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# ABOUT THE POSSIBILITIES OF IMPLEMENTING THE PRINCIPLE OF CONTINUITY OF MATHEMATICAL TRAINING

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## *Abstract*

Breaking the gap between middle and higher schools is one of the conditions providing the realization of the philosophy of mathematical training continuation and increase of the level of mathematical knowledge. Elective courses allow studying beyond the teaching book and receiving additional knowledge, developing expertise in the solution of practical problems, beginning research work, expanding the outlook, forming a specific level of mathematical training and reaching educational results. Computer and information technologies are of the tremendous potential for solving problems of improved methods and means of education. They ensure an effective interaction of geographically separated learners. The application of the Internet is an innovative method that allows simulating learning in real time, closing the difference in time zones, uniting several remote regions into unified educational environment for interaction of a teacher and students, and remotely disseminating expertise, skills and pedagogical experience. Online elective courses enable improvement of the mathematical skills up to the level required by universities and provide continuation of learning, which is the main principle of continuous education. The concept of continuous education in terms of active role of a subject in the educational process, their development in vertical and horizontal direction, is implicitly demonstrated in the concepts of the classical education model of prominent philosophers and teachers Ya. A. Komenskiy, J.-J. Russo, I.G. Pestalocci, I.F. Herbart and many others. However, it was rapidly developing under the historical conditions of every country into in 1950s under the socio-economic conditions and rate of industry development.



**Keywords:** Elective source, mathematical training, continuation in education, continuous education.

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## 1. Introduction

The development of the concept of continuous education in Russia (USSR) first dates back to 60s and 70s when the capabilities of the scientific and technological revolution, "Law on reinforcement of connection between school and life and further development of the system of public education in USSR" as of December 24, 1958 and task of structural reformation of school lead to the creation of 11-year "general-education polytechnic labor middle school with industrial activities". The main focus in the training of students was made on labor training: in senior classes, the graduates, together with the general education certificate, were receiving the certificates on working qualification (Kolmogorov, 2006). By early 1980s, the understanding of tasks and goals of continuous education was extended: constant augmentation and updating of knowledge for their application in various spheres of life. Approximately starting from 2000s and until now, a continuous education concept became popular which assumes active role of the subject himself in the educational process, his ability to develop in vertical and horizontal directions (Grebenev, Ermolaeva, & Kruglova, 2012). The educational activities were regulated by documents and laws reflecting new reality: RF law "On education" as of July 10, 1992 No. 3266-1 (amended on 12.11.2012) and Federal law "On higher and after-university professional education" as of August 22, 1996 No. 125 (amended on 01.02. 2012), "Concept on modernization of Russian education by 2010" as of February 11, 2002, State RF program "Development of education" for 2013–2020 as of April 15, 2014. During this period, new forms of higher educational institutions originate that allow realizing new educational concepts. New-generation universities open, for example, open technical universities (uniting scientific school of different universities in terms of their directions), joint legal entities (educational platforms "school-college-university-industry"), educational districts (federal universities). The movement of subject's educational process development is possible if strong base knowledge is present. With the collapse of USSR in 1990s, the post-Soviet educational system underwent deep transformation: educational programs of middle general school were reworked (federal, regional and school components are distinguished), private educational sector started developing. An important direction becomes the creation of experimental schools (Talalova, 2005). New school models and educational technologies were tested, there were attempts of transferring the experience of foreign schools, profession-oriented schools and classes are opened (Grishina, 2017; Kharchenko, 2011). The transitions from unified labor polytechnic school to a variety of school types required creating different schoolbooks according to stated goals, learning conditions and teacher's taste. For instance, review (Shevkin, 2002) of teaching books on geometry for 10-11 class in early 2000s included into the list of the Ministry of education (from 2000s until now, the full name of the ministry has changed several times) analyses the teaching books by L.S. Atanasyan, A.D. Aleksandrov, I.F. Sharygin, I.M. Smirnova and V.A. Smirnov that are intended for realization of various original concepts of school geometry course organization, including for different profiles (physics and mathematics, natural science, humanitarian, etc.). The multiprofile character of schools, gymnasiums, lyceums and hence, teaching books, (not only in geometry, but in algebra and elements of analysis) has preserved and keeps developing. Thus, the graduates have different level of base knowledge. After graduating from school, they enroll in higher education institutions (with rare choice of continuing education in the profile chosen in school) based on the results of the Unified State Exam (USE) introduced as an experiment in certain regions in 2001 and as an obligatory procedure everywhere in 2009. These reasons prohibit the realization of the main principle of continuous education, continuation of education.

## 2. Problem Statement

The continuation of education, as the main principle of didactics, is the establishment of a necessary bond and correct relation between the sides of a subject at different stages of its learning (Kolmogorov, 2006; Sukharev & Kochugayev, 2015). In the context of mathematical training continuation principle being realized in middle and higher school, let us consider the continuation as the application of mathematical knowledge and skills acquired by students in middle school for further study of mathematical disciplines in higher school. Let us assume that mathematical training of learners in higher school is a system of theoretical knowledge, practical skills and expertise necessary for studying the disciplines of their specialty and application of mathematical skills for becoming proficient in the regularities of industrial and engineering processes. One of the problems in the realization of the mathematical training continuation principles unstable, and even poor level of knowledge. The results of USE in mathematics and those of admission test (AT) of first-course students of all directions and specialties at Saint Petersburg Mining University (SPMU) have confirmed the existence of the problem. The goal of the AT is to determine the mathematical knowledge level of school graduates to arrange the most effective study process in Mathematics, Theory of Probability and Mathematical Statistics and other disciplines. The content of AT tasks complies with the USE codifier in Mathematics. An AT question paper includes 10 open questions that correspond to the main requirements imposed on the mathematical proficiency of middle school graduates and described by the groups of skills: be able to perform calculations and transformations; be able to solve equations and inequalities; be able to perform operations on functions; be able to operate geometric shapes. The time for the AT is 90 minutes. Interestingly, the requirements to the content of mathematical tasks in the USE and provided in the AT question paper overlap; however, the accuracy of measurement by two or three tasks is very approximate (Kolacheva, Kosheleva, & Pardala, 2017). In SPMU, the AT is performed annually beginning from 2009. Table 01 presents the AT results from 2011 to 2015. Since, the threshold value of USE minimum admission score in mathematics is regularly changing and set by the University, it is given in column “Admission year”.

**Table 01.** Results of admission test in 2011–2015

| **Admission year, minimum admission score** | **Number of tested people** | **Number of people failed to get minimum threshold score** | |
|---|---|---|---|
| | | **People** | **[%]** |
| 2011 – 2012, 39 | 1386 | 371 | 26.7 |
| 2012 – 2013, 40 | 1597 | 403 | 25.3 |
| 2013 – 2014, 43 | 1767 | 454 | 25.7 |
| 2014 – 2015, 43 | 1577 | 394 | 24.9 |
| 2015 – 2016, 45 | 1571 | 385 | 24.5 |

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**Table 02.** Results of admission test in 2011–2015 (as per tasks)

| Admission year | Average score for admission test | | | |
|---|---|---|---|---|
| | task 1-7, 50 points | task 8, 15 points | task 9, 15 points | task 10, 20 points |
| 2011 – 2012 | 33.8 | 8.6 | 6.7 | 1.8 |
| 2012 – 2013 | 35.3 | 8.9 | 6.1 | 1.7 |
| 2013 – 2014 | 34.6 | 9.7 | 6.7 | 1.9 |
| 2014 – 2015 | 35.9 | 10.3 | 7.1 | 2.1 |
| 2015 – 2016 | 35.8 | 10.4 | 6.9 | 1.8 |

Regardless of the number of tested people and threshold value, the number of those failed to get required number of points changes with negligible deviation (%) and remains in a shocking range of 24.5–26.7%. The AT question paper includes 7 basic tasks (1–7 giving 50 points max) and 3 profession-oriented tasks (tasks 8 and 9, 15 points each; task 10, 20 points). The analysis of statistical data (average score) of the AT is given in Table 02.

According to the AT analysis, the majority of first-course students can repeat the solution of basic tasks which they frequently solved in school (tasks 1–7); however, not so many students can solve tasks with altered or new statement (tasks 8–10). The main mistakes were: calculation, misunderstanding of the primary properties of roots and orders of magnitude, logarithms, trigonometric formulas and inability to use them correctly, inability of composing the equation to a word problem, not knowing the methods of solution of equations and their systems, not knowing the method of intervals to solve fractional rational inequalities. The AT allowed revealing the real level of mathematical training and readiness of first-year student to continue studying various sections of mathematics.

To solve the problem in the University, the Center of pre-university and special programs has organized preparatory mathematics courses with terms of 8 months (192 hours) and 5 months (120 hours). However, only school students from Saint Petersburg and its suburbs within the public transport range may attend them. The geography of AT participants covers school graduates almost from all Russian regions. This is explained, in the first place, by the fact that SPMU prepares highly qualified experts in 38 directions of training and specialties for such industries of mineral reserve complex as surveying, extraction, transportation, processing of natural resources, manufacturing of ready products and applied industries (ecology, economics). Thus, the department faced the challenge of finding the formats of additional courses in mathematics for school students from 10th and 11th grades in remote areas that will be aimed at receiving additional knowledge demanded in professional education and will promote the formation of a specific level of mathematical training.

## 3. Research Questions

To solve the problem, elective course titled “Selected sections of mathematics” was elaborated with the tasks organized as lessons. It is purposed for students of 10th and 11th grades and intended for 34 hours. The course is delivered online in Skype video-conferencing software (Arsaliev, 2015). This was conditioned by hardware and software capabilities in the schools of remote areas.

The elective courses are mandatory selected courses and connected with the satisfaction of individual capabilities, inclinations and cognitive interest of learners. Mathematical training in the elective

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course plays important functions: educational, pedagogic, prognostic, aesthetic, practical and integrating. In important scientific and methodological problem connected with the development and realization of elective courses is distinguishing their specific character as an educational form, selection of variating mathematical part, determination of dorms, means and methods of mathematical training (Perevoshchikova, 2015).

Elective course "Selected sections of mathematics" is simultaneously a subject-oriented and increasing proficiency (Grishina, 2017). Course objectives:

1. Create conditions to organize the educational process with involvement of leading specialists, regardless of the geographical position;

2. Systematize and build a complete structural and logical system of knowledge received in the mathematics lessons;

3. Inrease the proficiency of learners in certain sections of the basic course, extend the understanding of learners on the application of this knowledge in practice, applied mathematical issues and adjacent sciences.

Let us focus on the representations of section "Inverse trigonometric functions" aimed at profound knowledge and skills acquired by learners when studying the main trigonometry course. The theory of inverse trigonometric functions is a reflection of the theory of trigonometric functions and contains a large number of interesting problems. The school program does not envisage a big number of hours for exercises on finding values and using properties of arc sine, arc cosine, arc cotangent and arc tangent. It is assumed, that this will be reinforced when solving trigonometric equations. That is why for school student, the theory of these functions is blurry, complex and with a large amount of puzzling formulas that cannot be derived or recalled. On the contrary, the solution of problems with arc functions will facilitate the learning of the theory of trigonometric functions and development of functional mentality and skills in identical transformations. The study of the section takes 6 hours, contains final research task and includes the following topics (Table 03). Noteworthily, the topics taken in a lesson include more detailed review.

**Table 03.** Topic plan of section "Inverse trigonometric functions"

| Topic | Qty of hours | Holding form |
|---|---|---|
| Lesson 1. Definition and properties of inverse function. Determination of arc functions. | 1 | Lecture on review of the properties of inverse trigonometric functions and extension of learners' knowledge about them. |
| Lesson 2 Trigonometric operations over arc functions. | 1 | Practice on proof of identities, transformation by derivation of formulas. |
| Lesson 3. Correlation between arc functions. | 1 | Seminar on derivation of correlations between arc functions |
| Lesson 4 Plotting functions with symbols of inverse trigonometric functions. | 1 | Practice on plotting. |
| Lessons 5 and 6 Solution of equations and inequalities with inverse trigonometric functions. | 2 | Practice on problem solving. |
| Choice of research topic, execution and defense during the week of mathematics in school or on a school-level practical conference. | | Research work |

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## 4. Purpose of the Study

The majority of studied dealing with pre-university mathematical training of school students (Zayniev, 2011; Zayniev, 2015; Ronald & Roberta, 2006) demonstrate that the level of mathematical training, i.e. the quality of mathematical training is constantly decreasing from year to year. The analysis of the publications allows distinguishing the difference between the requirements of universities to a predetermined level of mathematical training of future students and poor basic level of school students' mathematics proficiency. The revealed controversy and necessity of its solution determine the topicality of the work, which aim and goal is to show the potential of additional pre-university mathematical training and formation of fundamental basic knowledge of school students in mathematics, increase of continuation between school and university in the context of continuous education, in particular, the continuation of the mathematical training.

## 5. Research Methods

The study used comparative-historical, historical-logical analysis of facts and main definitions, theoretical analysis of scientific literature, quantitative methods of data analysis, generalization of scientific experience and correlation analysis.

## 6. Findings

Elective course "Selected sections of mathematics" in the form of online-courses for school students of Vorkuta (Komi Republic), Nizhnevartovsk and Surgut (Khanty-Mansi Autonomous Okrug – Yugra), Noyabrsk (Yamalo-Nenets Autonomous Okrug) is being delivered from 2015. The analysis of AT results in 2016–2018 has shown decreased number of first-year students that acquired less points than the admission threshold (equals 45 starting from 2016). Besides, the authors have made a statistical analysis of the correlation between the results of USE, AT, and examination in Mathematics in the first term. When benchmarking the results, we used arranging in four levels (Table 04).

**Table 04.** Results of USE, admission testing and examination

| **Ranging of results** | | **Number of points** | **Results of USE [%]** | **Results of AT [%]** | **Results of examination [%]** |
|---|---|---|---|---|---|
| 2016 | Low | ≤ 44 | 16 | 23 | 14 |
| | Basic | 45-65 | 20 | 36 | 34 |
| | Elevated | 66-79 | 50 | 27 | 38 |
| | High | 80-100 | 14 | 14 | 14 |
| 2017 | Low | ≤ 44 | 16 | 20 | 14 |
| | Basic | 45-65 | 30 | 40 | 30 |
| | Elevated | 66-79 | 44 | 28 | 44 |
| | High | 80-100 | 10 | 12 | 12 |
| 2018 | Low | ≤ 44 | 12 | 18 | 10 |
| | Basic | 45-65 | 31 | 42 | 28 |
| | Elevated | 66-79 | 45 | 26 | 46 |
| | High | 80-100 | 12 | 14 | 16 |

## 7. Conclusion

The results of USE, AT and examination in the first term have shown that the problem of realization of the mathematical training continuation principle still exists. 80% of elective course learners entered SPMU. In the total amount of first-year students it amounted to 7–8%. This affected the emerging positive dynamics in the estimation of the knowledge level in mathematics. Nevertheless, the analysis has demonstrated poor qualitative agreement between the results of USE, AT and examination. Hence, the majority of the school graduates, regardless of the USE results, are not prepared for learning the sections of Mathematics in a university. The study results testify that the problem in realization of the continuation of mathematical training between middle and higher schools is one of crucial ones in modern education. The versatility of USE does not allow assessment the readiness of school students for continued education. The majority of first-year students are in the state of learned helplessness (Grebenev et al., 2012). The study of elective online courses (Parkes, Stein, & Reading, 2015; Zhu, Au, & Yates, 2016) allows school students to assess their potential from the perspective of education, while university departments receive a unique opportunity both to save and disseminate knowledge and pedagogical experience regardless of the geographical position.

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