mathematics in a rich information and educational environment are effective. The model of integrating mathematical and information knowledge and activities of school students based on Web 2.0-technologies is developed and justified. The components of integration of mathematical and information knowledge and forming universal educational actions based on Web-technologies and using information environments are identified. The following principles of integrating mathematics and computer science are also revealed and justified: founding of personal experience, relationship of theory and practice, science nature (integrating science and education). The cognitive and activity-based aspects of implementing Web-technologies and information environment in the processes of integration of mathematical and information knowledge and activities of school student's, based on implementing technology for assimilating of complex knowledge and procedures with the effect of forming mathematical literacy, are presented.

Online learning provides more opportunities for student's traditional education, if it allows you to use and process additional sources of information and interactive dialogue operatively [19]. When learning in an online environment, space and time do not matter [20]. In this case school students are able to carry out their educational activities at their own pace and at selected intervals of time, which is significant for the processes of assimilating complex knowledge and procedures based on integrating of mathematics and computer science. The use of new didactic practices contributes to the involvement of school students in an effective and rich mathematical activity, improves critical and creative thinking, reduces apathy and promotes collegial learning [21]. Thus, the implementation of Web-technologies and information environment in the mathematical activities in the context of information interaction on the Internet will ensure the development of not only mathematical literacy, but also contribute to the effective development of personal substructures: motivation, reflection, criticism and creativity. This symbiosis of traditional and online mathematical education corresponds to the information stage of development of society, makes it possible for the school students to develop stable skills of receiving and processing information, form ideas about the importance of IT in modern digital society and develop mathematical literacy.

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