МАТЕМАТИКА И МАТЕМАТИЧЕСКО ОБРАЗОВАНИЕ, 2015
MATHEMATICS AND EDUCATION IN MATHEMATICS, 2015
Proceedings of the Forty Fourth Spring Conference
of the Union of Bulgarian Mathematicians
SOK "Kamchia", April 2–6, 2015

ORGANIZATION OF SCHOOLCHILDREN'S RESEARCH WORK IN THE AREA OF MATHEMATICS APPLICATIONS WITHIN THE "SCHOOL–UNIVERSITY" SYSTEM*

Larisa Forkunova

The transition to the competency approach in the design of the goals of education determines that a modern school should form the core competencies, among which, according to many experts, is the research competence. Solution to the problem of formation of research competence is carried out by two (either alone or interconnected) areas: 1) organization of students research work carried out during the learning process, 2) organization of students research work in the framework of extracurricular activities. The article describes the methodological features of the organization of the students research work in the second direction: the formation of research competence of students in the framework of extracurricular activities. The submitted technique has been tested in the framework of the PhD thesis of the author, and has proven its effectiveness.

1. Introduction. The feature of schoolchildren's research in the area of mathematics applications is their orientation to solving problems that arise outside the scope of mathematics but can be solved by mathematical means. The purpose of schoolchildren's research work in this area is not only solving the research problem, but also systematic and consequential development of schoolchildren's research competence.

Problems of school research in the area of mathematics applications can be the problems that have arisen in the process of studying similar subjects or in the extracurricular communication, methodological problems of mathematics teachers, scientific problems that university lecturers are working at.

The content of the school-university interaction must be determined: 1) by the tasks of different steps of schoolchildren's research work in the area of mathematical modeling, and 2) by the tasks of forming research competence in the process of taking these steps. The latter made it possible to introduce the notion of an "elementary cycle" of forming schoolchildren's research competence in the sphere of mathematics applications through the medium of schoolchildren's research work. This notion can be understood as a minimum element of the process of forming research competence through the medium of schoolchildren's research work in the sphere of mathematics application. This element is supposed to be significant in terms of forming research competence as an integral system of interconnected personal qualities (Table 1).

*Key words: mathematical education, extracurricular activities, students' research work, mathematics applications, school-university interaction.

Table 1. An elementary cycle of forming schoolchildren's research competence in the area of mathematics applications through the medium of schoolchildren's research work

Choosing a trend (topic) of the research	Formulating the research design	Implementation of the research design			Evaluation of the research results			
Building a model			Intramodel research			Interpretation and evaluation of the results		
Content-related statement of the task of the model research (building a conceptual model and elaboration of a technical task)	Conceptual statement of the task	Conversion of the conceptual task into the language of mathematics (formal statement of the task)	Choosing the decisive model (elaboration of the technical means of the intramodel research if possible and necessary)	Examination of the decisive model (approbation of the technical means)	Obtaining the results of the intramodel research	Interpretation of the obtained results	Scientific explanation of the results	Review of the results for compliance with the technical task	Evaluation of the prospects of the use and development of the research results
The stage of the acquisition of the research competence constituents that are connected with the "problem originator" competence			The stage of the acquisition of the research competence constituents that are connected with the "mathematician" and "programmer" competence			The stage of the acquisition of the research competence constituents that are connected with the "expert" competence			

2. The technique of actualization of the elements of research competence which are formed in the course of study of school mathematics. The school course of mathematics gives schoolchildren an opportunity of acquiring elements of research competence that are connected with the formal task definition, choosing the decisive model, obtaining the results of the intramodel research, interpretation of the obtained results.

The acquired elements find their application in schoolchildren's research work due to the usage of Methodical scheme 1 (it is illustrated by Example 1).

Scheme 1. Actualization of the research competence elements acquired in the process of studying mathematics and their transfer into the sphere of schoolchildren's research work:

1) actualization of an academic situation that a transferred competence element (component) is connected with in the pupil's experience;

2) reflexive analysis of the pupil's activity in the given academic situation with an eye to singling out that competence element (component) and its abstracting from the peculiarities of the situation;

3) involvement of pupils into the activity of comparing the academic situation with the research task in order to find possibilities for transferring the competence element (component) in question and its further specification in new conditions.

Example 1. Research on the topic "Development of an empirical correlation making

it possible to predict the risk of oncological diseases in the territory of the Arkhangelsk region based on the analysis of the main risk factors" (Form 11).

Table 2 presents a methodical scheme of actualizing activities on obtaining an analytic formula setting an exponential function, abstracting from its content basis and transferring it into schoolchildren's research work conditions with the purpose of developing a hypothesis about the formula that sets a correlation between the risk factors and the frequency of oncological diseases in the Arkhangelsk region.

Table 2. Example of realization of the scheme of actualizing research competence elements acquired in the process of studying mathematics and their transferring into schoolchildren's research work conditions

Introduction of the notion of an exponential function	**Plan of plotting the empirical dependence**	**Plan of completing the research task**
Presenting data on the growth of a bacterial colony (decay of radioactive matter, growth of a deposit in a savings bank).	1. Plotting a table of dependence.	1. Plotting a table of dependence on the basis of the selected reference statistical data.
Plotting dot diagrams of correlations (scatter diagrams) on the basis of the given data.	2. Proving the existence of the determined connection of values.	2. Plotting scatter diagrams (pupil); conducting a correlation analysis (research supervisor).
Pointing out the following correlation as a common characteristic feature of the dependences: $\frac{f(t+T)}{f(t)} = k(T)$	3. Defining characteristic features of the connection of values.	3. Describing basic properties of the empirical dependence as based on the table and scatter diagram.
Using this feature for determining an analytical formula that sets an exponential function: $\frac{f(t+T)}{f(t)} = \frac{m_0 a^{t+T}}{m_0 a^t} = \frac{a^t \cdot a^T}{a^t} = a^T$ $f(0) = 1 \Rightarrow f(T) = a^T$	4. Obtaining an analytical formula that expresses a correlation with the required properties (or close to those required).	4. Developing hypotheses about the analytical formula that sets the dependence, defining the parameter values.

3. The technique of acquiring the elements of research competence that are not formed in the course of study of school mathematics. The school course in mathematics does not enable schoolchildren to form research competence elements that are connected with the content-related and conceptual statement of the task and scientific explanation of the research results as well as examination of the adequacy of the model. Acquisition of these elements takes place due to the usage of Methodical scheme 2 (it is illustrated by Example 2).

Scheme 2. Enriching the schoolchild's research competence with new elements while concerted solving the research tasks:

1) designing methodical means that restrict the degree of the schoolchild's independence in solving the research task with due consideration of the current/potential levels of their research competence;

2) acquainting the schoolchild with the bases of decision-making by giving them tasks for independent work and instructing the schoolchild;

3) acquainting the schoolchild with the criteria of evaluation of success in solving the tasks followed by a concerted critical review of the results of the schoolchild's independent work.

Example 2. Research on the topic "Pick's formula – problems of usage" (Form 5).

In the process of conducting the research, the pupil saw a way to replace a curvilinear figure with a polygon with vertexes in the grid nodes and to find its area according to Pick's formula with the help of a square grid (Figure 1).

Having posed the question of precision in calculating the area of the figure, the research supervisor suggested the pupil checking it with the help of the means available in mathematics.

Having counted first the area of the circle with the help of the square grid with large, medium and small squares and then the area of the ellipse, the pupil got involved into the activity of comparing the obtained data with the data that had been obtained by the research supervisor according to the formulas. As a result the pupil drew the following conclusions: 1) Pick's formula can be used for approximate calculation of the area of any flat figure, since the computational error when using this formula is not significant; 2) the smaller grid cells are, the more precisely one can calculate the area of a curvilinear figure.

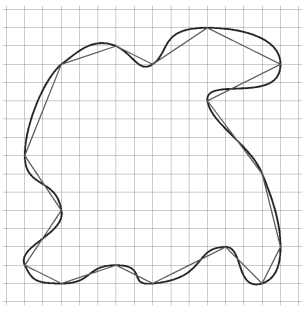

Fig. 1

4. The technique of organizing the interaction "School-University". To organize an educationally significant interaction of a school and a department or institute of mathematics, the following people are involved: the subjects of the interaction in the sphere of schoolchildren's research work on the part of the university can be academic teaching staff whose area of scientific and pedagogical interests lies in the sphere of application of various branches of mathematics and who thus have research work experience in the given sphere; students enrolled in the programme "physico-mathematical education" or training to be mathematics teachers and thus having research work experience in this sphere and simultaneously being the objects of pedagogical influence which is aimed at preparing them for scientific supervision of schoolchildren's research work. On the part of the school, the subjects of such an interaction are mathematics teachers, as having pedagogical experience in competence-oriented teaching, and schoolchildren themselves, as subjects of schoolchildren's research work and objects of pedagogical influence aimed at forming their research competence.

Table 3 presents a list of organizational steps of schoolchildren's research work that are realized within the school-university interaction and singles out forms of work providing an educationally significant interaction.

Table 3. Organizational steps and forms of work of school and university aimed at forming schoolchildren's research competence

Steps of schoolchildren's research work		School's forms of work	University's forms of work
I. Identification of the interested pupils		Conducting research lessons; using methods of involving pupils into research activities during the lessons, etc.	Generalization and dissemination of experience in research-oriented teaching among teachers by means of organizing round-table conferences and publishing teachers' articles.
II. Preparation of the pupil	2.1 Bringing the pupil to the point of choosing a trend (topic).	Organization of attending popular science classes. Inviting lecturers to give public lectures in schools. Informing the university's organizer of schoolchildren's research work about pupils' choice.	Teaching popular science classes for schoolchildren (practical work, lecture) through the efforts of lecturers, postgraduate students, students.
	2.2 Entry assessment of research competence	Furnishing information on the pupil's experience in research work.	Holding a meeting with the pupils who have chosen a research topic in order to assess the initial level of their research competence.
III. Conducting the research work	3.1 Distribution of roles	Selection of a research team for the organization of schoolchildren's research work.	
		Preparing the research team members for working with the pupils with due consideration of the initial level of their research competence; holding preparatory meetings and discussions.	
	3.2. Interaction	Holding a kick-off meeting with the pupils. Statement of the research tasks that pupils can complete on their own. Holding consultative meetings, working meetings, "mini-discussions" that pupils take part in. Holding training "scientific" seminars for pupils.	
	3.3. Current assessment of research competence	Making pedagogical observations of the pupil's activities in the process of schoolchildren's research work with an eye to assessing the way elements (components) of their research competence are formed. Discussing the obtained data at pedagogical meetings of the research supervisor with the university's consultant and the organizer of schoolchildren's research work.	
IV. Summing up	4.1. Presentation and evaluation of results	Acquainting the pupils with the requirements to the results of schoolchildren's research work and different forms of their presentation. Giving the pupils the task to prepare a written report and oral reports on the results of their research work for different target audiences (research team members, pupils, contest committee experts, customers). Organizing a preliminary defense of the pupil's work in the research team.	
		Organizing the pupil's participation in the proceedings of a school scientific conference.	Organizing the pupil's participation in the proceedings of a scientific conference of schoolchildren and students, scientific seminars of the department (laboratory). Preparing a review of the work. Organizing the pupil's activities on preparing an article to publish, etc.
	4.2. Final assessment of research competence	-	Conducting a final assessment of the pupil's research competence level.

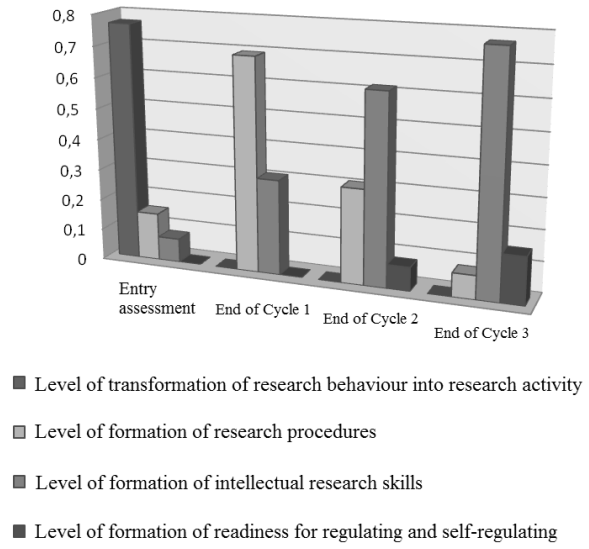

Fig. 2. Dynamics of research competence formation

5. The experiment and its results. The designed method was experimentally tested during three years. Throughout that period pupils had an opportunity of taking one to three elementary cycles of forming their research competence. Schoolchildren's achievements bear testament to the effectiveness of the suggested method. Here are some topics of research works in the sphere of mathematics applications that took medal positions in contests and conferences on different levels (from the school level to the international one): "Pick's formula – problems of usage", "Origami in the hands of a mathematician", "Mystery of the disappearance of area", "Combinatorics around us", "How to assess the correctness of a verse translation with the help of graphs?", "Operational research helps to choose university", "Who is to profit from a sale?", "Respectable pension – is it in our hands?", "Tax mitigation of a small trade enterprise", "Development of an empirical correlation making it possible to predict the risk of oncological diseases in the territory of the Arkhangelsk region based on the analysis of the main risk factor".

Collecting data on the level of schoolchildren's research competence was conducted with the aid of the constant method of experimental work organization. The entry assessment was conducted with the aid of the method of involving pupils into a microresearch by means of giving them diagnostic tasks and providing necessary assistance. Collecting data on the level of schoolchildren's research competence formed within experimental teaching was conducted by means of pedagogical observation.

Figure 2 demonstrates the dynamics of the research competence level of the schoolchildren who have taken three elementary cycles. To substantiate statistical significance of the tendency for increasing of schoolchildren's research competence, Jonkir's S-criterion of tendencies was used. It showed that the hypothesis of the existence of such a tendency

can be accepted with a 95 per cent probability.

The conducted formative experiment, the analysis and statistical processing of its results enable us to draw the following conclusion: an educationally significant interaction between the university staff and students with the application of the designed method makes it possible to form schoolchildren's research competence in the sphere of mathematics applications.

REFERENCES

[1] S. Grozdev. Students – Researchers, Proc. 3rd Int. Conf., August 3–9, 2003, Rousse, 49–52.

[2] S. Grozdev. For High Achievements in Mathematics. The Bulgarian Experience (Theory and Practice). ADE, Sofia, 2007. (ISBN 978-954-92139-1-1), 295 pages.

[3] Т. Сергеева, С. Гроздев. Субектность как методологический принцип информатизации образования, Математика и информатика, т. 55, 3, 2012, 201–206 (ISSN 1310-2230).

Larisa Forkunova
Department of Experimental Mathematics and Informatization of Education
Institute of Mathematics, Information and Space Technologies
Northern (Arctic) Federal University
Arkhangelsk, Russia
e-mail: l.forkunova@narfu.ru

ОРГАНИЗАЦИЯ НА ИЗСЛЕДОВАТЕЛСКАТА РАБОТА НА УЧЕНИЦИТЕ В СФЕРАТА НА ПРИЛОЖЕНИЯТА НА МАТЕМАТИКАТА В СИСТЕМАТА „УЧИЛИЩЕ–УНИВЕРСИТЕТ“

Лариса Форкунова

Преходът към компетентностния подход при разработване на образователните цели предопределя, че едно модерно училище трябва да формира ключови компетенции, между които, според много експерти, е и изследователската компетенция. Решението на проблема за формиране на изследователска компетенция се постига в две (самостоятелни или взаимосвързани) области: 1) организация на изследователската работа на учениците по време на учебния процес; 2) организация на изследователската работа на учениците в рамките на извънкласните дейности. Статията описва методическите характеристики на организацията на изследователската дейност на учениците във второто направление: формирането на изследователска компетенция у учениците в рамките на извънкласни дейности. Предложената техника е тествана в рамките на докторската дисертация на автора и е доказала ефективността си.

Ключови думи: математическо образование, извънкласни дейности, изследователска работа на учениците, математически приложения, взаимодействие училище-университет.