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DEVELOPING SELF-REGULATION SKILLS OF CHILDREN IN MATHEMATICS LESSONS

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Abstract

The study focuses on developing the self-regulation skills of high school students when learning mathematics. The introduction of distance learning brings an urgent focus on the development of students' self-direction, cognitive activity and motivation during the online lesson. The authors analyse the research in this area and identify a list of methodological techniques for developing this skill. The purpose of the study is to assess the effect of methods aimed at developing self-regulated learning, to make a qualitative analysis of students' knowledge and to develop recommendations for the organization of teachers' activities aimed at developing self-regulation skills. The study involved 264 students from secondary schools in Kokshetau, Republic of Kazakhstan. The authors conducted the experiment among 11th-grade high school students and covered the sections of algebra and geometry. The experiment used active methods to assess their impact on the development of self-regulation skills. Due to the organization of distance learning, the authors applied different types of digital technologies and online learning platforms during the experiment. The online lesson series assesses students' beginning, intermediate and final tests according to predetermined assessment criteria. The results of the study showed an increase in students' learning ability and self-study. At the same time, these results point to isolated issues in the organization of online mathematics teaching and highlight gaps in key aspects of learning. This allows the authors to develop the necessary recommendations for the organization of student learning that contribute to the development of self-regulation skills.

1. Introduction

As we know, developing a scientific outlook and self-regulation skills of students requires identifying features of mathematics' reflection of reality and using them in the teaching and educational process.

There is now sufficient experience and evidence to assist teachers in setting up a methodological system for developing self-regulation skills in the teaching of the basic sciences. We have benefited from studies that examine the psychological and pedagogical basis of self-regulated learning, self-control, self-criticism and goal-setting (Bandura, 1986; Dalinger, 2001; Dinsmore et al., 2008; Kagazbaeva, 1999; Kolyagin, 1977; Shamova, 1979; Tereshin, 1991; Schunk, 1990; Zimmerman, 1989).

According to these researchers, students with advanced self-regulation skills view learning as a systematic and manageable process. Self-regulated learning results when students are active in their learning in terms of metacognition, motivation and behaviour (Bandura, 1986; Dinsmore et al., 2008; Zimmerman, 1989). Such students also show high performance in learning and developed intrinsic motivation (Kagazbaeva, 1999; Schunk, 1990).

The goal of the modern educational process is to develop a motivated individual who is capable of self-education and who applies his or her knowledge in practice. Learning mathematics requires perseverance and mental work. The tasks of high school often require diligence, commitment and rationality in action and thought process. Such qualities are provided by self-regulated learning.

The Covid-19 pandemic has dictated new conditions for the organization of learning in schools, as the shift from a classroom-based form of learning to distance learning has suddenly increased the burden on the student's self-study. Lack of teacher supervision and reduced direct contact with the teacher, require students to have high self-regulation skills and motivated learning. The development of self-regulation skills, therefore, becomes one of the key tasks of the educational process today.

This study looked at methods to promote the self-regulation skills of high school students in mathematics lessons. An analysis of research in this area has identified effective methods for promoting self-regulated learning and testing these methods with different ICT tools.

2. Problem Statement

Distance learning in mathematics, introduced during the Covid-19 period, necessitated a review of the organization of teacher and student learning activities. As the practice of working with high school students has shown, poorly developed self-regulation skills have caused a decrease in concentration during online lessons and have affected students' academic performance. We have also found that some students cannot analyse learning material by themselves, to offer their own versions of the learning material and to draw generalizable conclusions.

We obtained a picture of the state of self-directed learning activities among school students through a questionnaire survey, which aimed to establish the measure of self-regulated work and the need for such organization among school students.

A survey of students in grades 9–11 in schools 1, 3, 4, 5, and 6 of Kokshetau allowed us to identify the ability of schoolchildren to work on their own. The survey involved 264 students.

The results of the survey revealed a 47 % of students indicated distance learning as a convenient form of learning. Students prefer the new learning methods used by teachers, the possibility to review videos from the lesson, the absence of unnecessary noise and distractions, etc. At the same time, 53 % of the students were against distance learning or favoured partial use of distance learning. These students justified their answers by the need for self-directed learning, the constant lack of counselling and feedback from the teacher.

In addition, it was revealed that 71 % of students cannot find a way of solving a simple non-standard problem on their own; 82 % cannot make simple generalizations; 79 % cannot apply knowledge in a new situation.

3. Research Questions

Pedagogical activities should purposefully regulate the process of developing self-regulation and raise the experience of students' self-directed activity to a systemic level. Implementing this function of the learning process requires strengthening the developmental function of learning, including the student in the learning and integrating cognitive, research and subject-specific activities and learning.

According to Osnitsky (2009), working with different age groups of students, along with diagnostics of self-regulation of activity, it is useful and productive to demonstrate and solve typical tasks, emphasizing the need for forming each of the listed functions of activity self-regulation and requiring appropriate skills to ensure the implementation of the function. This further encouraged greater cognitive activity and a greater depth of reflexive analysis of the activity by teachers and students who grasped the patterns of providing conscious self-regulation of activity.

3.1. Components of self-regulation

Osnitsky (2009) identifies the following components of self-regulation in learning:

- goal setting;
- modelling conditions;
- programming actions;
- evaluating results;
- correction.

Also Pintrich (2000) suggests 4 components of self-regulation of learning. His research outlines these stages in the development of self-regulation:

1. Planning and activation;

2. Observation;

3. Management;

4. Reaction and reflection.

We also recommend the working scheme developed by Tereshin (1991) for the development of the attitudinal goal of the lesson. This scheme, based on the methodological analysis of the content of the teaching material, allows to easily identify the components that are most clearly presented in the studied material and to formulate near and far goals based on them.

As we know, a person develops if there is searching and finding the things one seeks. Learning makes sense if there are research and design. Complete knowledge only comes to those who seek it. One can make a mistake, get the wrong result, but only correcting the mistake and going forward, one will gain full knowledge. One who is afraid to make mistakes does not improve. So, it is essential to organize self-directed work and self-searching of students.

3.2. The role of tasks in developing self-regulation skills

Well-chosen and methodologically correct tasks help schoolchildren to absorb the theoretical material, make the mathematics course more interesting, arouse a need for new knowledge and form the ability to acquire it independently.

Thus, in mathematics teaching, the teacher should train students to translate a practical problem into the language of mathematics, to operate with numerical data, to work with calculation tools, tables, measuring instruments, special literature used in production. High computational culture of students is one of the necessary conditions for mathematical culture (Dalinger, 2001; Kolyagin, 1977; Shamova, 1979). Strengthening the connection between school and life is the guiding principle of learning and education in school.

Here is an example. To realize the learning objective of the 11th grade exponentiation function, it is sufficient to inform the students that it is a function of the form $y = a^x$, $a > 0$, $a \neq 1$. However, to achieve the educational goals, we should inform the students about the following: "In the middle of the 18th century, scientists began to study fast-growing and slowly decaying processes, which cannot be described by power functions. Fast-growing processes include yeast fermentation, bacterial proliferation, radioactive decomposition, etc.

These processes include the famous problem of the chess inventor. Here's a demonstration of that. $S_{64} = 2^{64} - 1$ is the number of grains lying on 64 squares of the chessboard. We can see how big this number is: $2^{10} = 1024 \approx 10^3$; $2^{64} = 2^4 \cdot 2^{60} = = 16 \cdot 10^{18} = 1{,}6 \cdot 10^{19}$. If we take a grain with a diameter of 1 mm, the distance from the Earth to the Sun ($\approx 1.5 \cdot 10^{14}$ mm) can be laid out ≈ 100000 times".

Figure 1 showing the graphs of all the functions studied by the students also has an educational effect. We see that the fastest-growing function is the exponential function and the slowest-growing is the logarithmic function.

In addition to the direct impact (the formation of new knowledge), the content of the tasks has an implicit hidden impact on the students. When starting to solve a problem, the student is first familiarized with the wording of the problem, while the solution remains outside the student's field of work. It is therefore important that the content of the task arouses lively interest. It is helpful when the task texts appeal not only to the mind, but also to the emotions of the children. The educational impact of the content of the tasks is not only made by the task, but also unintentionally, by the implication of the material. Assimilating any information involves shaping attitudes towards it. From here, it is clear to see the significance of the content of the task in question.
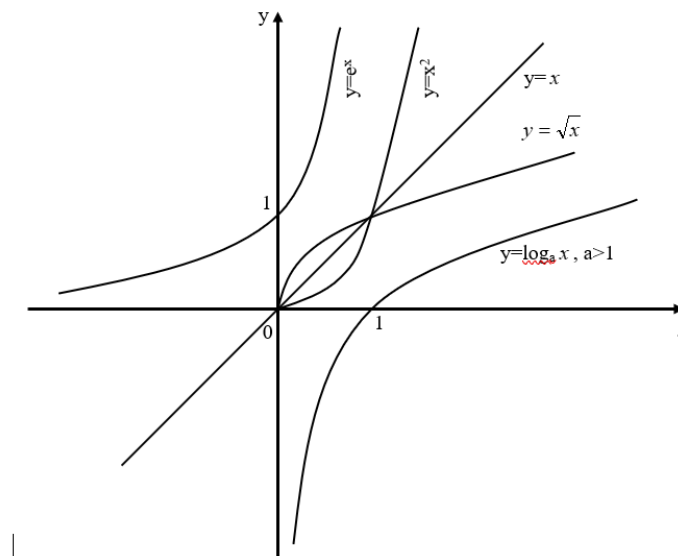
Figure 1. Function graphs

4. Purpose of the Study

Purposes of research include:
- assess the effect of methods aimed at developing self-regulated learning;
- experiment and make a qualitative analysis of students' knowledge;
- develop recommendations on organizing teachers' activities in the development of self-regulation skills.

The Research hypothesis is as follows:
1) without consciously setting up and shaping independent work in the learning process, there is no transition to higher levels of self-regulation of learning and improving learning skills;
2) measure of students' awareness and self-management of learning activities is closely related to the structure and organization of students' learning activities at school.

5. Research Methods

To test the validity of the research hypothesis, according to the self-regulation components highlighted by A.K. Osnitsky and P.R. Pintrich, we selected the following methods to activate students in mathematics lessons.

1. Involvement of students in formulating the purpose and outcome of the lesson.

Targeting is an integral part of the assessment. It helps to set priorities, make decisions and implement things as planned. The clearer the objectives, the more effective and accurate the assessment will be. The students' participation in formulating the aims and outcomes of the lesson fosters a sense of ownership of the process.

We can define the expected results of the lesson in terms of success criteria. For the students, the success criteria are the steps leading them to the lesson objective. This methodology is also based on research by Boekaerts (2005).

2. Planning the progress of the task by formulating task assessment descriptors.

In mathematics teaching, descriptors describe the sequence of actions taken to solve a problem. Usually, the number of descriptors shows the number of steps in solving the problem. When solving the task, there are two possible outcomes: the student performs the action or the student does not act. The action performed incompletely cannot be accepted as a correct answer.

So, it is critical to plan the progress of the task together with the students.

For example, we consider the problem: "A body is thrown vertically upwards with speed V_0=30m/s. In how much time will it be at height H = 40 m?"

We will formulate the descriptors to evaluate the task:

1. Student knows the law of motion of a body thrown vertically upwards.
2. Student expresses the task as a mathematical model.
3. Student applies the method of solving an equation.
4. Student answers the assignment question.

Thus, by planning the task in advance with the students, they will know that they receive 4 points for solving the task correctly.

Solution. The law of motion of a body thrown vertically upwards is expressed by the formula $H=V_0t-\dfrac{gt^2}{2}$. After substituting the values we obtain a quadratic equation $x^2-6x+8=0$, whose roots are 2 and 4. This means that the body will be at the specified height twice: 2s and 4s after the start of the movement.

3. Organizing self-evaluation, self-assessment by students and effective feedback from the teacher.

Based on the requirements of the time, the most productive learning process is collaborative learning, based on interaction, where an important component is forming and developing the ability to self-assess and self-evaluate. Students must take full responsibility for their own learning, as no one else can do it for them. Thus, students should be involved in the learning and assessing of learning. According to Druckman and Swets (1988) provided feedback and peer feedback are just as influential or more influential than teacher criticism in achieving sustained outcomes. However, the learning process is only effective when students have a clear idea of their knowledge and skills at the beginning of the work and the results they will learn after completing the task.

To organize effective feedback, we developed a teacher feedback model, which can be delivered using the MsTeams environment.

The teacher's feedback does not list the student's shortcomings or use words that negatively affect their motivation. Opinions and suggestions are given only on a specific assignment, and there are recommendations for further improvement.

Here is an example of teacher feedback given to a problem meeting the 'good' criterion: "You have mastered the properties of the arithmetic square root well and can use them in solving problems.

However, it is important to avoid mistakes when applying properties and calculations. Please, do the tasks on the worksheet to consolidate your knowledge and check yourself against the ready answers.

6. Findings

For experimental testing, we developed a series of lessons on "Polynomials" and "Polyhedrons" in 11th grades with 52 students.

The lessons followed all the methods chosen to develop students' self-regulation skills. In each lesson, the teacher defined a problematic task or situation which determined the topic of the lesson. After the lesson objectives were presented, the students formulated the assessment criteria to determine their success in mastering the knowledge. The students formulated descriptors for the tasks provided, carried out self-assessment on the prepared answers and self-assessment in pairs or as a group. MsTeams environment served as a tool for organizing online lessons. Group work sessions were facilitated using MsPowerPoint online presentations, Whitebord.chat, etc. The individual work involved worksheets prepared by Liveworksheets.com, individual Whiteboard.fi, etc. For self-regulated consolidation of the topic, students worked on assignments on the Bilimland.kz online portal, BilimMediaGroup. After the introduction and consolidation of each topic, there were check-ups with teacher feedback on the assessment criteria.

During the experiment, students had problems formulating lesson assessment criteria and task assessment descriptors, as these skills require high order mental work, such as analysing the purpose of the lesson, analysing the task condition and constructing an action plan. We have also found that students have problems with reasoning and justifying their own point of view.

During the lessons, we noticed that some students were quicker than others in coping with the tasks. Some students, on the other hand, find it difficult to complete their tasks. For this reason, the students were asked to work in pairs. There are also extra tasks prepared in advance for the strongest students. And slow learners could get advice from the teacher. These changes ensured differentiation in lessons and allowed students to maintain their own pace of work (Fig. 02).

During this learning style, students showed a 93 % completion rate on their homework, which was an indicator of an increase in student motivation.
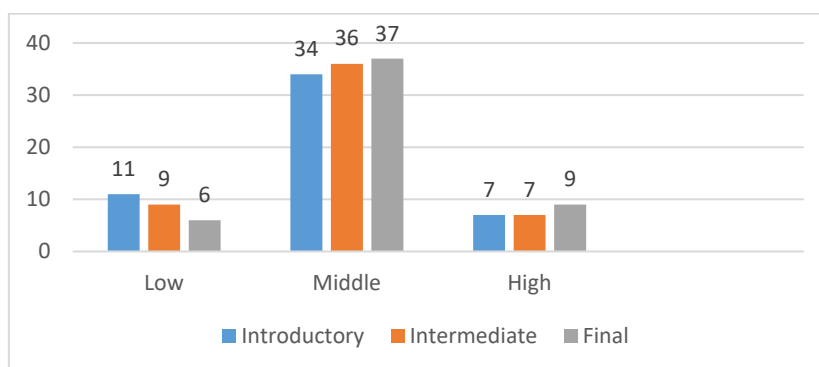

Figure 2. Test results

The results of the three tests show a significant decrease in the number of low-performing students and an increase in the number of medium- and high-performing students.

At the end of the experiment, there was a reflection on the impact of this method on students' learning and motivation. Students commented that the daily monitoring of the learning objective and getting timely feedback from the teacher had a good impact on their subsequent preparation for the lesson, thus improving their performance in mathematics lessons. Parents also noted the effectiveness of this method, and as they took an interest in their children's progress, they had the opportunity to monitor their homework.

7. Conclusion

The experiment revealed the following benefits of using the self-regulation skills method in mathematics teaching:

1. The participation of learners in the process of formulating learning outcomes and assessment descriptors for assignments has influenced the development of learning responsibility and awareness of the activities to be performed.
2. The interaction of students in paired and group work contributed to the development of a collaborative environment and students' communication skills.
3. Participation in self- and peer-assessment facilitated the development of argumentation of one's point of view, based on the assessment descriptors of the assignment.
4. Regular teacher support in the form of feedback motivated students to improve their performance and work on their mistakes.

Based on the findings, we have developed the following recommendations for the development of self-regulation skills to follow in lesson organization:

- use the problem-based learning method to formulate the topic of the lesson, the learning objective of the lesson and the results of the students' learning activities;
- organize collaborative activities between students through paired or group work;
- increase students' motivation through the use of modern lesson organization methods, didactic techniques and ICT tools;
- provide academic and emotional support to students during the lesson;
- introduce differentiation in lessons, considering the needs of individual categories of pupils.

All of these activities focus on the development of students' intrinsic motivation as a consequence of cognitive and personal activity. Since, according to S.L. Rubinstein (Rubinstein, 1986), personal activity in learning is the precondition for the development of self-regulation.

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