



Integration of Mathematical and Natural-Science Knowledge in School Students' Project-Based Activity

Olga L. Luneeva
21-st Lyceum, Russia.

Venera G. Zakirova
Kazan (Volga region) Federal University, Russia.

Received 24 October 2016 • Revised 27 March 2017 • Accepted 17 April 2017

ABSTRACT

New educational standards implementation prioritizes the projective beginning of training in school education. Therefore, consideration of educational activity only as the process of obtaining ready knowledge should be abandoned. Thus the relevance of the studied problem is substantiated by the need to develop methodical works connected with the introduction of inter-subject projects into mathematics teachers' pedagogical activity as mathematics has a wide application in various sciences, though, at lessons, it is left behind due to time limits and insufficient mathematical apparatus school students possess. All that said specifies the goal of the paper: to define opportunities of project-based activity application in integration of mathematical and natural-science disciplines and development of methodical recommendations on its broad application in the course of training in the subject. The key research method of this problem is modeling the system of possible project-based activity directions aimed to work purposefully to increase results in subject studied as well as to develop meta-subject abilities. The paper proves the necessity to apply project-based technology in the form of inter-subject projects on mathematics; the basic models of school disciplines integration in the context of project-based learning opportunities realization are revealed; project themes of integrated disciplines that differ in time periods, volume and quantity are elaborated; features of their use in the course of studying mathematics are identified. Practical application of this system compensates the lack of tools of meta-subject technologies in pedagogical activity as it demands the ability to work in team, communicative skills, tolerance, self-organization, abilities to set goals independently, to achieve them and to analyze obtained results.

Keywords: additional mathematical education, project-based activity, inter-subject projects, integration of mathematical and natural-science knowledge, meta-subject abilities.

© **Authors.** Terms and conditions of Creative Commons Attribution 4.0 International (CC BY 4.0) apply.

Correspondence: Olga L. Luneeva, 21-st Lyceum, Kirov, Russia. Address to 133A Vorovskogo Street, Kirov City 610000, Russia. Tel: +7 (909) 131-96-79.

✉ luneeva.olga@gmail.com

State of the literature

- Social and economic processes have generated such form of labour organization as project-based activity, however details and peculiarities of such activity in training mathematics at school are insufficiently considered in scientific-pedagogical and methodical researches.
- The available project themes on mathematics are generally limited to the retelling of related historic facts or concern their application in daily life. Mathematics itself is actually absent in them.
- The vast majority of teachers ascertain the need to introduce project-based activity; however, they do not master necessary methodical techniques to implement it in their work.

Contribution of this paper to the literature

- The core models to integrate various disciplines in educational process in the context of their applicability are considered in the course of project-based learning as a means of meta-subject abilities development.
- Some probable inter-subject project themes on mathematics and natural-science disciplines with specification of age categories are proposed. Subject knowledge which can be improved is identified; possible products of these projects are suggested.
- Features of techniques aimed to prepare, conduct and assess such projects as well as difficulties the teacher can face in practice are distinguished.

INTRODUCTION

Every time when the person faces this or that problem in life, they should work out the plan of its solution and attract obtained practical experience. The same happens to the modern science: it demands complex, synthetic knowledge from various areas and spheres. Hence the role of inter-subject integration as a means of school students' mental and creative abilities as well as meta-subject skills development increases. It is therefore necessary not only to regard the prospects of school subjects interaction to facilitate the development of knowledge and to make school students aware that different school subjects have common ideas (Vinokurova & Episeeva, 1999) but also to raise the issue of universal educational actions elaboration which will allow the person to realize both as the personality and expert (FSES of basic general education, 2010).

Thus we believe that both practice-focused knowledge and meta-subject abilities are necessary for the modern school leaver for their successful socialization and adaptation in the society (Romanovskaya, 2006). The use of methods and techniques in pedagogical process that allow to create school students' skills of independent active search, collecting and analysis of necessary information, ability to make hypotheses, to draw conclusions and to employ reasoning acquires a specific relevance (Rokhlov, 2006). In addition, training techniques should use active methods and forms to integrate knowledge and ways of different sciences activity to guide school students to independent creative search and research (Lyamin, 2007), and therefore, to direct realization of meta-subject education the

purpose of which is not to assimilate educational activity but to generate and produce the educational result valuable for the school student and for the society, the world and humankind (Khutorskoy, 2012).

Project-based technologies can be considered as such ones.

On the other hand, the first thing that is evident when it comes to projects "on mathematics" is almost total absence of actually mathematical activity in most of them. The subject theme of such projects is very limited; generally these are themes on the history of mathematics. The majority of projects pretend to have some mathematics; there is some indirect activity connected with mathematics. Modern branches of mathematics are not involved as they are not included in the curriculum (Testov, 2012).

According to surveys on project-based activity, teachers of mathematics seldom use project-based activity due to the lack of corresponding theoretical knowledge and methodical abilities to create a problem situation, organize school students' project-based activity in general, and its assessment. More than a half of respondents specify in their questionnaires that they do not have methodical knowledge and abilities to organize school students' project-based activity in the course of training in mathematics (Kochetkova, 2011).

Goals and research objectives

The goal of the work is to define opportunities of project-based activity application in integration of mathematical and natural-science disciplines, and development of methodical recommendations on its extensive application in the course of training in mathematics.

The following tasks have been specified to achieve the goal: to define possibilities of synthesis of integrative and project-based technologies in mathematical and natural-science education; to consider the basic models of their interpenetration; to study and describe possibilities of project-based activity application to implement the integrative approach in teaching mathematics; to develop methodical recommendations on the method of inter-subject projects application (according to the stages of their development) in training mathematics, and also to mark out features and difficulties of their realization; to provide the list of possible themes for inter-subject projects.

LITERATURE REVIEW

Analysis of the Russian scientific and pedagogical literature

The experience of project-based activity application in practice is considered by many scientists. Gavrilova (2006), Monakhov (2009), Bukharkina, Moiseyeva & Petrov (2008), Polat (1999), Pakhomova (2004), Slobodchikov (1996) and other scientists developed and analyzed basic concepts of project-based activity, studied the features of its organization. Novikova (2000) shares the experience of telecommunication projects application in which objects of reality are studied at an inter-industrial and interregional scale already.

There appear more scientific works devoted to project-based activity used at studying various school subject: informatics, foreign languages, technology, literature, geography, etc. Barkova (2006), Laperdina (2007), Lomakina (2003), Nikolina (2002), Sergeev (2006), Fedorova (2004), etc. Chechel (1998) pays special attention to research projects as means of cognitive activity activation, development of creativity and personal traits related to personality realization in the society.

Many researches concerning inter-subject projects on mathematics specify some methodical aspects and sections of mathematics: project work on geometry and mathematical analysis (Antonova, 2007; Zadorozhnaya, 2016, etc); creation of educational texts as the project on mathematics (Gelfman, 2004; Gelfman & Podstrigich, 2006).

Analysis of foreign researches

Dewey (1915), Kilpatrick (1925) and Collings (1926) are the founders of the project method. "All is from life, all is for life" was the core idea of their scientific school when training does not imply the study of ready material but assimilation of the new through activity.

Furner & Kumar (2007) prove the need to use mathematics widely for natural-science disciplines; they assign it an important part in understanding relationship between scientific concepts, especially in the field of physics. They focus on the fact that success of each learner in these fields of knowledge depends on the degree to which mathematics is integrated with them as it is capable to motivate and involve students in profound studying of these subjects.

Kim & Cho (2015) relying on their work experience draw a conclusion that school students study more consciously within the frames of integrated education as it helps them to find links of school education with their real life.

Pardhan & Mohammad (2005), considering the need of active introduction of integration techniques into teaching mathematics, propose their ways of teachers' methodical training for this purpose: introduction of courses of subject specialization that will allow teachers to study one or more subjects at a deeper level, creation of the school of partnership relations that, by means of network technologies, will make it possible for teachers to communicate and impart experience with each other.

Bilgin, Karakuyu & Ay (2015) have shown high efficiency of project learning in their experimental researches. They explain it by the fact that working at the project in the area that learners are interested in they become aware of own beliefs, an opportunity to declare them, to show activity.

Special attention is paid to STEM education (S – science, T – technologies, E – engineering, M – mathematics). Shahali et al. (2017) give research results which prove high efficiency of project activity in such a form of educational programs when separate

disciplines are not distinguished, and work is conducted within the integrated studying according to "subjects".

MATERIALS AND METHODS

Theoretical base

Developing the designated problem, we relied on the integrative approach that assumes interrelation of mathematical and natural-science knowledge in school students' project-based activity.

The project-research activity in mathematics that integrates it with natural-science disciplines can possess various degree of integration (depending on the profile) and be applied widely both at a lesson and supplementary education.

The distinctive feature of such project activity is that the teacher takes over the process of project development and participates in its creation more actively. It is connected with the fact that time at a lesson (or several lessons) is strictly limited, and basic material has to be assimilated by each learner. Here we see a certain complexity of project method application at a lesson of mathematics. However, when the process of project creation is skillfully organized and its product is chosen correctly, this method is rather effective since it allows to create conditions to form school students' skills to identify a problem, to search the ways to solve it, to gain information (it can be a textbook, additional materials; access to school electronic library if the lesson is conducted in a computer class, etc.), to generalize it, to present conclusions in the form of some final product; all this confirms the meta-subject potential of such work.

Project-research activity in natural-science and mathematical disciplines have the greatest efficiency in additional mathematical education, especially in the form of integrated projects. This is because the subject themes are not limited to either school material, or time, or lack of access to some sources of information which cannot be used fully at a lesson (materials which one can meet only in library stocks, data acquisition as a result of long-term observations, etc.).

Research methods

The following methods were applied to implement the research: the analysis of psychology-pedagogical and mathematical-methodical literature on the research subject, the analysis and synthesis of teachers' experience and own experience of project-based activity implementation in the system of the basic and additional mathematical education, the analysis of educational activity products, the method of mental experiment, forecasting, systematization and generalization of facts and concepts, modeling, design, method of expert evaluations, the analysis of educational activity results, development of educational and methodical materials, diagnostic techniques, pedagogical experiment.

Experimental research base

Approbation, generalization and introduction of research results are performed on the basis of the innovative educational platform "Interrelation of contents, forms and methods of additional mathematical education of school students" by:

- conducting experimental teaching in the course "Projecting on the basis of scientific creativity" for students of the 10th grades; the course has been delivered since 2015 in the basic educational institution lyceum No. 21 of the city of Kirov (more than 70 school students annually);

- implementation of inter-subject projects within summer school camp-training "Mathematics. Creativity. Intelligence" since 2009 (more than 200 school students annually);

- conducting distant advanced training courses "Theory and technique of additional mathematical education of school students in the conditions of Federal state educational standards and the professional standard of the teacher" implementation (108 hours); since December 2012, 229 teachers of mathematics attended them on the platform of the portal of the Interregional center of innovative technologies in education (the city of Kirov);

- reports and speeches at scientific conferences and seminars of various levels, including international ones, publications in collections of scientific articles and scientific-methodical periodicals.

Research stages

The research is conducted in three stages.

In the first stage, the state of the studied problem in the theory and practice of school students training in project activity in the basic and additional mathematical education realized at the basic school was identified. Studying and analysis of psychology-pedagogical and methodical literature on the research problem (both on mathematics and other school disciplines), observation and analysis of mathematics teachers' experience to research possible ways to implement project activity of an inter-subject orientation and probable organizational forms of such activity for effective and continuous formation of personality owning projective abilities were performed.

In the second stage, methodical approaches to the introduction of project activity within the frames of the summer mathematical camp as well as during academic year were developed. Discussions of their realization were conducted and are being continued in reports at conferences and seminars of various levels; that leads to consecutive improvement of the technique of work on inter-subject projects in teaching mathematics.

The third stage is realized in parallel with the second one; it covers experimental teaching according to the proposed methodical aspects on the basis of lyceum No. 21 of the city of Kirov.

RESULTS

Models of integrated educational technologies creation in the context of inter-subject projects method

The development of learners' informative skills, abilities to independently design knowledge, abilities to orient in extensive information space, to analyze obtained information, abilities to independently make hypotheses, to make solutions (search of the direction and methods of the solution), development of critical thinking, ability to conduct research and creative activity make the cornerstone of the project method (Romanovskaya, 2006). At the developing, creation and maintaining of the project, the teacher is not the carrier of ready knowledge but the organizer of students' activity; the teacher does not give a solution but directs an independent search.

Famous teachers Kamensky, Ushinsky and others emphasized a specific importance of inter-subject interrelation for the reflection of a complete picture of the nature in representations of school students for the creation of a structured system of knowledge and correct world outlook; they noted the necessity of generalized system knowledge and completeness of informative process (Alad'yina et al., 2006).

Nevertheless, Selevko (2006) writes in the chapter "Pedagogical technologies on the basis of didactic improvement" in "Encyclopedia of educational technologies" that traditional contents of school education (especially of natural-science) is fragmented and is far from ideas of synergetics which "would allow to illustrate most fully the unity of all existence, to construct a uniform procedural model of the world... in which all – lifeless and life nature and creativity of the human, society and culture – is interconnected and subordinated to uniform universal laws".

Mathematical and natural-science disciplines like no any others demand integration in the course of training as they are aimed to form holistic ideas of the surrounding material world, about links between objects on the basis of leading ideas and concepts (Lyamin, 2007).

Sergeyev (2006) in the book "How to organize school students' project-based activity" divides all school subjects into two types. He writes: "The leading role in the logic of educational process creation on the objects that form the system of special and all-educational knowledge and abilities of school students is assigned to training content. Systematic creation of the training program – a condition for high quality knowledge "at the exit" – dictates rigid selection of teaching forms and methods. In ordinary consciousness they are "serious" subjects: geography, biology, chemistry, physics and mathematics. At lessons of these subjects the method of projects has rather a low efficiency; it was proved by both world and Russian practice" (Sergeyev, 2006). According to the author, realization of project-based activity in these disciplines is best of all performed in the form of inter-subject projects. When it comes to the second type of disciplines, Sergeyev (2006) writes: "Teaching subjects focused on the formation of competencies (information, communicative, etc.) does not only allow but

requires the introduction of project-based method both in school and extra-curricular activities of school students". He refers informatics, ecology, economy and some other humanitarian subjects to such disciplines. Thus, it is obvious that to enhance the efficiency of project-based method in mathematics, it is necessary to integrate it with other school disciplines, in particular with natural-science disciplines.

The vast majority of teachers use inter-subject links of mathematics with other school subjects in case if the studied theme has vivid practical significance or real representation in life. Apparently, other material remains torn off from real practical use of mathematical knowledge, and, therefore, the problem of integration is only designated, but not solved. The synthesis of integrated and project educational technologies might improve the situation.

The creation of integrated educational technologies comprises a sufficient variety of specific solutions – models differing in these or those parameters. In turn, an educational project can act as an integration basis for several subjects.

The method of projects can be one of the ways to implement *the model "Integration of school subjects"* that unites subject systems of different sciences. For example, now school practice includes the study of such subject as "Natural sciences" and also introduction of the elective course "Bases of natural-science knowledge of the world" which combines such disciplines as mathematics, physics, chemistry and biology. Special efficiency is gained due to the development of research projects. This results from the fact that the project becomes a basic platform to process the material so that both natural sciences and bases of natural-science knowledge of the world represent the discipline in which various branches of science are integrated on a uniform logical basis (Selevko, 2006). Besides, within integrated days or weeks devoted to these or those disciplines, it is possible to maintain inter-subject projects which have been prepared in advance.

The temporary model of school subjects' integration – *the model of parallel programs, training courses and subjects' synchronization* – allows to synchronize programs constructed in such a way that themes close in contents or any other signs should be studied on integrated subjects at the same time. The method of projects can serve as the means to consolidate, generalize and deepen school students' knowledge of integrated disciplines (Method of projects, 2003).

The model of *inter-subject links* gives the chance to agree training programs due to the contents of sciences and didactic goals. Project technologies, in this case, can directly be used at mathematics lessons in the form of short-term projects which would be aimed at training school students in methods of research activity, opening new facts, establishing interrelations between disciplines (Selevko, 2006).

Besides, Lyamin (2007) specifies *a lesson – project maintenance* as a specific form of integrative training.

These or those mathematical methods and concepts can be applicable and used in the most different sciences. However, it is impossible to state the opposite. Therefore, when preparing to use project technologies in training mathematics, it is important to specify what role mathematics plays in this very inter-subject project: if it is the source of methods to study another science or an equal component. The second case is most often met when mathematics and physics integrate as physics promoted the development of some important fields of mathematics.

It should be noted that in mathematical education projects of two types specified by the results of disciplines integration when in the course of project development the following takes place:

- merge of means and methods of the basic science with the science participating in integration;
- the course of interacting sciences combination on the basis of one of them (Lyamin, 2007).

It is connected with the fact that mathematics has a number of fundamental differences from natural sciences that interferes with their synthesis and interpenetration (integration unilateralism). However, elements of synthesizing projects (bilateral integration) can be manifested when projects on mathematics and more than two natural-science disciplines (for example, mathematics and biophysics, biochemistry, etc.) are developed.

Guzeev (1995) suggests introducing "weeks of projects" into school practice; this kind of activity has been popular abroad for several decades already. During such actions school students are not limited to frameworks of subjects, and can apply gained knowledge in a generalized form.

Probable subject themes of inter-subject projects on mathematics and other disciplines

Mathematical and natural-science disciplines (first of all, in their inter-subject links) give wide opportunities for effective application of the project method and it, in turn, promotes school students' achievement of subject results. Lessons conducted on the basis of integrative approach develop school students' potential, stimulate knowledge of the surrounding reality, and develop the logic of thinking. That is, such preparation that includes the use of project technologies and inter-subject links (the development of inter-subject abilities and informative universal educational actions (UEA)) provides the competitiveness of an expert in the integrated information space of modern society (Gubanova, 2001). In addition, such type of education work organization requires the ability to work in team that is often comprised of different-type members, the skill to communicate, tolerance (development of communicative UEA), skills of self-organization, the ability to independently set goals and achieve them (development of regulatory UEA) (Novikov, 2008).

The analysis of available literature showed that the themes of projects on mathematics is restricted and, in general, they concerns application-oriented issues (calculations in daily life) or history (origin of this or that mathematical concept, biographic data of famous mathematicians) (Velichko, 2007). It results in narrow understanding of applicability of mathematics in practice. Mathematics remains torn off from scientific reality, its universality is not demonstrated to its full degree. Besides, such projects do not completely realize the potential of project activities as they come down to retelling or adaptation of some known material. It is worth noting that despite all shortcomings that such projects have there is also a positive impact if school students are offered to arrange the results of their work creatively, i.e. to implement the transition to humanitarian oriented projects. It can be especially interesting for learners in the 5-6th grades as it will diversify educational activities. For high school students, having a low level of motivation in studying mathematics, such projects can become an incentive to more serious studies. However, the inter-subject project has more opportunities to develop research abilities as the work in this case is aimed at forming representations of own research, uniqueness of the activity product and abilities to provide, present and maintain own results. Insufficiently developed mathematical apparatus in school students of the 5-6th grades greatly limits the application of inter-subject projects for this age category. That is why humanitarian oriented inter-subject projects on mathematics become most successful. Mathematical fairy tales, poems written by children, compositions, and other creative works subsequently included into kinds of collections can make the product of such activity. Creation of expositions, for example, related to the history of calculation, can become an interesting project (children select exhibits, create them on their own, arrange the stands). Another example of the project is the creation of thematic brochures. For instance, our students created a study guide for sixth-graders containing information on plants of Kirov region included in the Red Book. The task to create images according to the points on the coordinate plane made its mathematical contents. Thus, the inter-subject project on mathematics and biology becomes not only subject but socially oriented as well. It in turn stirs school students' interest in the subject, mathematical knowledge is promoted and motivation to study is increased (The concept of the development of mathematical education in the Russian Federation, 2013).

Projects of higher level of integration can already be realized upon transition to the 7th grade when physics appears in the curriculum.

Physics at secondary school is the key subject where various applications of mathematics are implemented (Homutsky, 1981). "At the same time, – a famous physicist-methodologist A. A. Pinsky writes in the article "A mathematical model in the system of inter-subject links", – physics provides mathematics with almost unlimited training material the analysis of which requires versatile application of mathematical methods (Inter-subject links of natural and mathematical disciplines, 1980). Therefore, it is expedient to transform content links of physics and mathematics into inter-subject links realized in training methods at lessons". **Table 1** presents some project themes integrating physics and mathematics.

Table 1. Inter-subject projects on mathematics and physics

Name, grade	Questions on mathematics	Questions on physics	Possible product
"Measurement of physical quantities. Measuring devices" (9-10th grades)	Mathematical methods of formula derivation	Physical quantities and ways of their calculations	Portfolio
Ways to calculate body volume" (11th grade)	Rotation body volume	Calculation of body volume using physical methods	Development of own calculation methods of body volume
The proof of mathematical theorems with the help of physical concepts	Mathematical theorems	Physical concepts	Proof of theorems and their presentation
Mathematical modeling in physics	Mathematical modeling	Bubble model of a crystal, model of a solid body, etc.	Creation of a model and its presentation
"Vector in mathematics and physics" (10-11th grades)	Vector	Vector values	Wall newspaper, portfolio, etc.
"Complex numbers in physics" (9-10th grades)	Complex numbers	Problems of theories of heat, light, etc.	Wall newspaper, portfolio, etc.
"Symmetry in physics" (9-10th grades)	Symmetry	Symmetry in physics, the solution of physical tasks	Portfolio, system of hypotheses, solution of tasks etc.
Geometry in physics (the 10th grade)	Solution of geometrical tasks	Tooth gearing, angular reflectors, etc.	Creation of a model and its presentation
Conic sections in physics and their mathematical properties" (10th grade)	Conic sections	Technical means on the basis of conic sections	Project of the technical tool
"Physical tasks for optimization" (the 10th grade)	Differential calculus elements	Physical tasks	Problem solution
Functions in physics	Functions	Alignment processes, cable of equal resistance and others.	Processing of practical results
Resonance	Trigonometrical functions, differential calculus	Resonance phenomenon	Search of resonance application in equipment and life
"Travellings in time and their mathematical description" (the 11th grade)	Symmetry	Theory of relativity	The system of hypotheses, portfolio, wall newspaper
"Mathematical fundamentals of wave optics" (11th grade)	Integral and differential calculus	Phenomena of wave optics	Search of application spheres of phenomena
"Irreversibility of thermal phenomena and statistics" (11th grade)	Statistics	Thermal phenomena	Statistical data processing

Wide application of mathematical methods has defined the emergence of mathematical chemistry. Tikhomirova (2007) writes: "Interaction of chemistry and mathematics can be considered as a unilateral process. Chemistry practically did not promote the development of new spheres in mathematics, and borrowed some sections of mathematical science developed earlier". For this reason it is impossible to speak about the application of chemistry in mathematics. Therefore, available integration projects contain material about chemistry in which, in this way or another, mathematical methods are applied. **Table 2** presents probable subject themes of such inter-subject projects.

Table 2. Inter-subject projects on mathematics and chemistry

Name, grade	Questions on mathematics	Questions in chemistry	Possible product
"Mathematical modelling in chemistry", 10-11th grades	Mathematical modelling	Chemical phenomena	The structured system of mathematical-chemical models
"The language of chemistry and mathematics", 9th grade	Symbolical designations of mathematics	Symbolical designations of chemistry	Portfolio
"Functions in chemistry", 10th grade	Functions	Chemical phenomena	Processing of practical results
"Differential equations in chemistry", 11th grade	Differential equations	Chemical processes	Solution of differential equations
"Graphs in chemistry", 9th grade	Graphs	Images of chemical structures	Presentations, the brochure on the use of graphs in chemistry
"Combinatory methods of organic chemistry", 10th grade	Elements of probability theory and statistics	Isomerism	Presentation, portfolio, etc.
"About the symmetry planes of chemical reactions", 9-10th grades	Symmetry	Chemical reactions	Presentation, portfolio, etc.
"Geometrical bodies formed by molecules", 10-11th grades (Larionova & Kharin, 2007)	Geometrical body	Chemical substances	Solution of geometrical tasks and their creative composition
"Chemistry and logic", 9-11th grades	Logical concepts	Isomerism	Structural scheme

It is impossible to speak about contribution of biology as well as chemistry to mathematics. It is more difficult to limit to the framework of general mathematical laws living beings with their self-regulation, ability to adaptation, purposeful activity and difficult schemes of behavior. However mathematical modeling opens huge opportunities in the development of areas which these sciences integrate. At the same time, mathematical methods applied in biology are actually various, but most of them are beyond school curriculum in mathematics and refer to the solution of specific biological problems.

On the other hand, neither experimental studying of difficult biological systems, nor simple observation of their properties changes in the course of activity, nor the creation of models of similar systems is possible without adequate mathematical description. In this regard, integration of biology and mathematics is necessary at school, and one of the means of its realization is project-research activity.

Let us give examples of projects on mathematics and biology (**Table 3**).

Table 3. Inter-subject projects on mathematics and biology

Name, grade	Questions on mathematics	Questions in biology	Possible product
Differential equations in biology, 11th grade	Ordinary differential equations	Problems of definition of biological systems characteristics	Creative design of results
Mathematical processing of experimental data, 10-11th grades	Statistics	Studying of a complex of uniform biological processes and objects	Processing of statistical data
"Probabilistic character of genetics laws", 11th grade	Probability theory elements	Genetics laws	Processing of experimental data
"Laws of organic growth and alignment", 9th grade	Progressions	Intensity of individuals reproduction	Creative design of the results
"Fibonacci's numbers in biology", "Golden ratio in biology", 9-10th grades	Fibonacci's number, golden ratio	Biological dependences	Creative design of the results
"Symmetry in biology", 9-10th grades	Symmetry	Symmetry in biology	System of hypotheses, creative design of results

After consideration possible projects themes on mathematics and physics, mathematics and chemistry, mathematics and biology, let us present examples of projects on mathematics and geography (**Table 4**).

Table 4. Inter-subject projects on mathematics and geography

Name	Questions on mathematics	Questions on geography	Possible product
"Triangulation method in geodesy", "Measurements on the area", 9-10th grades	Geometry	Measurements on the location	Development of mathematical methods for geographical measurements on a specific area
Geodesic tools	Mathematical basis of work	Geodesy	Work on the location, generalization of obtained data
"Conformal projections and cartography", 11th grade	Conformal projections	Cartographic projections	Creative design of results
"Non-Euclidean Geometry in Geography", 10-11th grade	Spherical geometry	Cartography	Creative design of results
"Statistical indicators of resource availability of minerals", 9-10 class	Elements of statistics	Natural resources, economic geography	Mathematical calculations, creative design of results
"Topology in Geography", 11th grade	Topology	Economic geography	Application development of topological surfaces

We have considered projects integrating two disciplines. However, project-research activity can be implemented in three and more subjects. It is explained by interrelation of natural-science disciplines with each other, a close interweaving of some of their areas (Inter-subject links of natural and mathematical disciplines, 1980).

The projecting technique provides school students' solutions of the task demanding considerable time and system approach while working at it. Knowledge of solution technology, ability to see the final product and ways of its creation are of great necessity (Shvartsburd, 1969).

Peculiarities of the technique to apply the method of inter-subject projects in mathematics training

In the preparatory stage, just before the teacher has informed school students about the project theme, it is necessary to pay special attention to differentiation of scientific areas to which the project will be devoted, to analyze a possible volume of mathematical material, to formulate didactic goals and didactic tasks. It is the time when the teacher of mathematics has to consult with teachers of other subjects to get acquainted with requirements of the state standard for integrated disciplines.

Let us note that in this stage it is necessary to define the nature of integration of disciplines in the project – unilateral or bilateral.

Let us consider methodical features of inter-subject project stages on mathematics and natural-science disciplines.

In the first preparation stage, the work with school students starts: they are divided into groups, the theme and goals are formulated (Savenkov, 2004).

Students define a creative title of the project that would reflect both a mathematical component and the material of other natural-science disciplines in it. This will always remind students that they are not working at a mono project but inter-subject one, integrating two or more disciplines. Projects on three and more subjects in which the role of mathematics can strongly vary can be exceptions.

The goal and problems of the inter-subject project have to be determined due to the nature of integration and ratio of volumes of material in mathematics and material of integrated subjects. Here arises the need for the subject teacher to participate as the project implies the achievement of both didactic objectives set by the teacher of mathematics and gaining knowledge in integrated disciplines.

In certain cases mathematics makes only the basis for the choice of these or those research methods and mathematical processing of its results. For example, the project on mathematics and geography devoted to the description of climate of the region can form a basis for studying fundamentals of mathematical statistics; studying Mendel's laws in biology

may initiate the project on the probabilistic nature of genes distribution. Mathematics, in these cases, gives methods to study the phenomena of reality that should be reflected in project purposes.

The next stage is the planning stage that includes:

- definition of information sources;
- definition of ways to collect and analyze information;
- definition of the way to represent results (form of the report, final product);
- establishing of procedures and criteria to evaluate results and process;
- distribution of tasks (duties) between team members.

After school students have defined the way to represent results, it is worth focusing their attention on the correct arrangement of mathematical formulas and calculations. It is also important to list all possible sources of information available to school students (these can be popular scientific books and magazines, electronic resources). A short list of references should be provided which, if necessary, makes the basis for acquaintance with some initial theoretical provisions. However, anyway, the school student has to face the shortage of information and necessity to search it.

Besides literature and Internet resources, students can obtain information from experiments, observations, production of models, etc.

Therewith, a specific feature of inter-subject projects on mathematics and natural-science disciplines is that the description of real world phenomena, processes occurring in it and natural-science concepts should be transferred into mathematical language using more abstract representation of reality. Thus, the investigation stage has to solve some mathematical tasks the answer to which will be transferred back from mathematical into natural-science language at the stage of results and/or conclusions design.

In these two stages, the teacher's role narrows down to advisory help to school students. The teacher has to direct their activity along a methodically necessary course. It is significant to attract subject teachers in this stage. The work on such projects (especially at stages of its development) demands from the math teacher a high level of knowledge in the field of the developed themes, a wide outlook, and the ability to quickly appreciate the situation.

The implementation of educational projects assumes the creation of subjectively new, personally significant product focused on the formation of profound knowledge and meta subject abilities, independence development, increase of interest in the subject (Testov, 2012). Therefore, at presentation of the final product or report, at its maintenance the presence of

subject teachers who could estimate the project from the point of view of their discipline, ask questions and determine drawbacks is desirable.

Approaches and strategy used to assess project-based activity can be actually various. The math teacher, subject teachers and authors of projects themselves have to assess the project. Assessment strategies and criteria should be thought over in advance; scorecards have to be worked out.

Application of project technologies at school is accompanied with serious difficulties and contradictions, and demands teacher's great skills. These difficulties are as follows:

- need to equip special classrooms for work on projects;
- need of teacher's all-round education;
- absence of thorough investigation of the ways of organization and assessment;
- lack of the developed practical action plan.

A large preparatory work makes a serious problem for inter-subject projects implementation. The teacher has to get acquainted with basic theoretical provisions which will be used in the project, to think over possible directions of students' research, questions which can arise during the development, etc.

However, it should be remembered that research and project activity at school has fundamental difference from scientific researches and projects as the main objective of their development at school is to provide school students with their own research skills, abilities to work with information, development of volitional qualities and creative abilities. Besides, inter-subject projects allow to realize the so-called "research training" which A. I. Savenkov (2004) defines as "a special approach to training constructed on the basis of child's natural aspiration to independent studying of the surrounding". The key goal of research training is the formation of school student's readiness and ability to master and reconstruct new ways of activity in any sphere of human culture independently and creatively (Methodical recommendations on the organization of students' project and research activity in educational institutions of Moscow, 2003).

DISCUSSIONS

The following results were obtained in the course of the research: on the basis of the school mathematical camp courses of project activity bases were conducted; as a result school students created a number of inter-subject projects; conditions for further improvement of projective skills are proposed; ideas of project stages, their development and maintenance are elaborated. We have come to the conclusion that project activity training in mathematics is most effective within additional mathematical education and on the basis of inter-subject links. Such approach is substantiated by ample opportunities of our subject as a means to describe reality, as a universal language.

We have described key models of school disciplines integration in the context of project activity realization in them; some probable project themes on mathematics and disciplines of a natural-science cycle are given. A more developed description of the aforementioned and other project topics is presented in the study guide "Inter-subject projects of high school students. Mathematical and natural-science cycles" (Gorev & Luneeva, 2014).

We have come to the conclusion that despite a number of organizational difficulties, the work in this sphere is perspective as it creates both subject and meta subject abilities, realizes basic principles of system-activity approach.

CONCLUSION

The analysis of basic theoretical provisions of projective and integrative educational technologies in the context of subject and meta subject abilities development has shown that their active interpenetration and introduction into practice of work of the teacher give the chance to increase the level of school students' motivation to study mathematics and natural-science disciplines. It happens due to preparation and participation of school students in various student conferences. Inter-subject projects are implemented during "subject weeks" when special days for their maintenance are provided. Systematic work on projects is implemented in the summer school mathematical camp where each participant works on the project on the material of entertaining mathematics (5-6th grades) or on inter-subject integration (7-8th grades). The school museum of entertaining sciences is actively filled with exhibits created by school students in the last two years. Thus, the first-hand experience of inter-subject projects application in additional education allows to draw a conclusion that their harmonious combination with class activity meets the key requirements to the results of the main educational program assimilation of general education formulated in FSES. This is proved by both participation and victories of our students in competitions and olympiads of various levels, and by the fact that students themselves become initiators of project activity, they propose inter-subject project themes and the ways of their implementation.

ACKNOWLEDGEMENT

This work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

REFERENCES

- Alad'yina, M. E., Olomskaya, S. V., Zhdanova, L. N. & Koptseva, T. O. (2006) Integration of various areas of natural-science knowledge at the lessons of mathematics, physics, informatics. Retrieved March 25, 2009, from http://festival.1september.ru/2005_2006/index.php?numb_artic=312534.
- Antonova, E. I. (2007) A technique of school students' project activity at studying geometry in profile classes. PhD Thesis. Vladimir: Moscow State Pedagogical University.

- Barkova, E. Yu. (2006) Preparation of learners for project activity in training of physics at high school. PhD Thesis. Astrakhan: Astrakhan State University.
- Bilgin, I., Karakuyu, Y., & Ay, Y. (2015). The Effects of Project Based Learning on Undergraduate Students' Achievement and Self-Efficacy Beliefs Towards Science Teaching. *EURASIA Journal of Mathematics, Science and Technology Education*, 11(3), 469-477.
- Chechel, I. V. (1998) Method of projects: subjective and objective assessment of results. *Director of school*, 4, 7-12.
- Collings, E. (1926). American School Experience in the Method of Projects. Moscow: New Moscow.
- Dewey, J. (1915) How we think. Moscow: World.
- Fedorova, G. A. (2004) Methodical training of future teachers of informatics for the organization of school students' project activity. PhD Thesis. Omsk: Omsk State Pedagogical University.
- FSES of basic general education. The order of the Ministry of Education and Science of the Russian Federation of 17.12.2010 No. 1897. Retrieved April 15, 2010, from http://minobr.gov-murman.ru/files/Pr_1897.pdf.
- Furner, J. M. & Kumar, D. D. (2007) The Mathematics and Science Integration Argument: A Stand for Teacher Education. *EURASIA Journal of Mathematics, Science and Technology Education*, 3(3), 185-189.
- Gavrilova, M. A. (2006) Method of projects as the basis of research training organization. *Integration of education*, 2, 165-167.
- Gelfman, E. G. & Podstrigich, A. G. (2006) The educational project as a way of monitoring school students' intellectual abilities at lessons of mathematics. *The Bulletin of Tomsk State Pedagogical University*, 3, 57-60.
- Gelfman, E. G. (2004) Methodical bases of educational texts designing on mathematics for secondary school students. Tomsk: Tomsk State Pedagogical University.
- Gorev, P. M. & Luneeva, O. L. (2014) Inter-subject projects of high school students. Mathematical and natural-science cycles. Kirov: Publishing house MTsMTO.
- Gubanova, A. A. (2001) Realization of inter-subject links of informatics and mathematics for the formation of school students' holistic outlook. Retrieved September 9, 2013, from <http://www.ito.su/2001/ito/I/1/I-1-19.html>.
- Guzeev, V. (1995) "Method of projects" as a special case of integrated training technology. *Director of School*, 4, 39-47.
- Homutsky, V. D. (1981) Inter-subject links in teaching fundamentals of physics and mathematics at school. Chelyabinsk: ChSPI publishing house.
- Inter-subject links of natural and mathematical disciplines (1980): study guide for teachers: collection of articles. Ed. V. N. Fedorova. Moscow: Education.
- Khutorskoy, A. V. (2012) Meta subject content of education from the perspective of human congruity approach. *Bulletin of the Institute of education of the human*, 1. <https://eidos-institute.ru/journal/2012/100/Eidos-Vestnik2012-115-Khutorskoy.pdf>.
- Kilpatrick, V. (1925) Method of Projects. Application of a goal set in the pedagogical process. Leningrad: Brockgauz-Efron.
- Kim, M. K. & Cho, M. K. (2015). Design and Implementation of Integrated Instruction of Mathematics and Science in Korea. *EURASIA Journal of Mathematics, Science and Technology Education*, 11(1), 3-15.

- Kochetkova, O. A. (2011) Training of students of mathematical specialties at teacher training universities for the organization of school students' project activity in educational institutions. Penza: State Pedagogical University named after V. G. Belinsky.
- Laperdina, M. G. (2007) Historical and pedagogical aspect of realization of methods of projects. *Siberian pedagogical Journal*, 3, 171-183.
- Larionova, O. G. & Kharin, N. P. (2007) Organization of school students' project activity in studying geometry. *Mathematics at school*, 8, 8-10.
- Lomakina, O. E. (2003) Projecting in education: necessity and reality. *School technologies*, 4, 86-93.
- Lyamin, A. N. (2007) Integrative training in chemistry at modern school. Kirov: KIPK and PRO.
- Method of educational projects in natural-science education (2006) Ed. V. S. Rokhlov. Moscow: MIOO.
- Method of projects (2003). Retrieved April 9, 2009, from http://muk21-konkovo.narod.ru/UPK-WEB/proj_2loci1103.htm.
- Methodical recommendations on the organization of students' project and research activity in educational institutions of Moscow (2003). Retrieved March 15, 2010, from <http://www.educom.ru/ru/documents/archive/advice.php>.
- Monakhov, V. M. (2009) To the question of the use of indistinct modeling methodology at informatization of pedagogical objects. *XVII International conference "Mathematics. Education"* (pp. 46-49). Cheboksary.
- Nikolina, V. V. (2002) Method of projects in geographical education. *Geography at school*, 6, 37-43.
- Novikov, A. M. (2008) Post-industrial education. Moscow: Publ. house "Egves".
- Novikova, T. A. (2000) Project technologies at lessons and in extracurricular activities. *National education*, 7, 151-157.
- Pakhomova, N. Yu. (2004) Project training – what is it? *Methodist*, 1, 42.
- Pardhan, H., & Mohammad, R. F. (2005). Teaching Science and Mathematics for Conceptual Understanding? A Rising Issue. *EURASIA Journal of Mathematics, Science and Technology Education*, 1(1), 1-20.
- Polat, E. S. (1999) New pedagogical and information technologies in the education system. Moscow: Academy.
- Polat, E. S., Bukharkina, M. Yu., Moiseyeva, M. V. & Petrov, A. E. (2008) New pedagogical and information technologies in education system. Moscow: AKADEMA.
- Romanovskaya, M. B. (2006) Method of projects in educational process: study guide. Moscow: Pedagogical search.
- Savenkov, A. I. (2004) Research training and projecting in modern education. Retrieved April 9, 2009, from http://www.researcher.ru/methodics/teor/a_1xitfn.html.
- Selevko, G. K. (2006) Encyclopedia of educational technologies: in 2 v. Moscow: SRI of school technologies. V. 1.
- Sergeyev, I. S. (2006) How to organize school students' project-based activity. Moscow: ARKTI.
- Shahali, E. H. M., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2017). STEM Learning through Engineering Design: Impact on Middle Secondary Students' Interest towards STEM. *EURASIA Journal of Mathematics, Science and Technology Education*, 13(5), 1189-1211.
- Shvartsburd, S. I. (1969) Mathematics and natural sciences. Problems of the school specialized in mathematics. Moscow: Education.
- Slobodchikov, V. I. (1996) Bases of projecting of developing training. Petrozavodsk.

- Testov, V. A. (2012) Updating of training content in mathematics: historical and methodological aspects. Vologda: VGPU.
- The concept of mathematical education development in the Russian Federation (2013, Desember 27) *The Russian newspaper*. Retrieved June 10, 2015, from <http://www.rg.ru/2013/12/27/matematika-site-dok.html>.
- Tikhomirova, F. A. (2007) Mathematics and natural sciences. On the problem of mathematical chemistry. Retrieved April 9, 2009, from http://www.philosoph.onu.edu.ua/elb/articles/tihomirova/math_chem.htm.
- Velichko, M. V. (2007) Mathematics. 9-11 grades: school students' project activity. Volgograd: Uchitel (Teacher).
- Vinokurova, N. & Episeeva, N. (1999) One of the methods of integrative approach implementation in training. *Mathematics*, 36, 2-3.
- Zadorozhnaya, O. V. (2016) Bases of project activity at lessons of mathematical analysis. Scientific notes. *Online journal of Kursk State University*, 3. <http://cyberleninka.ru/article/n/osnovy-proektnoy-deyatelnosti-na-zanyatiyah-po-matematicheskomu-analizu>.

<http://iserjournals.com/journals/eurasia>