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Diagnostics of Pupils' Meta-Subject Competence During Lessons on Mathematics in Secondary Schools

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ABSTRACT

The relevance of diagnostic meta-subject competence measures in secondary schools is caused by the fact that the importance of a meta-subject competence formation was officially defined in educational standards, but there are still no qualitative and informative diagnostic tools for this competence development. The purpose of the article is to develop and test a method of pupils' meta-subject competence diagnostics in secondary schools during mathematics lessons. The main method of the research is modeling. This method was the basis for further methodic set development and the pedagogical experiment, which allowed to use the approved methods. During the research we created a complex set of methods for pupils' meta-subject competence diagnostics in secondary schools during mathematics lessons, which allowed to assess levels of pupils' meta-subject knowledge and skills, to identify problematic aspects of their meta-subject competence, to define advantages of the method set and to develop recommendations for its further use. The developed diagnostic method set can be used by teachers of mathematics in secondary schools to assess levels of pupils' meta-subject competence, which helps to draw further plans for individual meta-subject competence development in the system of mathematical education.

KEYWORDS
Meta-subject competence, mathematics, secondary school, diagnostics, meta-subject knowledge meta-subject skills

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Introduction

The relevance of the study

The actual content of the federal state educational standard includes a new requirement: pupils' meta-subject competence results should be available, corrected and evaluated. As R.M. Asadullin (2009) notes, development of a theoretical teaching science regularly brings new trends and needs to the educational process enhancing educational results. Undoubtedly, such a step to modern general

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education innovation is essential, as it involves development and improvement of educational standards, a new level of problems and potential educational results comprehension (Asadullin, 2009).

At the same time, the essence of meta-subject concept of education in the current version of state standards is not just disclosed, but even distorted (Testov, 2014). That is why meta-subject educational results is an unreasonable requirement for the majority of supervisors, teachers, administrators and education textbooks authors, which does not find its implementation in the content of educational resources (Guruzhapov, 2012).

Developing subject specific competences, a pupil also acquires meta-subject competences. A pupil involved in activities dealing with numbers not only learns how to add, multiply but mainly gets acquainted with numbers, signs, letters, which are used in mathematical expressions. They are meta-subject because a pupil can come across them during other lessons and studies acquiring other competences. And this meta-subject aspect is traced in each lesson, no matter what kind of substantive competence a pupil develops (Semenov & Atasyan 2014). Therefore, we can conclude that a subject called 'Mathematics' should be called 'Meta-mathematics', because its results are used in a variety of cognitive and studying activities. Meta-subject competence acquired by a pupil at mathematics lessons in the future is actively used by him in everyday life. Therefore, this feature is of particular importance, and it emphasizes the need to develop meta-subject competences connected with mathematical fundamental educational objects.

Improving the process of pupils' meta-subject competence development, mathematics lessons should be accompanied by fixed meta-subject educational outcomes in the FSES and by teachers' personal competences enhancement (Konovko, 2012). Moreover, there is a strong need to update a methodological definition of a 'meta-subject competences diagnostics' and to search for the specific educational evaluation set of methods which are not fully formed at the moment.

Development of effective and holistic methods for pupils' meta-subject competence diagnostics is very relevant because the Federal State Educational Standard requires teachers not only to form these competences, but also to conduct a diagnostics of them. A.A. Verbitskiy and O.B. Ermakova (2009) stated that 'there is no elaborated diagnostic methodology at the moment; this problem remains unsolved; therefore, this issue should be considered by authors of FSES and by researchers in methodology'.

Materials and Methods

Research Methods

Methods of theoretical analysis were used in the research. Particularly we studied and systematized psychological and educational sources, analyzed school educational standards and curricula, used empirical research methods (observation, testing, surveys), conducted a quantitative and a qualitative analysis of a pedagogical experiment.

The following scientific theories and approaches served as a theoretical and methodological basis of the research:

- the theory and methodology of education: R.M. Asadullin (2009), I.Y. Lerner (1981), A.M. Novikov (2010), V.V. Kraewskiy & A.V. Khutorskoy (2003) and others;

- the basis of psychological and pedagogical theory of learning and training activities: L.S. Vygotskiy (1999), A.N. Leontiev (1956), S.L. Rubinstein (1913) and others;

- the theory of a meta-subject competence, based on fundamental educational objects and processes: A.V. Khutorskoy (2003), O.E. Lebedev (2004) and others.

Experimental research base

The developed diagnostic meta-subject competence model was tested on the basis of municipal educational establishment secondary school №3 of Nadym city. The experiment included 30 pupils of the sixth grade studying in the mentioned school. The specific age of respondents was selected according the complexity of the curriculum and their need to obtain meta-subject competences which can help pupils to perform tasks successfully (therefore these methods are recommended for implementation in teaching of pupils of 5-8 grades in secondary schools).

Stages of the study

The research was carried out in the following steps:

- formation of the experimental group of secondary school pupils;
- diagnostics of pupils' meta-subject knowledge;
- diagnostics of pupils' meta-subject skills;
- summarizing and discussion of the diagnostic procedures results.

During the experiment 6 lessons of mathematics were taught to pupils per week. Taking into account the duration of the program, in general 54 lesson of mathematics were taught (the experimental work lasted for two months). Each lesson of mathematics developed in the framework of meta-mathematics, characterized by the presence of specially designed meta-tasks, developing pupils' meta-subject competence. The choice of basic educational framework for the topics covered in the mathematics lessons in the 6th grade was based on the correspondence of fundamental educational bases to mathematical issues. It allowed to develop meta-tasks which are relevant to studying topics and do not distract pupils' attention from the subject specific competences.

Studying a certain topic and performing tasks presented in textbooks during each lesson of mathematics we also used meta-tasks from the meta-subject competence development program. 8 lessons of meta-mathematics were included in studies of each fundamental educational bases. Each of the meta-subject lessons included 2-3 meta-tasks presented in the program. This implementation allowed to develop pupils' meta-subject competence without deviation from the educational program, and this is the main advantage of the developed approach.

Results

Essence and criteria set for meta-subject competence diagnostics

Two diagnostic approaches – knowledge-oriented and skills-oriented – were combined in the diagnostic procedure meta-subject competence program developed by the author. 'Knowledge' means a level of pupil's acquired material about meta-objects; 'skills' characterize presence and degree of cognitive skills

development. Diagnostics should check both pupils' meta-subject knowledge and skills integrally.

Diagnostics is performed through testing. Designed test contains 28 questions. Questions 1-18 are dedicated to fundamental educational bases, and the other ones are directed to assess meta-subject features of mathematical units. In addition, each test question is related with a specific meta-subject area, and such areas as 'Figures', 'Numbers', 'Signs', 'Symbols', 'Tasks', 'Sets' are clearly distinguished. Meta-subject features of mathematical units mean assessment of knowledge used in such subjects as the Russian language, Literature, Geography, Physical Education, etc. The following table shows the test structure and describes the content of each issue.

During the process of diagnostic methods model development of meta-subject knowledge assessment special attention was paid to the creation of a criteria-based assessment system. Considering meatsubject features we cannot give right or wrong answers to the questions due to the lack of a standard meta-subject competence evaluation system. Moreover, the same meta-objects and even entire meta-sphere may be perceived by pupils differently due to their subjective features. As a result, it was decided to choose a criterion for pupil's meta-subject knowledge evaluation which characterizes a pupil's answer, which contains two cognitive aspects: 1) At what degree has a pupil understood the subject matter? 2) Is a pupil's answer complete enough? Has a pupil expressed the idea fairly meaningful?

Here are the examples of some questions:

- Are mathematical tasks solutions useful in everyday life? How can they be applied in real life? Have you ever been in situations presented in the mathematical textbooks as tasks?

- Why is a sign important to us? How do signs help us in education? In everyday life?

- In which areas of education (school education) are numbers used? List subjects dealing with numbers and briefly explain how numbers are used there (for example, in mathematics we use numbers to solve a task)?

Assessment of pupil's answers content given for a particular question is conducted with the help of scaling, which suggests the following criteria:

- No answer (lack of understanding of the issue, unwillingness to answer, lack of knowledge);

- Lack of meaningfulness in an answer (an answer is very short, consists of one or several phrases and does not contain elements of reasoning);

- Average meaningful answer (reasoning about the issue is partly presented, not all the key aspects of the issue are disclosed, a pupil presented ideas not fully);

- High meaningful answer (a pupil describes thoughts on the issue in a detailed way, talks about the results in several versions, admits the correctness / incorrectness of a particular version).

Even if a pupil's answer is not absolutely correct but meaningful, we can consider it as the best answer, since in accordance with the requirements of the educational results, students are not required to know all the fundamental educational basics; it is important that a pupil shows eagerness to their understanding, expresses the presence of figurative understanding of a meta--object.

The second part of the diagnostics is a series of tasks, accompanied by one question - how to use the knowledge gained at mathematical or other lessons? Pupils get a list of subject disciplines; next to each subject they write down their own understanding of how mathematical knowledge can be applied in each of the subjects. Therefore, this stage of the diagnostics can be considered as a supplement to the first stage: at the first stage we diagnose how fully a pupil understands the essence of the fundamental educational bases; at the second stage we check if a pupil understands how these bases can be applied in other areas of mental activity and at mathematics lessons.

Evaluation of the answers at the second stage of the diagnostics was also carried out according to the criteria of meaningfulness, even if answers were not correct. If a pupil used mathematical objects and operations in other subject areas and everyday situations (or was aware that some knowledge can be applied), this meant that a pupil understood their meta-subject essence.

The second step of diagnostics was to estimate meta-subject skills. Modern scientific approaches to assessing meta-subject skills including range of student characteristics (philosophical, communicative, cognitive, creative, methodological skills) reveals the need for an individual approach, which can provide with an individual approach to meta--subject skills evaluation. Application of the test methods, which have a long history in educational psychology, do not seem appropriate because then a pupil's meta-competences is evaluated, as well as meta-skills, meta-qualities which can lack attention in traditional diagnostic methodology.

Issues on implementation of diagnostic meta-subject competence model in education

The developed model for pupils' meta-subject skills evaluation involves open observation of a pupil by a teacher and a school psychologist (if necessary) to define a certain level of meta-skills. Pupil's skills should be evaluated from a personal point of view, without comparison with other pupils and generalizing, because in most cases a low level of meta-skills does not mean their total absence.

Thus, after two stages of meta-subject competence diagnostics (the first stage – knowledge assessment, the second stage – skills evaluation), a teacher receives two actual assessment marks; the first one identifies a level of a pupils' meta-subject knowledge, the second mark reflects a meta-subject skills level.

The teacher of mathematics tested and observed students, obtained final results reflecting a level of competence meta-subject competence.

The established levels of the pupils' meta-subject competence

The established levels of the pupils' meta-subject competence are the following:

P1) understanding of fundamental educational bases as the specific objects for meta-subject knowledge implementation;

P2) fundamental knowledge in mathematics as a subject area;

P3) awareness of basic educational foundations implementation in other subject areas;

P4) awareness of basic educational foundations implementation in everyday life;

P5) awareness of fundamental education meaning and role in the context of cognition process.

Finally, it was found out that almost half of the pupils diagnosed for meta-subject competence had an average level of knowledge (49%). Pupils with this level had an average level of the fundamental educational foundations awareness of such categories as 'Numbers', 'Figures', 'Signs', 'Symbols', 'Set', 'Tasks'. These pupils understood the tasks of the test, but their answers cannot be considered sufficiently informative.

Other categories of pupils were also identified: 18% of pupils showed a high level of meta-subject knowledge, 14% showed a low level and 10% of pupils had a very low meta-subject knowledge level. The best results were established in 9% of cases where pupils gave meaningful answers to the questions and demonstrated their own knowledge about meta-subject objects. This category of pupils were aware of the origin of certain meta-objects, could describe their features, their possible application in life and in other disciplines (see. Figure 1).

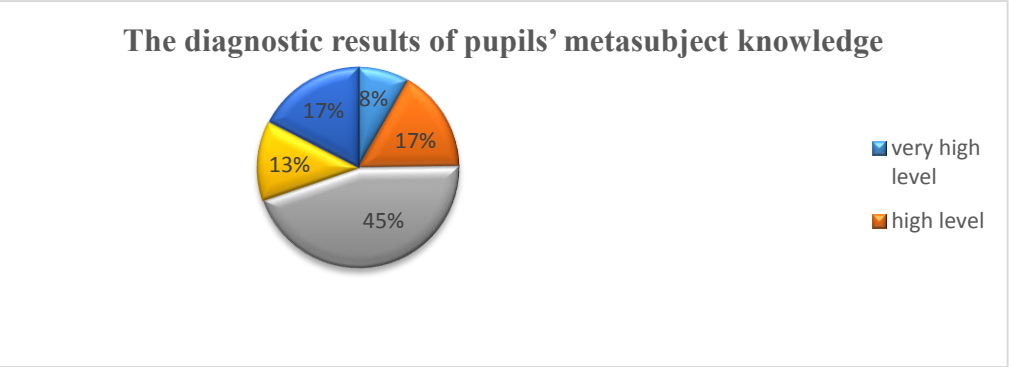

Figure 1. The diagnostic results of pupils' meta-subject knowledge

Overall, the diagnostic results indicate a fairly satisfactory level of meta-subject knowledge. 24% of the pupils failed tests, that is one-fifth of the class, while the rest of the pupils showed relatively positive results.

Also, we paid attention to the results of the diagnostic meta-subject skills, which were assessed according to the following criteria:

- presence of cognitive abilities and qualities;
- presence of creative abilities and qualities;
- presence of methodological skills and qualities;
- presence of communicative abilities and qualities;
- presence of ideological understanding.

The experiment was carried out within 45 days. Finally, it was found that 25% of diagnosed pupils had low meta-subject skills (equal to the low level of meta-subject knowledge), 42% had an average level, and 33% of pupils a high level (see Figure 2).

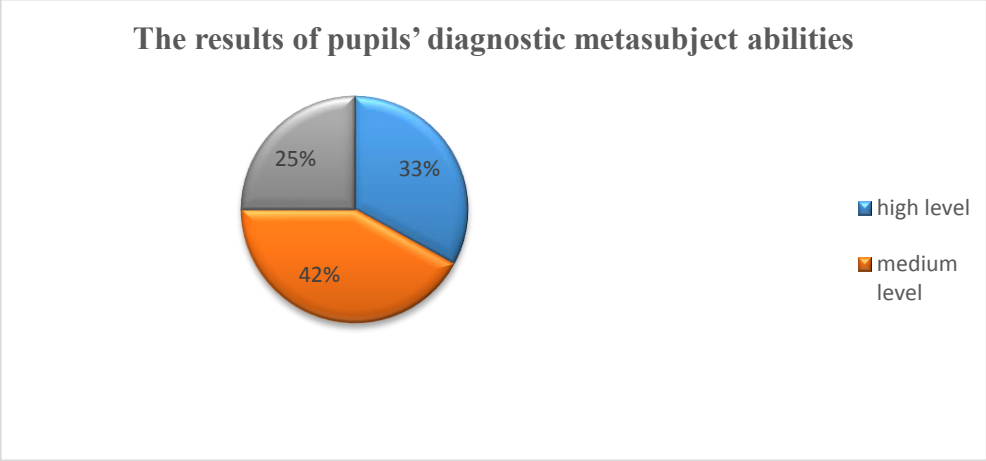

Figure 2. The results of pupils' diagnostic meta-subject abilities

In fact, the present results cause the previous stage results: a fifth of the pupils have not demonstrated meta-subject skills in cognitive activities, and the category of 'laggards' in knowledge by 85% coincides with a similar category concerning skills (the same students).

Specific meta-subject qualities served as a basis for meta-subject skills assessment, and the most frequent of these qualities were cognitive and creative ones. Almost all survey respondents, even those whose total estimation mark is low, demonstrated their cognitive and creative activity. Strong methodological and philosophical qualities were less frequent: pupils could not sufficiently cope with the task, did not know how to set objective targets for the process of learning, did not express ideological activity without showing personal emotional evaluation.

Discussions

Here we consider the diagnostics of a meta-subject competence problem in the scientific literature. V.A. Guruzhapov (2012) explains the term 'meta-subject competence diagnostics' as 'identification of certain meta-subject knowledge results of a pupil, educational foundations acquisition quality, necessary meta-subject knowledge, skills and abilities'.

Analyzing the definition above concerning specific diagnostic meta-subject competence of pupils, we came to the conclusion that such a diagnostics can be carried out in two directions. The first diagnostic direction involves pupil's meta-subject knowledge evaluation, or evaluation of the degree of basic fundamental educational principles acquisition. The second direction is connected with the assessment of pupil's qualities which develop (or formed) on the basis of meta-subject knowledge. In other words, following the second direction of the diagnostics a teacher evaluates results of meta-object cognition.

In addition to different directions of pupils' meta-subject competence diagnostics, there is a problem of determining assessment criteria not connected with a diagnostic direction selected by a teacher. When there is need to assess pupils' meta-subject knowledge, then how can a teacher of a secondary school define the boundaries and limits of such an assessment, which can reveal a pupil's full meta-subject competence? Likewise, if we estimate pupil's meta-subject qualities, at

what degree should they be formed so that diagnostics shows the best meta-subject results?

In contrast to the existing system of subject knowledge and skills evaluation, in which the evaluation results and the level of pupil's competence is estimated according to a set point system, diagnostics and assessment of a meta-subject competence remains unclear, both at the federal (in FSES) and the methodological levels.

In addition different directions of pupils' meta-subject competence diagnostics, there is also a problem of determining the criteria of this assessment not connected with a diagnostic direction selected by a teacher. Many researchers have diverse and distinct points of view on this matter. Some of them believe that 'there is a need to develop a unified meta-subject results evaluation system, including diagnostics of pupil's knowledge and skills' (Maslova, 2013). Other researchers think that 'we should only have a meta-subject knowledge assessment system, while meta-subject qualities should be assessed individually' (Yakushev, 2013).

We agree with the third point of view and suppose that results of diagnostic meta-subject competences of each pupil, regardless of a diagnostic direction, should be evaluated individually. Undoubtedly, the question of competence meta-subject assessment should be considered on a global methodological level and subsequently has to be taken into account and fixed in the Federal State Educational Standard.

Considering a question which direction of the diagnostics can provide the most objective and informative results, A.I. Ritov and E.S. Zozulya (2013) argue that 'it is advisable to evaluate pupils' meta-subject competence considering their meta-subject knowledge and qualities'. We agree with this point of view because, to our mind, combining these two directions of diagnostics a teacher can:

1) assess which categories of fundamental educational bases are fully developed by a pupil and which require further training;

2) assess which qualities were formed due to meta-subjects studies (meta-topics);

3) give a complex and the most informative assessment of a pupil's meta-subject competence.

The developed method of meta-subject competence diagnostics is based on the approach of A.V. Khutorskoy and N.V. Gromyko, who offer to implement so-called 'meta-subjects'. The main link connecting meta-subjects for Khutorskoy are specific fundamental spheres of objects (Numbers, Culture, Attitude to the world), while N.V. Gromyko selects problem areas (Objectives, Signs, Problems, Knowledge). This diagnostic method is intended to assess only those meta-subject competences, which can only be formed mainly during lessons on mathematics in a comprehensive school (Khutorskoy, 2003).

At the same time, complex methods of meta-subject mathematical competence diagnostics in secondary schools are not formed, and therefore the problem of optimal methodological solutions in the study area continues to exist.

The content of the modern educational system has a fundamental core, and the essence of this core is identical regardless of the countries, cultures and nations, where an educational process takes place. But still meta-subject features presented in the domestic standards as universal ways of any activity are not components of the fundamental core of any education content. In other words, a meta-subject component is not evident in the content of the education system including

educational meta-subjects , meta-subject topics, etc. Meanwhile, the results of A.G. Bukhara's researches show that 'meta-subject features need to be reflected not only in activity-related forms, but also in the content of education and in the meta-subjects taught' (Khutorskoy, 2003).

Conclusion

In the research, based on the author's understanding of a meta-subject competence, we proposed to evaluate a meta-subject competence in two directions – according to a level of pupils' meta-subject knowledge and meta-subject skills. Both directions are systematized into a single methodology, consisting of a set of meta-subject competence parameters and criteria which make their assessment possible.

Developed diagnostic methods of meta-subject competence assessment were further implemented, and their results allowed to define a number of methods implementation peculiarities:

- almost all pupils were interested in the implementation of diagnostics methods, showed interest in the issues, but were confused by the lack of specific reference to a certain subject and assessment;

- during diagnostic procedures many pupils asked teachers questions concerning the essence of the issue; it proves that such a diagnostics should be done only in classrooms with a teacher;

- most of the pupils after the test were interested to know correct answers: pupils asked a teacher how they should have answered a particular question; this fact indicates pupils' personal interest and quality of the diagnostic questions.

Thus, we described our developed method of pupils' meta-subject competence diagnostics in a comprehensive school during lessons of mathematics. The method involves pupils' assessment of meta-subject knowledge and skills, their correlation with a certain quality level, individual assessment of pupils' meta-subject skills and obtaining integral parameters of a meta-subject competence. These methods can be used by teachers of mathematics to evaluate a meta-subject competence concentrating on the development of those pupils' competences which, according to the results of diagnostics, were not fully formed.

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No potential conflict of interest was reported by the authors.

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