European Proceedings of
Social and Behavioural Sciences
EpSBS
www.europeanproceedings.com
e-ISSN: 2357-1330

DOI: 10.15405/epsbs.2021.09.02.171

ICEST 2021
II International Conference on Economic and Social Trends for Sustainability of Modern Society

NATURAL-SCIENTIFIC CASES AS A TOOL FOR THE DEVELOPMENT OF CRITICAL THINKING

M. V. Solodikhina (a, b), A. A. Solodikhina (c)*
*Corresponding author

(a) Moscow Pedagogical State University (MPGU), Moscow, Russian Federation, mv.solodikhina@mpgu.su
(b) Peoples' Friendship University of Russia (RUDN), Moscow, Russian Federation, solodikhina-mv@rudn.ru
(c) National Research University Higher School of Economics (HSE), 11, Pokrovsky Boulevard, Moscow, Russian Federation, 109028, asolodikhina@hse.ru

Abstract

Critical thinking is recognized as a key skill of the 21st century. The basis for the development of critical thinking can be integrated scientific disciplines and the associated scientific method. The learning model should be based on the essence of science as a process of discovering something new and teaching materials should become simulators of 'making discoveries' by recreating the situation of scientific search. The article describes a relatively new type of educational materials – natural-scientific cases (NSC). NSC is based on real-world problem situations, which are solved with the help of a chain of tasks that guides the student along the path of the scientific method. The formulations of the tasks are aimed at the development and diagnosis of critical thinking. An experiment on the introduction of cases into the educational process of two Moscow universities is described in the article. The results obtained indicate that the use of a set of NSC has a double positive effect: the natural science complex serves as an excellent basis for the development of critical thinking, and an increase in the level of thinking contributes to a more productive assimilation of natural science material.

Keywords: Natural-scientific case, logical thinking, creative thinking

https://doi.org/10.15405/epsbs.2021.09.02.171
Corresponding Author: A. A. Solodikhina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

1. Introduction

Critical thinking is a necessary skill for the 21st century (Utami et al., 2019). Usually, it is taught in a special course. But there is a point of view that the development of critical thinking in the framework of academic disciplines is more fruitful (McPeck, 1981): thinking and knowledge are interconnected, thinking allows you to assimilate knowledge, and knowledge is the basis for the development of thinking (Halpern, 2014). Natural sciences have a high potential for the formation of critical thinking. Critical thinking is the cognitive foundation of the scientific method. On the other hand, following the scientific method in teaching develops critical thinking (Parwati et al., 2019). The starting point for the scientific method is the problem situation. Since the problem associated with real processes, phenomena, objects is difficult to attribute to any specific discipline, then for the development of critical thinking, it is integrated courses (Dumitru, 2012). But for this, from a learning model based on memorizing and reproducing knowledge, it is necessary to move to a model based on the essence of science as a process of discovering something new: a process-oriented model is more productive for developing thinking than a content-driven model (Forawi, 2016).

To implement such learning model, special teaching materials are needed, which, firstly, would serve as a guide in comprehending the scientific method, focusing not on the correctness of the answers, but on the approaches and ways to solving the tasks, opening science for students not as a warehouse of ready-made knowledge, but teaching tools for discovering something new (Mitra & Arora, 2010), and secondly, their content would not be the sum of tasks of monodisciplines, but integrated – that is, it considered natural phenomena and processes from different angles of view, third, the wording of the tasks contributed to the development of critical thinking, and fourth, some of the tasks performed diagnostic functions.

2. Problem Statement

Such teaching materials have not yet been developed in Russia. Thus, the problem arises of testing the hypothesis that critical thinking can be effectively developed on the content of integrated scientific courses without losing the quality of scientific training.

3. Research Questions

- Identification of the features of educational materials that contribute to the development of thinking.
- Exploring the diagnostic capabilities of such training materials.
- Assessing the impact of these materials on students' thinking.
- Assessment of the influence of these materials on the assimilation of natural science material by students.

4. Purpose of the Study

Development, testing and analysis of educational materials aimed at developing students' critical thinking on integrated natural science content.

https://doi.org/10.15405/epsbs.2021.09.02.171
Corresponding Author: A. A. Solodikhina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

5. Research Methods

The experiment was conducted in two universities in Moscow.

5.1. Research on question 1

From 2013 to 2016, the MPSU was developing, testing and correcting educational materials, with which 152 students-future teachers of physics, computer science and technology -worked at seminars of the discipline 'Natural Science Picture of the world' under the guidance of 1 professor and 2 assistants.

It was determined that the learning model based on following the scientific method, as if repeating the path of the scientist to the discovery, well corresponds to problem-situational tasks (cases). The use of case studies improves students' understanding of the content of natural science disciplines (Korobova et al., 2019) and significantly affects critical thinking skills, especially if problem situations are related to the reality of the surrounding world (Abrami et al., 2015). Therefore, the training materials were created in the form of natural science case studies (NSC).

To design an NSC, it is necessary to have a context-sensitive definition of critical thinking. There are many competing definitions of critical thinking (Wilson, 2016). For example, there is debate over whether creativity is part of critical thinking (Wechsler et al., 2018). But studies by Danczak et al. (2017) have shown that students, teachers and employers associated with natural sciences associate critical thinking with the concepts of 'analysis', 'objectivity', 'rationality', 'assessment', 'identification of opportunities and problems', 'research' and 'project', the implementation of which is impossible without creativity. Therefore, thinking logical, rational, creative and reflective can be considered as the main components of critical thinking from the point of view of the practice of science education.

The NSC consists of 3 parts: a description of the problem, 30-40 tasks and reference material. The problem situation of the NSC should not have an obvious or well-known solution, since only an object about which there are no reliable ideas prompts our thinking to research (Plato, 1936). Tasks help to isolate the essence of the problem, suggest a way to overcome difficulties, focus on the features of experiments and the applied meaning of theories. The assignments play the role of Socrates' questions.

The third component of the NSC is background information in the form of formulas, pictures, diagrams, tables, which allows even humanities students to work with NSC without resorting to additional sources of information, relying only on their thinking skills.

It is advisable to begin acquaintance with the problematic situation of the NSC under the guidance of a professor at the seminar, which is explained by the tendency of people to become more curious as the volume of knowledge about the subject they perceive increases (Loewenstein, 1994). When the situation becomes clear and interesting to the student, its solution is transferred to the area of independent work.

The second reason for such organization of work with the NSC is associated with the Zeigarnik effect, when students who have partially completed the NSC are more likely to prefer to finish an already started case than to complete a new task of the same volume. At the seminar, it is advisable to complete about half of the tasks that make up this NSC and discuss with the students the specifics of the tasks remaining for independent study. This is due to the Hemingway effect, in which the motivation for completing a task is inversely proportional to the volume of the remaining part of the task and is directly

https://doi.org/10.15405/epsbs.2021.09.02.171
Corresponding Author: A. A. Solodikhina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

proportional to the understanding of what exactly needs to be done to complete the task (Oyamaa et al., 2018). The group interaction also appears to be a significant contributor to the improvement of reasoning (McConnell et al., 2018). Therefore, students work in groups of 2-3 people.

Let us consider as an example some of the tasks of the 'Galilei' NSC (Solodikhina, 2020). The starting point for the scientific method is the observation of Galileo Galilei during the Sunday service in the cathedral at Pisa at a chandelier: he found that the oscillation frequency of the chandelier does not change.

The first problem situation: 'How could Galileo measure the frequency of vibrations of the chandelier, if he did not have a clock with him?' - embarrasses students.

Many students are accustomed to the fact that any question or problem has the only correct answer, and all the information necessary and sufficient to answer is contained in the formulation. With this approach, a shortage of new ideas arises. There is no "correct" answer to this question - it is not known for certain whether Galileo really observed the chandelier and somehow determined the frequency of its oscillations. One can only make hypotheses where the meter can be any uniform process: pulse, breath, music rhythm, internal counting, uniform walking, candle melting, etc. It is critical thinking that initiates the act of hypothesis, and the generation of hypotheses serves as an impetus for the release of students' creativity. The scientific method uses experimentation to analyze any hypothesis. Therefore, to answer the question: 'What does the frequency of oscillation of the chandelier depend on?' students should plan and implement experiments. The skill of designing and conducting scientific experiments is among the most important skills influencing the development of critical thinking (Forawi, 2016).

The conclusion of the experiment is that the frequency of vibrations does not depend on mass led Galileo to the inference that the speed of falling bodies is independent of mass. This contradicted the assertion of Aristotle, the indisputable authority in the time of Galileo, that the speed of falling bodies is proportional to their mass. This is the second problem situation.

To develop critical thinking skills, it is useful to show students situations when everyday feelings or the opinion of an authority turned out to be inconsistent with the truth. One of the obstacles in the practice of critical thinking is the tendency of people to agree with 'authoritative' statements without subjecting them to validation, therefore, the main abilities of critical thinking include clarifying the subject matter (Ennis, 1996) using, for example, active debate (Aini et al., 2019). The description of the experiment with the fall of two nuclei from the Leaning Tower of Pisa does not unambiguously solve the problem, since, according to legend, the lighter nucleus fell behind by the thickness of two fingers. The dispute can be resolved on the basis of a mathematical calculation. This reveals mathematics as an effective way to practice critical thinking (Su et al., 2016).

Similarly, other real and thought experiments of Galileo, their consequences, which led to many discoveries and the creation of modern science, are considered. Most importantly, drawing the attention of students to such imperatives of the ethos of science as universalism (evaluation of an idea by its content, not the author) and skepticism (critical attitude to any scientific ideas and their verification) (Merton, 1942), which in a broad sense forms the basis of the critical thinking strategy.

5.2. Research on question 2

In a experiment 2016-2020, 62 students of the Master's program 'Modern Natural Science' and 'Astrocomic Education' of the MPGU participated. All students studied 10 NSCs and 7 tests to assess logic, creativity, reflection, and rationality. For 2 years, the work of each of the students was analyzed in the study of three scientific disciplines, the development of a natural science project and the writing of a master's thesis. The mechanism for comparing tasks for evaluating logical thinking was described Solodikhina et al. (2020). The criterion validity of tasks was proved as the degree of correlation between the indicators obtained by the subjects, on the one hand, by the NSC method, on the other hand (the comparison was carried out in pairs) - when using tests with previously proven validity and expert evaluation. The criterion validity of tasks for evaluating the components of thinking ranged from 0.58 to 0.89, which allowed us to consider the case tasks as a fairly reliable tool for diagnosing the components of critical thinking.

5.3. Research on question 3

The participants of the experiment were 3 teachers and 3 subgroups of RUDN's students: 32 students of the Faculty of Physics, Mathematics and Natural Sciences (the main subgroup); 76 students of the Philological Faculty (the main subgroup); 216 students of the Philological Faculty (an additional subgroup, studying on-line). There was no control group.

About half of the tasks of each of the eight NSCs were performed by students at seminars. These tasks served as a teaching function. The rest of the assignments were performed by students as independent homework. These tasks performed a diagnostic function.

Students performed the NSC voluntarily. Instead of NSC, they could prepare reports. Such students were not included in the study (there were 5.4% of the total number of students).

In the survey, students identified creativity and logic as the most important for their future professional activities. Therefore, the study focuses on these components of critical thinking.

5.3.1. Studying the influence of NSCs on student' creative thinking

In the experiment, creative thinking was estimated by:

- the ability to put forward a hypothesis and suggest ways to test it (for example, to put forward a hypothesis of the reasons for the lag of the pendulum in French Guiana by 2 minutes a day relative to Paris, and to propose ways to test it),
- the ability to offer ideas for solving a problem (for example, ways in which Galileo could find the mass of air) or resourcefulness when creating models for experiments from available tools,
- the creativity of the plot of the video, which explained the experiments (for example, the plot of the video, which reproduces Galileo's thought experiment with the movement of balls on an inclined plane).

In total, there were 65 creative tasks in the NSCs, of which 38 tasks were used as diagnostic ones: 16 tasks of type 1, 14 tasks of type 2 and 8 tasks of type 3. Answers to creative tasks were evaluated on 10 parameters:

- the presence of a description of the problem with the statement of several (as many as possible) possible parties and connections,
- proposing several ideas or approaches to solving the problem,
- diversity of the proposed ideas and flexibility as the ability to abandon the acquired point of view,
- unusual, originality or rarity of ideas,
- the use of a transdisciplinary approach to ideas and methods of their assessment, that is, the ability to move into related fields of science,
- the ability to regroup ideas and connections, to comprehend the available information from a new perspective,
- the thoroughness of the development, the degree of detail of the answer,
- expansion and going beyond the expected result,
- use of imagination,
- richness of word usage.

Accordingly, the student was assigned an average score for all creative tasks in this NSC on a 10-point scale.

Figure 1 show the results of evaluation of students' creativity for the main subgroup.

Initially, science students were better at completing tasks of types 1 and 2, since they more often had contact with such mental operations as hypothesis and its verification, including by creating models and conducting experiments.

The lower score of students of philology on the interval [1;3] was also determined by the fact that in the NSC №1 they did not complete about an eighth of the tasks of the first and second types, and after NSC №3 the share of unfulfilled tasks decreased to one-thirty. Natural science students completed almost all of the assignments during the entire course, except for video assignments

. Starting from NSC №4, no significant difference between the average results (indicated by lines) of philological and science students has been revealed. But, science students created an average of 1.8 videos per person for the entire period of study, and philology students created 2.6 videos per person.

https://doi.org/10.15405/epsbs.2021.09.02.171
Corresponding Author: A. A. Solodikhina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

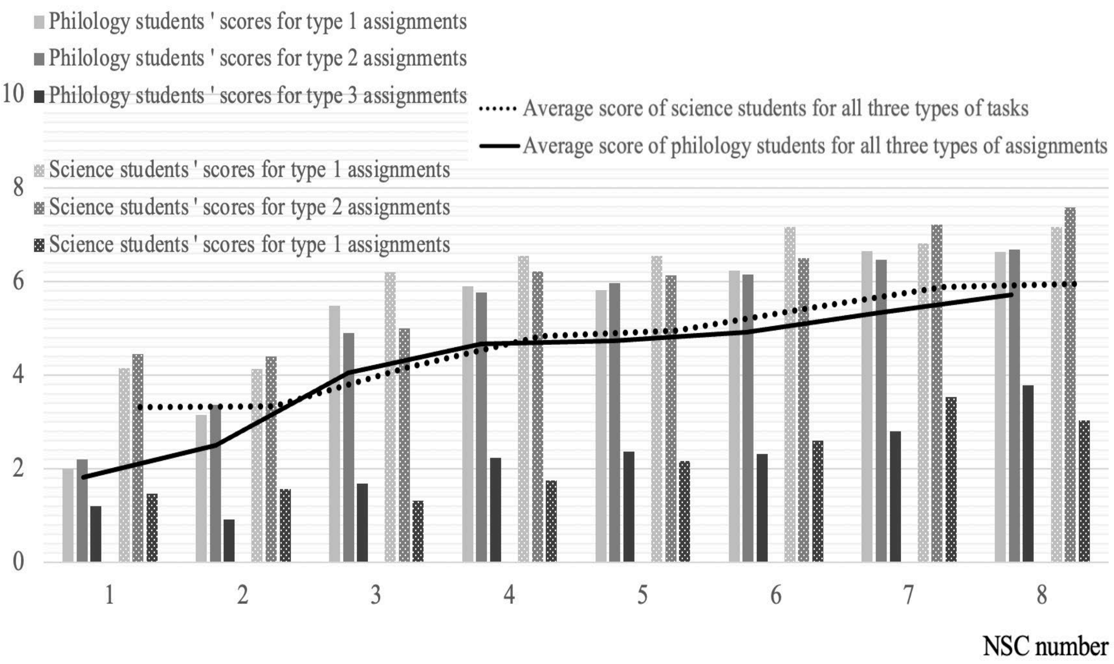

Figure 1. Points received by students for solving tasks for evaluating creativity of three different types

On the interval [1;3], the growth of points was ensured by an increase in

- the number of tasks completed;
- the number of expressed ideas and hypotheses (for example, when solving NSC # 1, students of each group suggested 1-3 different adequate experimental ideas, and starting from NSC 4 the number of proposed adequate sets began to reach 5),
- the complication of the video plots: the share of video experiments with a meaningful plot, and not only the recording of the experience, increased from 0,2 to 1 already to NSC №3.

Presumably, the increase in points in the interval [1;3] is explained by the gradual adaptation of students to new types of tasks, and the increase in points in the interval [4;8] reflects the change in the level of their creative thinking. The determination of the significance of changes in the interval [4;8] was carried out by calculating the empirical value of the t-test for dependent samples, where the initial data had a normal distribution, based on the average difference in values between the results of NSC №8 and NSC №4. Empirical value of the t-test (Table 1) for all types of tasks and groups of respondents, except for the task for creating a video clip of experiments (type 3) for science students ($t_{э}$=1,28), corresponds to a significance level of 0.05 and allows assessing the impact of NSC on development creative thinking of students as positive. Science students have produced too few videos for the change in score for Type 3 assignments to be statistically significant. The influence of case-based learning is more noticeable among students of philology, since the difference in values of the t-test between science students and students of philology cannot be explained only by a different number of respondents.

The results of the additional subgroup confirm the same trend: a noticeable increase in scores on the first three NSCs, especially for tasks of the first type, a slowdown in the growth of scores to the NSC №7.

https://doi.org/10.15405/epsbs.2021.09.02.171
Corresponding Author: A. A. Solodikhina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

The peculiarity of on-line training affected a large number of created videos, which gave the value t_e=3.32 for the empirical value of the criterion of type 3 assignment.

Table 1. The empirical value of the t-test for dependent samples based on the average difference in values between the results of performing tasks on creativity of NSC 8 and 4

Respondents	The amount of the respondents	t-test depending on the type of tasks		
		Type 1	Type 2	Type 3
Science students	32	2.796	2.524	1.276
Philology students	76	4.207	5.789	2.245

5.3.2. Studying the influence of NSCs on students' logical thinking

The basis of logical thinking is the ability to analyze and interpret information, evaluation the validity and acceptability of judgments, arguments and beliefs (Pešić, 2007), make logically correct inferences of three types: deductive reasoning, inductive reasoning, and conclusion of value judgments (Ennis, 1996).

Therefore, the NSCs contain tasks for assessing logical thinking of three types:

- on the analysis and interpretation of scientific information such as 'continue a logical chain', 'insert missing', etc., for example: add a visualization of Galileo's thought experiment about the fall of a chicken egg and marble egg, with which he explained the lag of the light nucleus (Figure 2);

Figure 2. Explanation of the lagging of the light nucleus

- on the formulation of inferences and their argumentation or on the analysis of certain hypotheses and judgments, for example: explain whether hypothetical experiment with the falling of nuclei from the Leaning Tower of Pisa has refuted or confirmed the hypothesis of Aristotle?
- on building an algorithm. For example, the task of constructing an extensive algorithm of Galileo's actions, where one of the finales is the creation of a pendulum clock, the second is the formulation of the law of inertia, the third is the definition of the laws of motion of bodies in the earth's gravity field and the magnitude of the acceleration of free fall, and on a global scale – to the formation of modern natural science, based on a verifiable experiment with a system of logically rigorous proofs.

https://doi.org/10.15405/epsbs.2021.09.02.171
Corresponding Author: A. A. Solodikhina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Eight NSCs had 132 tasks for evaluating logical thinking, of which 76 tasks were used for diagnostics: 36 tasks of the 1st type, 22 tasks of the 2nd type and 18 tasks of the 3rd type. All tasks were evaluated on a 10-point scale.

The score for the first type of tasks was proportional to the correctly spelled words or images. For tasks with the only one correct answer, the presence of the correct answer was estimated at 1-point, higher points were given in the presence of calculations and / or a chain of inferences that led to the answer.

In the scientific method, inferences are accompanied by logically rigorous evidence supporting them with proven reliability. Therefore, in the tasks of the second type, the presence of only inferences in the student's answer was estimated at 1 point. If, in addition to the conclusion itself, the student wrote down some arguments, but did not build a strict logical chain from them, then he received 2-3 points. Up to 7 points, the student received for argumentation with references to reliable sources, demonstration of the relationship of inference with arguments, and the arguments themselves are correct, relevant and directly related to the subject of discussion.

The results of evaluating three types of logic tasks are shown in Figure 3. The increase in the average score in the interval [1;3] can be explained by the students' habituation to the requirements to argue all statements and conclusions and was provided by the quantitative growth of reasoned answers. Starting with NSC №4, almost all students began to explain their decisions and write a chain of conclusions that led to the resulting conclusions. In the interval [4;8], the slow growth was due to an improvement in the quality of argumentation and a certain increase in the number of correct answers to logical tasks.

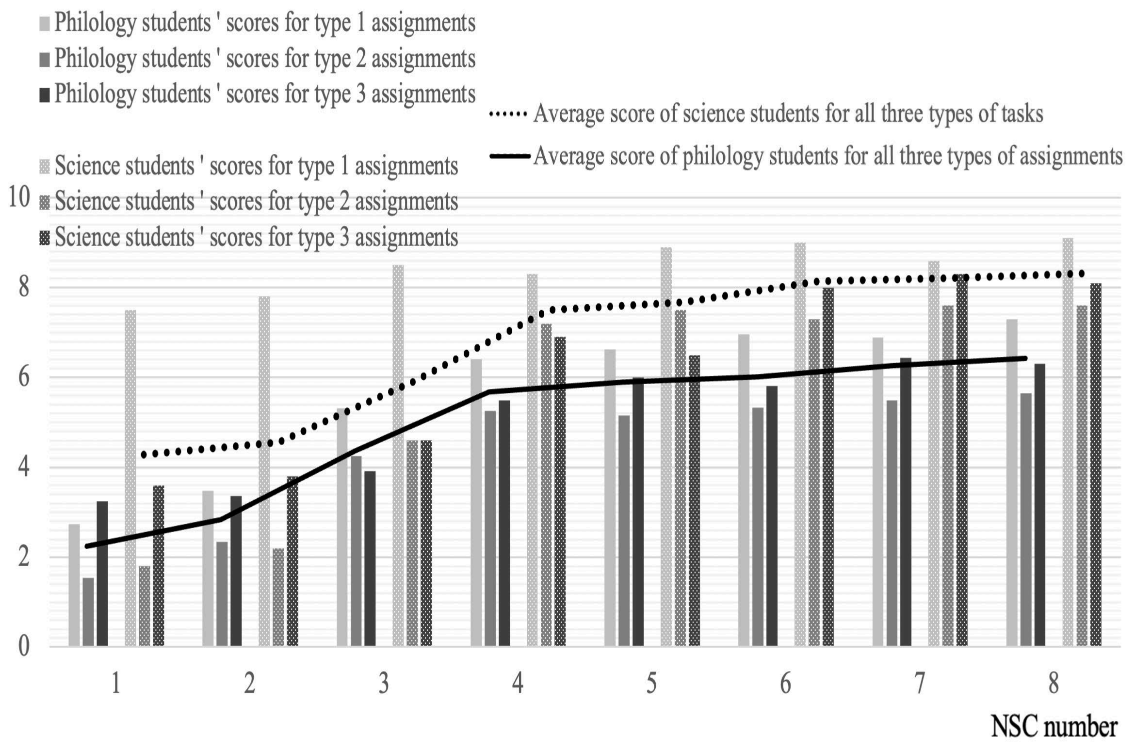

Figure 3. The points received by students for solving logical problems of the NSC of three different types

Students performed best on the tasks for the analysis and interpretation of information (type 1). For science students, this type of task is familiar, which determined the initially high scores. Many students wrote down only a brief conclusion when solving the first three NSC in answers to tasks where it was necessary to comment or explain the conclusion (type 2). They began to write down the entire logical chain that led to this conclusion, only after the fourth NSC. But the quality of argumentation of this logical chain by the NSC №8 improved only among those students to whom the teacher explained specific logical mistakes made by them in individual consultations. As a result, the scores for this type of tasks demonstrate the smallest growth in the interval [4; 8], up to the fact that for natural science students it becomes statistically insignificant at a significance level of 0.05: the empirical value of the t-test for dependent samples, where the initial data had a normal distribution, is 1.91 (Table 2). This probably requires more study of the NSC and the efforts of teachers to improve the quality of argumentation.

Table 2. The empirical value of the t-test for dependent samples based on the average difference in values between the results of performing tasks on the logic of NSC 8 and 4

Respondents	The amount of the respondents	t-test depending on the type of tasks		
		Type 1	Type 2	Type 3
Science students	32	5.518	1.913	2.048
Philology students	76	5.967	2.395	4.272

The rapid increase in the average score in the interval [1; 4] for solving tasks for composing algorithms (type 3) is due to the fact that students had no experience in composing algorithms related to some real situations, and not mathematical abstractions. Therefore, many students, when solving the NSC 1-3, either did not perform tasks, or made extremely schematic algorithms. But after discussing several algorithms in the class, the situation changed: all students began to perform tasks of the third type, and the points began to grow due to a better logical sequence of actions and more detailed algorithms. This growth was significant: in the interval [4;8] for 5 of 6 positions, the empirical value of the t-test for dependent samples is statistically significant for a significance level of 0.05, which indicates a positive effect of training on the results.

The results of the additional subgroup differed from the results of the students of the philological faculty of the main subgroup by no more than 20%.

5.3.3. Identify problems

The duration of adaptation is associated with problems caused by the focus of the education system on the formation of a system of knowledge, and not on the development of students' thinking.

First problem: it was found that it was difficult for students to perceive tasks that did not have a single unambiguous answer (for example, to describe the structure of Galileo's laboratory clock, their advantages and disadvantages, if they consisted of a bucket, a glass and scales) and suggesting the construction of a chain of reasoning (for example, to explain the lowering of the lever with the weight on Figure 5 at the moment of opening the hole in the upper vessel). Students accustomed to the fact that only the correct answer is important did not write down the reasoning that led to the answer.

https://doi.org/10.15405/epsbs.2021.09.02.171
Corresponding Author: A. A. Solodikhina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Figure 4. Galileo's installation for determining the force of impact

Second problem: initially, students were embarrassed to express 'strange' and 'absurd' ideas, but gradually they realized that such ideas can be the most productive. As soon as they found an idea that seemed 'optimal', they stopped coming up with new ones. It took some time for the students to realize that there can be several 'optimal' ideas, each of which takes into account other possibilities.

Third problem: The requirement not only to write down the answer to the question of the NSC assignment, but also to argue this answer (or evaluate the reliability of the answer), was also initially perceived by students as unnecessary and unjustifiably laborious. Some students admitted that the most difficult for them was not the selection of arguments itself, but the creation of clear and precise formulations, the construction of logically verified phrases. Later, students of philology recognized such tasks as one of the most useful for their future professional activities.

The fourth problem: students' poorly formed habit of critical assessment of educational material and discussing it with each other in a conversation format.

Thus, the students identified “the need to think when looking for and formulating an answer to a question” as the most significant common difficulty at the beginning of work on NSC.

5.4. Research on question 4

The participants of the research were 32 students of the Physics, Mathematics and Natural Sciences of RUDN University. The control group included 165 students from eight groups of the same Faculty, who did not study the NSC. The course of lectures, tasks and tests were the same for the students of the experimental and control groups.

To check the assimilation of natural science material by students, 8 on-line tests were used. Each test consisted of 10 questions related to different clusters of the studied topic and corresponding to the material of on-line lectures of the course 'Concepts of modern natural science'. Tests were graded on a 5-point scale.

The results of the control group were in the interval [4,13; 4,40] points (Figure 4). The empirical value of the t-test (t=1.08) for dependent samples is statistically insignificant for a significance level of 0.05, that is, the results of students during the course did not change. Fluctuations in the average score were probably determined by the level of difficulty of the test items. Each test checked the assimilation of a new topic, which was loosely related to the material of the previous topics.

https://doi.org/10.15405/epsbs.2021.09.02.171
Corresponding Author: A. A. Solodikhina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Since the material of the lectures was the same for all groups and was studied by students independently (there is no influence of the lecturer), and only the classes at seminars were different in which students of the experimental groups worked with NSC, and students of the control groups discussed the reports, it can be assumed that the positive dynamics of the experimental group related to learning using NSC. And since there is no direct connection between the content of NSC materials and the content of on-line lectures, then, presumably, a positive effect was achieved due to a change in the thinking of students in the experimental group. This argument is also supported by the shape of the curve in Figure 4, which practically repeats the shapes of the curves of Figure 1, 3 that is, an increase in scores for tests that control the assimilation of programmed natural science material, corresponds to an increase in scores for completing creative and logical tasks of NSC.

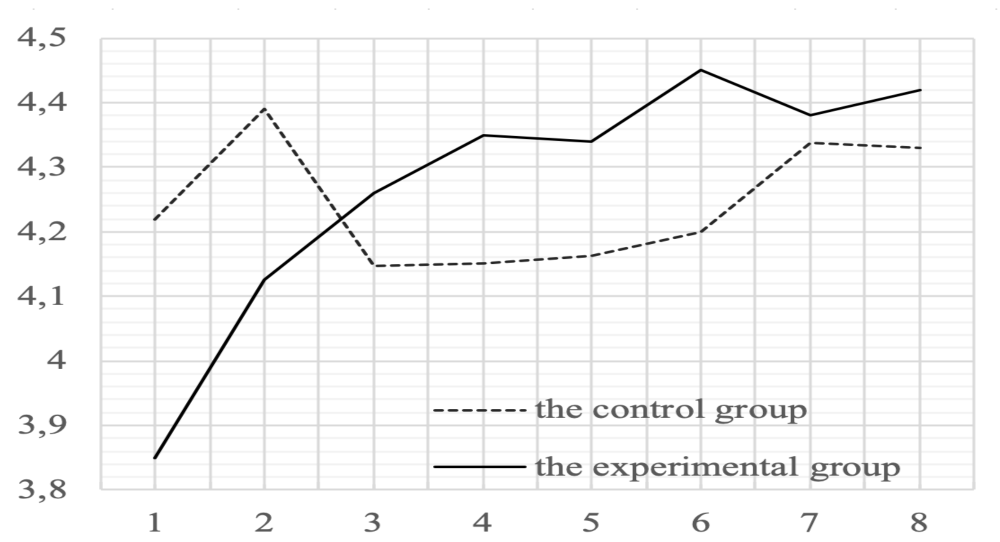

Figure 5. The results of the tests performed by the experimental and control groups, where along the x-axis is the test number, along the y-axis is the average score on a five-point scale

6. Findings

One of the tasks of the integrated science disciplines is the development of critical thinking in students without losing the quality of the natural science training itself. The vastness of the educational material in a limited time makes it ineffective when teaching such courses in using several different tools, each of which has its own purpose: the development of critical thinking, the formation of subject competencies, diagnostics of changes in the level of thinking, diagnostics of the assimilation of program material. Therefore, a new educational material for Russian students was created - NSC, which combines all these functions.

NSC are based on real problems of natural sciences, built as a study in which students master the method of scientific cognition and work with tasks that are trainers of critical thinking - thinking creative, logical, reflective and rational. Working with the NSC has a positive effect on the development of critical thinking and the assimilation of natural science material by students. NSC assignments are a reliable and valid diagnostic tool for critical thinking.

7. Conclusion

The conducted research allows us to assumed that there is a positive relationship between students' critical thinking skills and assimilation of science material. The use a set of NSC in the practice of teaching integrated science disciplines has a double positive effect: science serves as a good basis for the development of critical thinking, and an increase in the level of thinking contributes to a more productive assimilation of natural science material. This is largely due to the fact that when using NSC, teaching is carried out in accordance with the model of following the scientific method of cognition.

NSC can be used as a tool for teaching and diagnosing critical thinking in natural science education.

The continuation of the research concerns the influence of NSC assignments on other components of critical thinking, as well as motivation to study integrated natural science disciplines.

References

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for teaching students to think critically: A meta-analysis. *Review of Educational Research, 85*(2), 275-314. https://doi.org/10.3102/0034654314551063

Aini, N. R., Syafril, S., Netriwati, N., Pahrudin, A., Rahayu, T., & Puspasari, V. (2019). Problem-based learning for critical thinking skills in mathematics. *Journal of Physics: Conference Series, 1155*(1). https://doi.org/10.1088/1742-6596/1155/1/012026

Danczak, S. M., Thompson, C. D., & Overton, T. L. (2017). 'What does the term critical thinking mean to you?' A qualitative analysis of chemistry undergraduate, teaching staff and employers' views of critical thinking. *Chemistry Education Research and Practice, 18*(3), 420-434. https://doi.org/10.1039/c6rp00249h

Dumitru, D. (2012). Critical thinking and integrated programs. The problem of transferability. *Procedia - Social and Behavioral Sciences*, 33, 143-147. https://doi.org/10.1016/j.sbspro.2012.01.100

Ennis, R. H. (1996). *Critical thinking*. Upper Saddle River NJ: Prentice-Hall.

Forawi, S. A. (2016). Standard-based science education and critical thinking. *Thinking Skills and Creativity*, *20*, 52-62. https://doi.org/10.1016/j.tsc.2016.02.005

Halpern, D. F. (2014). *Thought and knowledge: An introduction to critical thinking* (5th Ed.). Psychology Press.

Korobova, I., Korobov, V., Baysha, K., Goncharenko, T., & Yermakova-Cherchenko, N. (2019). The case-method application in professional training of natural sciences teachers. *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, 19*(5.4), 301-308. https://doi.org/10.5593/sgem2019/5.4/S22.041

Loewenstein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin, 116*, 75-98.

McConnell, D. A., Steer, D. N., Owens, K. D., & Knight, K. C. (2018). How Students Think: Implications for Learning in Introductory Geoscience Courses. *Journal of Geoscience Education*, *53*(4), 462-470. https://doi.org/10.5408/McConnell_v53p462

McPeck, J. E. (1981). *Critical Thinking & Education*. St. Martin's.

Merton, R. K. (1942). *The Normative Structure of Science*. https://www.panarchy.org/merton/science.html

Mitra, S., & Arora, P. (2010). Afterthoughts. *British Journal of Educational Technology*, *41*(5), 703-705. https://doi.org/10.1111/j.1467-8535.2010.01079

Oyamaa, Y., Manalob, E., & Nakatanic, Y. (2018). The Hemingway effect: How failing to finish a task can have a positive effect on motivation. *Thinking Skills and Creativity, 30*, 7-18. https://doi.org/10.1016/j.tsc.2018.01.001

Parwati, N. W., Suarni, N. K., Suastra, I. W., & Adnyana, P. B. (2019). The effect of project based learning and authentic assessment on students' natural science learning outcome by controlling critical thinking skill. *Journal of Physics: Conference Series, 1318*, 012096

Pešić, J. (2007). Logical and epistemological approach to critical thinking. *Psychology*, *40*(2),173-190. https://doi.org/10.2298/PSI0702173P

Plato. (1936). *Theetetus*. Translation from Greek and notes by V. Serezhnikov. M.-L. SOTSEKGIZ.

Solodikhina, M. V. (2020). *Collection of case problems on integrated natural science courses: Textbook*. Prometheus.

Solodikhina, M. V., Odintsova, N. I., & Odintsova, E. E. (2020). Natural-scientific cases as an instrument for assessment of logical thinking. *Journal of Physics: Conference Series, 1691* 012218. https://doi.org/10.1088/1742-6596/1691/1/012218

Su, H. F. H., Ricci, F. A., & Mnatsakanian, M. (2016). Mathematical teaching strategies: Pathways to critical thinking and metacognition. *International Journal of Research in Education and Science, 2*(1), 190-200. https://doi.org/10.21890/ijres.57796

Utami, B., Probosari, R. M., Saputro, S., & Masykuri, M. (2019, November). Empowering critical thinking skills with problem solving in higher education. In *Journal of Physics: Conference Series* (Vol. 1280, No. 3, p. 032047). IOP Publishing. https://doi.org/10.1088/1742-6596/1280/3/032047

Wechsler, S. M., Saiz, C., Rivas, S. F., Vendramini, C. M. M., Almeida, L. S., Mundim, M. C., & Franco, A. (2018). Creative and critical thinking: Independent or overlapping components? *Thinking Skills and Creativity*, 27, 114-122. https://doi.org/10.1016/j.tsc.2017.12.003

Wilson, K. (2016). Critical reading, critical thinking: Delicate scaffolding in English for Academic Purposes (EAP). *Thinking Skills and Creativity, 22*, 256-265. https://doi.org/10.1016/j.tsc.2016.10.002