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Developing Computational Thinking of Specialists of the Future Through Designing Computer Games for Educational Purposes

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Abstract

The problem that the given paper aims to solve is associated with the need to resolve the contradiction between the requirements of the digital economy for a high level of computational thinking of specialists of the future and an insufficiently developed methodological base for training graduates that meets these requirements.

The purpose of the research is to theoretically prove and experimentally verify the need for the use of gamification technology in training of specialists of the future to form computational thinking skills which are most in demand in the digital society.

The research methodology includes the analysis and generalization of scientific works on the problem of determining the phenomenon of computational thinking, the use of digital gamification resources in training, and clarifying the requirements for training of highly qualified specialists of the future. The HTML 5 language was used as a software tool. The pedagogical experiment is presented on the example of the assessment of changes in the levels of skills that make up the essence of computational thinking.

Results. The paper clarifies the concept of computational thinking and describes the directions of educational and cognitive activity based on the gamification principles which most effectively form computational thinking. The authors formulate didactic principles for the inclusion of computer games to foster students' cognitive activity, support professional self-determination, and develop systematic and critical thinking. Specific materials are proposed to improve the methods, tools, and organizational forms of the training focused on the formation of computational thinking as the basis for the supra-professional skills of specialists of the future.

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In the end, conclusions are made which confirm that the included educational and cognitive activities on game designing in the training of highly qualified specialists of the future fosters the formation of computational thinking skills.

Keywords: computational thinking, gamification technology, educational space, algorithm, game world, HTML 5 language, thought process, professions of the future, digital economy.

1. Introduction

1.1. Relevance of the problem

Training qualified personnel is one of the key directions to improve the country's competitiveness. It is stated in the Strategy for the Development of the Information Society in the Russian Federation for 2017–2030 (Strategiya razvitiya..., 2017), in the Federal Program "Personnel for the Digital Economy", etc. In order to develop future specialists' professional competencies that are in demand in the digital society, it is necessary to develop and implement new approaches to training (Karakozov, Ryzhova, 2019). A global trend in modern education is the focus of training on the development of students' computational thinking skills (Chevalier et al., 2020). E.K. Henner defines computational thinking as a thought process involved in problem setting and its solution, presented in a form that can be effectively implemented using information processing tools (Khenner, 2016). Information and communication technologies affect all spheres of society, so the desire to study the possibilities of new digital means becomes a prerequisite for the development of modern man (Soboleva et al., 2020). To use computer devices and digital tools effectively, computational thinking skills are required. Moreover, UNESCO defines the principles of the use of artificial intelligence in education, coding activities and the formation of computational thinking (Cropley, 2020). This activity involves skills that allow everyone to create a code and solve problems using various algorithms. In addition, modern educational environment requires that a digital school teacher should include game elements and gamification services in educational and cognitive activities (Legaki et al., 2020). It is the gaming educational space, as proved by N. Legaki, N. Xi, J. Hamari, K. Karpouzis, V. Assimakopoulos, where there are additional opportunities to increase the motivation of the learning generation Z, foster cognitive activity, support professional self-determination, and develop systematic and critical thinking (Legaki et al., 2020). Designing a virtual game world, developing algorithms for the characters' behavior and their activities, game strategies, writing a code make up the essence of computational thinking (Papert, 1993). Indeed, it is computational thinking that uses logical and algorithmic approaches to problem formulation, analysis, and its solution.

On the one hand, the development of computational thinking skills, as well as by means of gamification, appears to be an important factor for a graduate's successful professional personal fulfillment in the modern technological society. On the other hand, in Russia until recently, there has been no special research on the concept of computational thinking. The exception is E.K. Henner' research in which this concept is analyzed from foreign authors' points of view and is determined as relevant for domestic education (Khenner, 2016). He defines that this term in practice aims at updating the teaching content and methods, fosters increasing efforts to form meta-subject results of education.

Thus, there is a contradiction between the requirements of the modern economy for a high level of computational thinking of specialists of the future and an insufficiently developed methodological base for training graduates that meets these requirements. The hypothesis of the research is that the internship in designing and developing computer games for educational purposes included in students' educational and cognitive activities will contribute to the formation of actions that determine the essence of computational thinking.

1.2. Purpose and objectives of research

The purpose of the research is determined by the need to use gamification technology in training specialists of the future in order to form computational thinking skills which are most in demand in the digital society.

Research objectives:

- to study approaches to the definition of computational thinking;
- to clarify the sequence of actions that are characteristic of computational thinking and are most in demand in today's technological society;

- to identify the possibilities of using software and gamification resources to form the actions that determine the essence of computational thinking;
- to describe the implementation of the selected system of actions on the example of a specific internship in designing a computer game world for educational purposes;
- to experimentally prove the effectiveness of the proposed educational and cognitive activities to form computational thinking skills.

2. Relevance

2.1. Literature review

2.1.1. Review of Russian scientific and pedagogical literature

Game elements and digital services included in student' cognitive activity are current trends in the development of the didactic system (Karavaev, Soboleva, 2017). To confirm the need for the formation of computational thinking skills among digital school graduates by means of digital gamification resources, fundamental scientific works were analyzed to identify the essence of computational thinking and to describe the didactic potential of software and gamification tools in terms of thought process, analytical and algorithmic actions.

E. Varshavskaya, E.S. Kotyrlo state that the global digital transformation has a significant impact on the needs of society, business, and the state regarding the professions in demand in the future (Varshavskaya, Kotyrlo, 2019). However, in practice, schools and universities often train graduates without taking into account the trends of long-term planning, competitiveness, and uncertainty of the future. Besides, motivational, psychological, social and economic, and technical conditions for supporting the future specialist's self-determination play a significant role. (Varshavskaya, Kotyrlo, 2019). According to A.V. Khutorskoy, a teacher' personality, their understanding and ability to design a digital educational space which meets the challenges of global transformation should remain consistently leading (Khutorskoy, 2017). It is the digital school mentor who can and should choose innovative teaching technologies that work as much as possible to form the type of thinking and way of action that is in demand in the digital society.

M.V. Solodikhina, A.A. Solodikhina prove that specialists who possess forecasting and planning skills under the conditions of uncertain future, the ability to independently formulate a problem and offer its best solution, the ability to develop a solution algorithm and implement it using software and hardware will be in great demand in the digital transformation era. (Solodikhina, Solodikhina, 2019). E.V. Soboleva, T.N. Suvorova, S.V. Zenkina, E.K. Gerasimova clarify that a professional of the future should also be able to use the solution of the problem to solve another problem in the future (Soboleva et al., 2020). All these characteristics form the basis of computational thinking.

According to M.M. Klunnikova, the term *computational thinking* is borrowed for Russian literature, science and practice (Klunnikova, 2019). She introduces the concept of mathematical computational thinking which is considered as a thought process that consists of a sequentially activated human memory chains of object images and mental schemes from mathematics and computer science to formulate the problem and effectively solve it using abstract tools.

M.V. Solodikhina, A.A. Solodikhina define computational thinking as "thinking involving problem solving, system design, and understanding human behavior based on concepts fundamental to computer science" (Solodikhina, Solodikhina, 2019). Computational thinking, according to E.K. Henner, involves mental activity when formulating a problem to make a computational decision (Khenner, 2016).

Indirectly, separate components of computational thinking were considered in the works of Russian scientists: mathematical (Kholodnaya, Gelfman, 2016) and algorithmic (Leontiev et al., 2017).

Analyzing approaches to the development of computational thinking by means of digital technologies, we noted three main areas of research: the definition of computational thinking as a cognitive thought process (Kholodnaya, Gelfman, 2016); a hybrid of other ways of thinking (Klunnikova, 2019); the use of information processing tools for modeling processes studied in other disciplines (Borissova et al., 2020). As mentioned above, E.K. Henner in his works, innovative for Russia, proves that the computational thought process involves special methods to formulate a problem, includes such principles as abstraction, decomposition, generalization, and pattern recognition to solve it (Khenner, 2016).

In terms of the current Russian research on gamification in education, T.N. Suvorova, N.I. Isupova should be noted. The authors convincingly prove that the digital technologies based on gamification principles included in educational and cognitive activities not only meet the goals and challenges of the education system, but also allow training in-demand and competitive professionals of the future for the country's economy (Isupova, Suvorova, 2018). E.V. Soboleva, M.S. Perevozchikova prove that designing interactive quest rooms as organizational forms of cognition and educational technology is not only one of the ways to gamify the digital educational space, but also contributes to the formation of the individual's intellectual competence (Soboleva, Perevozchikova, 2019). E.V. Soboleva and N.L. Karavaev analyze various didactically potential game services and platforms in terms of developing relevant skills (Karavaev, Soboleva, 2017). E.V. Soboleva continues her research and highlights the gamification principles the implementation of which is necessary to achieve the desired educational and cognitive effect in accordance with digital economy challenges (Soboleva, Perevozchikova, 2019).

D. Borissova, D. Keremedchiev, and G. Tuparov claim that working with the program and its interface contributes to the formation of users' communication abilities (Borissova et al., 2020). This confirms the theories that modern man's digital literacy necessarily includes a communicative component (Gruzdev et al., 2018). These assertions are also proved by O.V. Semenykhina and Y.O. Rudenko who study the experiment and information interaction in the development of mobile applications, game educational spaces (Semenykhina, Rudenko, 2018).

Thus, while the formation of the computational thinking of a highly qualified and competitive specialist is a priority of the modern educational space (Varshavskaya, Kotyrlo, 2019), there is a need to implement the didactic potential of digital technologies (including those based on the gamification principles) for the development of skills that determine the essence of the corresponding thought process.

2.1.2. Review of foreign research

In foreign theory and practice, it is noted that the term *computational thinking* was first used by Seymour Papert who proposed using computers to incorporate programming ideas into everyday life (Papert, 1993). Subsequently, the author called it *procedural thinking* (Papert, 1996).

In F. Hotyat, computational thinking is considered as thinking that includes a great number of skills which are necessary for programming (Hotyat, 1952). Theoretically, computational thinking also includes computer science concepts such as algorithm, recursion, decomposition, optimization, etc. (Barr, Stephenson, 2011).

J.M. Wing formulated a new definition of computational thinking as thought processes involved in problem setting and solving presented in a form that can be effectively implemented using information processing tools (Wing, 2017).

M. Chevalier, C. Giang, A. Piatti, F. Mondada develop this idea and add that the solution can be performed by a person or a machine, or, more generally, by both people and machines (Chevalier et al., 2020). A. Finkel notes that working in an information educational environment involves performing a sequence of actions characteristic of computational thinking: analyzing the task (formulating the task as a computational problem); decomposing the problem into small logical steps; algorithm development (identification and refinement of the steps required to solve a problem); analysis and evaluation of this algorithm (Finkel, 2017).

S. Bocconi, A. Chioccariello, J. Earp prove that developing program learning is one of the trends in global education policy (Bocconi et al., 2018). L. Ilomäki, M. Lakkala determine digital school trends and if modern educational systems correspond to these trends (Ilomäki, Lakkala, 2018). They identify mobile technologies, artificial intelligence, gamification of learning, video conferencing, cybersecurity, expansion of the educational space beyond the audience as prioritizing. A. Cropley studies the issues and processes of transformation of the global education system and proves the need for a comprehensive adaptation of digital schools to global realities and new approaches to learning (Cropley, 2020). The author analyzes the reasons why some educational institutions introduce innovative teaching technologies while others refuse to do it. K. Bovermann, T.J. Bastiaens provide statistical data for visual analysis and understanding of educational market trends (Bovermann, Bastiaens, 2020).

According to O.C. Yung, S.N. Junaini, A.A. Kamal, L.F. Md Ibharim, digital learning gamification resources are highly effective in the formation of skills for independent development of new technologies and evaluating their possibilities, existence in online and offline reality, constant knowledge updating and the acquisition of new skills and competencies (Yung et al., 2020). The authors claim that a teacher who loves their subject will not always be able to arouse a modern student' interest (overload with fundamental concepts and laws, focusing only on a specific curriculum without variable pace of work, limited communication channels). Digital learning gamification resources allow abandoning the authoritarian style of communication, removing the time and spatial limitations of the traditional class, etc. J.C. Paiva, J.P. Leal, R. Queirós note that currently it is important for a digital school mentor to possess minimal programming skills in order to apply gamification tools, effectively provide teaching in the online community (Paiva et al., 2020). There is a wide range of educational gaming platforms available to support teaching activities (Yung et al., 2020).

K. Bovermann, T.J. Bastiaens describe game mechanics, features of designing game educational spaces (Bovermann, Bastiaens, 2020): the plot component; requirements to selecting the content of the world; the specifics of the task system; the need to train qualified game teachers; emotional design supported by the rules for scoring points, the rating system. O.C. Yung, S.N. Junaini, A.A. Kamal, L.F. Md Ibharim consider designing and developing computer games for educational purposes in relation to teaching mathematics (Yung et al., 2020).

In J.C. Paiva, J.P. Leal, R. Queirós, it is convincingly proved that programming supports the development of analytical abilities (Paiva et al., 2020). F. Hotyat proves the importance of the ability to critically evaluate the result obtained and work under the conditions of uncertain future (Hotyat, 1952). Moreover, if applied correctly, this approach makes it possible to qualitatively increase the effectiveness of the acquired learning material and to stimulate students' cognitive activity, to foster their professional personal fulfillment (Helmlinger et al., 2020).

However, the literature review has shown that the practical implementation of game mechanics in the development of software applications that take into account the principles of didactics and contribute to the formation of students' computational thinking causes certain difficulties for technical specialists (Hsu et al., 2019). It should be noted that it is necessary to allocate additional time and labor resources, work with the application educational content, the basic knowledge of didactics and its practical use, select the software tools (Bocconi et al., 2018), the organization of information interaction in the game environment, the rationale for inclusion of this work in training, etc.

Therefore, there is a problem related to the need to implement digital gamification resources in order to form computational thinking.

3. Materials and methods

3.1. Theoretical and empirical methods

To obtain theoretical generalizations, we used the analysis of research papers on the problem of determining the phenomenon of computational thinking, the use of digital gamification resources in training.

The system and activity approach was used as the main research method. The activity system is considered in a virtual game environment supported by the appropriate software: the use of the functional capabilities of the digital gamification resource by students for data analysis, problem setting, building an information and mathematical model, developing an optimal solution algorithm and its computer-based effective implementation.

The stages of the corresponding activity are described on the example of designing and developing computer games for educational purposes using HTML 5 tools. This specification is chosen because it provides innovative interfaces for application programming and allows making more intensive, faster, or more indeterminable web pages.

The research methodology is complemented by the principles of the learning gamification methodology: gradual presentation of information; the principle of gradual complication; puzzles; instant feedback; storytelling; achievements and points; ratings; open profiles.

When designing and developing computer games for educational purposes, the principles that determine the essence of computational thinking were taken into account: decomposition; abstraction; pattern selection; creation of an algorithm.

Empirical methods (observation, analysis of the results of working with a digital gamification resource) to obtain up-to-date information about changes in the level of computational thinking skills constitute a specific group. A special entrance and final testing was developed and conducted, it included 5 tasks (each was evaluated from a maximum of 3 points). Statistical analysis of the reliability of the results of the pedagogical experiment was evaluated using Pearson's $\chi 2$(chi-square).

3.2. The base of research

In the course of the pedagogical experiment, we evaluated the effectiveness of the students' educational and cognitive activities to design and develop computer games for educational purposes for the formation of computational thinking skills.

To formulate the system of tasks, design a computer game world for educational purposes, 40 fourth-year students, 01.03.02 training program, Applied Mathematics and Computer Science (bachelor's degree), Vyatka State University (Kirov), were involved. The testing was carried out within the framework of Game Theory during the academic training and experience internship for obtaining professional skills. The average respondents' age was 22.

To fulfill the rules of probabilistic selection, the same teacher supervised all the students in developing computer games for educational purposes. The development was carried out in the same classrooms, using the same hardware and software. To carry out control measures, the authors developed test tasks. All questions meet the requirements of the State Federal Educational Standard for the specified training program.

3.3. Stages of research

The research was conducted in three stages.

At the first stage, the sequence of actions characteristic of computational thinking and the list of skills most in demand in the modern technological society were clarified. To assess the input conditions, we used the special test that took into account the priorities of the digital society, the competencies of the atlas of new professions. All questions and tasks were developed by the authors in accordance with the requirements of the State Federal Educational Standard. In the test, students were asked to solve 5 problems. A student received 3 points if they had solved each problem correctly and completely. With the help of the test results, it was possible to collect experimental data on the students, 01.03.02 training program, Applied Mathematics and Computer Science. Describing the sample, it should be noted that the experimental group consisted of 58 % of females and 42 % of males. Further, the participants were divided into groups (there were 20 students in the experimental group and 20 students in the control group) to ensure that each group had the same skills and personality traits that form the basis of computational thinking, and their equal distribution.

At the second stage, we determined the directions of educational and cognitive activities for the design and development of the computer game world for educational purposes with the programming language tools that as much as possible foster the development of skills to independently acquire new technologies and evaluate their possibilities, interact in virtual game reality, constantly update knowledge. Concurrently, we worked with complex systems and large amounts of data.

The third stage of the research involves experimental teaching and application of HTML 5 tools to form computational thinking skills.

4. Results

4.1. Clarification of basic concepts

The authors propose the following approach to the definition of computational thinking: this is a thought process that consists in the sequential execution of a set of actions: activation of a system of object images and connections between them from a person's memory for a specific subject area; problem setting taking into account the uncertainty of the future; development of a solution algorithm and its effective implementation using digital technology tools. The proposed approach takes into consideration all the characteristics that determine the essence of computational thinking.

In addition, we claim that the specialist of the future with developed computational thinking skills should be prepared to carry out activities to design, create and use innovative information and computer technologies to solve a wide range of research, technical, economic and managerial tasks. Based on the requirements of society, the state and business, we reasonably conclude that highly qualified personnel of the digital economy should be ready to use software information processing tools (including gamification services) in their research and design developments. The most important in such training is the use of digital technologies in order to gain the necessary experience, to apply it in practice.

The proposed approach to include digital gamification resources is focused not just on the development of practical techniques, functional capabilities of game mechanics, computer game technologies, but on the definition of a methodologically sound scientific base.

The game world of educational purpose in the framework of the given research will be considered as a digital model for solving a problem-based educational problem built on the principles of game mechanics.

The synthesis of scientific and theoretical knowledge and the applied nature of the development of the game world for educational purposes will support a competitive digital school graduate under the conditions of uncertain future when they get oriented in promising innovative developments, acquire and effectively apply them while solving a wide range of tasks.

4.2. Educational and cognitive activities for the design and development of computer games for educational purposes

To form computational thinking skills by means of digital gamification resources, the HTML 5 language was chosen. Technically, it is not just a formalized way of writing an algorithm according to certain rules and syntax. Moreover, it is not just a set of commands, operators, and their values. Methodologically, it is an additional language that represents the content of the virtual space, which is intuitive, emotionally attractive to the user (the student of the generation Z). This content may include images, videos, animations, and communication tools. In practice, HTML 5 makes it possible to link the transmitted information for educational purposes with the channels of perception. As a result, there is a powerful didactic effect. Through the game activity of manipulating virtual objects, a student carries out educational and cognitive activities and receives skills that are in demand in the digital society of the present and future.

Figure 1 gives an example of an implemented gaming educational space focused on the development of computational thinking.

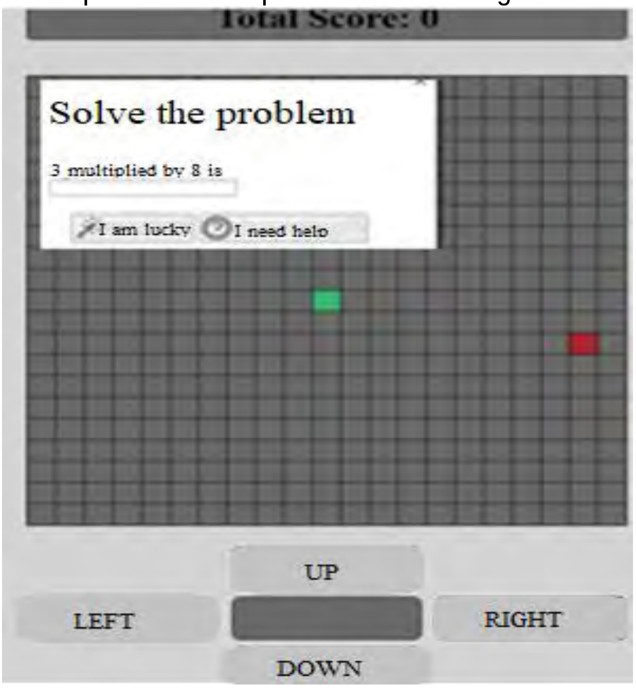

Fig. 1. Mathematical game for educational purposes

During the implementation, both didactic principles and game mechanics were taken into account.

1. Consistent material (splitting complex tasks into simpler ones without losing motivation to study a particular topic).

2. The principle of gradual complication. Students are involved while doing simple tasks. In order for the user to see progress while being in a dynamic state of thinking, it is necessary to gradually increase the complexity of tasks. Only in this case, educational, cognitive and mental activity, expressed through a sense of progress, will give pleasure, involve in the game educational space. At the same time, the number of simple tasks should be limited to avoid a quick loss of interest and make the students realize that they need to make efforts to achieve the desired goal. The latter can be not only ratings, points, awards, but also the social status, recognition in the group.

3. Puzzle type tasks which seem difficult at first glance, but suggest an obvious solution. The HTML and CSS code in this case can be publicly available, but the students need to choose the appropriate commands/operators to solve the puzzle. Most theoretical problems look differently and motivate the search, scientific discovery.

4. Instant feedback assuming that the student receives an immediate program response after running the code. This reaction can be implemented through the output of the result, receiving a message, a visual effect, etc. The principle implemented allows reducing the cost of error when writing code since the participant works in small iterations while completing the task. In addition, there is also the effect of professional orientation. Indeed, the student gets a practical experience similar to that of programmers. The skills of step-by-step program detailing, debugging and testing are formed. As for the methodological complexity, it should be noted that the student can spend a large amount of time when the problem solving method is already clear.

5. Storytelling game mechanics which involves combining a system of tasks with a common idea or scenario for educational purposes. For example, when studying the rules for calculating derivatives in a mathematics course, after completing all the levels and tests of the game world, participants receive a Reminder. As a result, complex theoretical material is supported by an emotionally attractive game situation (e.g., to save the world/girl and become a superhero).

6. The principle of awarding points, changing the rating to increase the status in the game space. All the researchers on the problem of education gamification previously mentioned necessarily note this condition. The desired didactic effect is achieved only when it is performed.

7. Open Profiles game mechanics which allows community members to view other students' the profiles. Such access makes it possible to maintain competitiveness, compare achievements, motivate and encourage new knowledge.

Thus, the given system of actions for the development of a game educational space allows forming computational skills, gaining experience in project research activities; using theory to solve applied problems; simulating work in popular professions. Therefore, a digital school graduate becomes competitive and as prepared as possible for the challenges and uncertainties of the future.

The use of HTML 5 in the design and development of the game educational space not only corresponds to the priorities of digital technologies, but also convincingly shows the didactic potential of game mechanics, for the formation of computational thinking in particular.

The obtained conclusions about the didactic potential of digital gamification resources in terms of improving the quality of learning and the formation of computational thinking are confirmed by M. M. Klunnikova (Klunnikova, 2019). The significant result of the research is the description of the basic ideas of the approach that expand the ideas of J.C. Paiva, J.P. Leal, and R. Queirós (Paiva et al., 2020 Paiva et al., 2020) about the possibilities of languages and programming tools in the development of such thought processes as decomposition, abstraction, pattern extraction, and algorithm development.

4.3. Experimental evaluation

4.3.1. The ascertaining stage of the experiment

At the first stage of the experiment, the materials of the special test were used to assess the input conditions taking into account the priorities of the digital society, the competencies of the atlas of new professions. All questions and tasks were developed by the authors in accordance with the requirements of the State Federal Educational Standard. In the test, students were asked to solve 5 problems. If the student solved each problem correctly and completely, they received 3 points.

1. During the distance learning period, student N. completed a task on mathematical logic and sent it to the teacher for verification. After some time, the teacher sent a response letter which said that some lines in the sent document took the wrong place and the table was incomplete. To the great misfortune of student N., the file with the completed task was not saved on his computer. The task is to help the student recover the information so that they do not have to complete the task again. In the answer, you should write down the letters x, y, z, w in the order corresponding to the columns.

2. Vasya N. is going to visit the buildings of the Vyatka State University. When moving, he leaves a trace in the form of a straight line. The actor has a fixed set of commands (with their description). Vasya N. is next to building 1 (at the origin). Vasya N. is given the following algorithm: to move by vector (5,2); to move by vector (-3, 3); to repeat 3 [to move by vector (1,0)]; to move by vector (3, 1). At what distance from building 1 will Vasya N be after performing this algorithm?

3. The cash register in the canteen of building 14 works according to the algorithm given below, where s is the number of purchased dishes, n is the number of apples that are attached to these dishes. The task is to determine at what the smallest number of dishes you can get 64 apples.

4. To store the bitmap image "Group PODb-5301-60-00", 128×320 pixels, 20 Kbytes of memory are given without taking into account the size of the file header. The same number of bits is used to encode the color of each pixel, and the pixel codes are written to the file one by one without gaps. What is the maximum number of colors you can use in the image?

5. Using the text editor, determine how many times, not counting footnotes, the word "must" or "Must" occurs in the text of the Federal State Educational Standard of basic general education. Other forms of the word "must" should not be taken into account. In the answer, specify only the number.

The maximum possible number of points was 15. If the student received more than 13 points, the level of the skills under study was defined as "high"; the range from 6 to 12 (inclusive) corresponded to "average", according to the rest of the results, the "low" level was registered.

Thus, we managed to collect experimental data on 40 students, 01.03.02 training program, Applied Mathematics and Computer Science. As a result of the entrance control, almost the same initial level of readiness of students participating in the pedagogical experiment was revealed. We can consider them as a total sample of 40 people. Therefore, the experimental (20 students) and control (20 students) groups were formed. Describing the sample, it should be noted that the experimental group consists of 58 % of females and 42 % of males.

4.3.2. Forming stage of the experiment

At the forming stage of the experiment, the teacher analyzed the requirements of the digital economy for the training of students of engineering and technical areas. The provisions of the current State Federal Educational Standard determine that within the framework of general professional competencies a student must be able to consult and use fundamental knowledge in the field of computer science in professional activities; find, analyze, implement software and use mathematical algorithms in practice, including the use of modern digital technologies.

Taking into account the specified requirements for the level of computational thinking skills, the following levels were defined.

The "high" level implied that the student was independent in setting the problem, identifying objects, phenomena and relationships between them in the subject area of the research problem; compiled information, mathematical and computer models without errors; applied the method of step-by-step detailing when compiling the algorithm, performing the necessary analytical and synthetic operations; technically competent and rational approach to writing the algorithm in the software; critically evaluated the result and made appropriate adjustments to the solution model.

The "average" level was registered if the student could formulate the problem at the required level of abstraction, identify the modeling objects and their essential properties only with third-party help; made one or two non-critical errors in modeling; the technical implementation of the algorithm was not optimal, but led to a solution; could not always critically evaluate the result, but when indicating shortcomings, made appropriate adjustments to the model.

In all other cases, the level of computational thinking was defined as "low".

Further, in the control and experimental group, Game Theory classes were held, educational and work experience internship was organized to obtain professional skills.

The students of the experimental group were offered possible topics of projects for the development of game worlds for educational purposes ("Quest for Future Professions", "Flying Dutchman", "Journey to Netland", etc.), from which they chose those that met their professional aspirations, cognitive interests, abilities, educational achievements. They started to implement the program after studying the relevant theoretical material not only on game theory, but also on the principles of didactics. Further, they studied the specifics of the HTML 5 language, the software implementation of algorithmic constructs. They were given one to two months to implement the concept/idea of the computer game for educational purposes.

For the control group, training was conducted in the traditional mode: the study of the basic concepts of game theory and constraints related to mathematical formalization; strategies and game mechanics. Further, the students solved classical problems (matrix and bimatrix games; cooperation in games with a discrete set of strategies, games with continuous strategies; Cournot, Bertrand, Stackelberg' games, etc.). The tasks to compile information and computer models, to implement them using the programming language were completed. Analysis and discussion of the results were compulsory.

4.3.3. Control stage of the experiment

At the control stage of the experiment, a repeated measurement was carried out – a test paper including 5 tasks, each of which was evaluated by 3 maximum points. The level of the computational thinking was determined using the criteria mentioned above.

Statistical analysis of the reliability of the results of the pedagogical experiment was evaluated using Pearson's χ2(chi-square).

Let us formulate the hypothesis:

H0: after the internship in designing and developing computer games for educational purposes by means of gamification resources was included in students' educational and cognitive activities, the level of the computational thinking skills remained unchanged.

H1: the level of the computational thinking skills has increased.

Table 1 contains the results of the measurement before and after the experiment for the students of the control and experimental groups.

We calculate the value of the criterion statistics before ($\chi2_{ob.1}$) and after ($\chi2_{ob.2}$) the experiment using the online resource http://medstatistic.ru/calculators/calchit.html. We choose the significance level $\alpha = 0.05$. In this case, c = 3, so the number of degrees of freedom $\nu = c - 1 = 2$. According to the distribution tables, χ^2 for $\nu = 2$ and $\alpha = 0.05$ the critical value of the statistics is 5.99. Thus, we get: $\chi2_{ob.1} < \chi2_{crit}$ (2.63 < 5.99), a $\chi2_{ob.2} > \chi2_{crit}$ (7.14 > 5.99).

Table 1. The results of the test

Level	The number of tested (people)			
	Experimental group (20 students)		Control group (20 students)	
	Before	After	Before	After
High	1	6	1	1
Average	7	13	12	13
Low	12	1	7	6

According to the decision-making rule, this means that before the experiment, the hypothesis H0 is true, and after the experiment, the hypothesis H1 is true. Therefore, H0 is rejected and the hypothesis H1 is accepted. In other words, designing gaming educational space by means of digital gamification resources has contributed to the development of computational thinking.

5. Discussion

The sample of students was not probabilistic since the experimental and control groups were formed in such a way that each group had the same skills and personality qualities which form the basis of computational thinking, and their equal distribution. For diagnostics, the results of the input control were taken into account. The selection of participants for the experiment and the sample size are justified by the specifics of the research: the study of game theory, the principles of gamification and their implementation by means of digital technologies is included in the training program for a limited number of specialties. Throughout the experiment, the work on the design and development of the game educational space using HTML 5 was carried out by the same teacher, on the same software in special classrooms. During the implementation, both didactic principles and game mechanics were taken into account.

In general, the dynamics of the values by level indicates a qualitative improvement in the learning indicators and the formation of the monitored personality qualities in the experimental group (see Figure 2).

Performing a quantitative analysis of the given results, we can conclude that after the experiment was completed, 33 % of the students in the experimental group had a high level of skills that form the basis of computational thinking, while initially this percentage was 13 %. The share of students, the level of computational thinking, which was initially determined to be low, qualitatively decreased from 62 % to 20 %. It can be stated that the majority of such participants are those respondents who initially had an average level, i.e., they made mistakes in analytical work, at the decision-making level, writing code, and evaluating the result.

The dynamics of changes in the control group is less significant. Thus, only 20 % of the control group students at the control stage of the experiment had a high level of computational thinking skills. Initially, this percentage was 15 %. The share of students, the level of computational thinking, which was initially determined to be low, qualitatively decreased from 5 8% to 44 %.

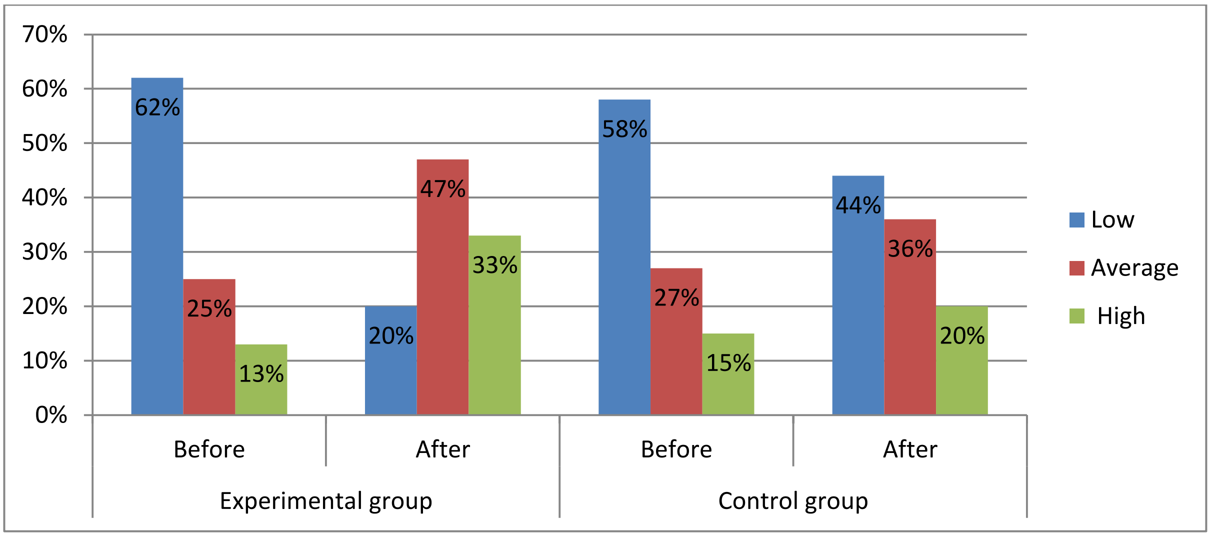

Fig. 2. Dynamics of changes in the level

Thus, the described system of actions for the development of game educational space allows forming computational skills, gaining experience in project research activities; using theory to solve applied problems; simulating work in popular professions. Therefore, a digital school graduate becomes competitive and as prepared as possible for the challenges and uncertainties of the future.

6. Conclusion

The study presents the solution to the problem caused by the need to expand the goals of the education system, update the tools and methods based on digital technologies. The corresponding digital learning environment should facilitate the activation of a sequence of images from a person's memory, support the process of problem setting, and develop an effective solution algorithm. In order to form the appropriate computational thinking skills, the authors propose to include the internship in developing game educational spaces by means of digital gamification resources in the system of students' activities.

We described the sequence of game educational and cognitive actions which involves the experience of mathematical modeling, designing and creating one's own software product. Scientific and theoretical facts, mathematical laws and methods, logic, game theory, etc. as presented are the necessary fundamental basis for high-quality training of a competitive professional of the future. Students activate their cognitive abilities, understand the fundamental scientific principles that constitute all digital technologies.

In the presented system of educational and cognitive activities for designing a virtual game world, it is important to obtain up-to-date information on advanced technological developments, digital tools and resources; their reasoned choice, effective application at a high technical level; analysis of the result obtained and its practical application.

Software and technical support is provided by the description of the work using the HTML 5 language. The effectiveness of the proposed approach is proved by the pedagogical experiment.

The paper summarizes the conditions that affect the formation of computational thinking: obtaining relevant scientific and theoretical facts, patterns, information on innovative methods and tools; their reasoned choice, effective implementation at a high technical level; analysis of the result and its practical application. Computational thinking uses a special method of problem formulation and applies principles such as abstraction, decomposition, generalization, and pattern recognition to solve the problem.

Thus, while designing and developing educational game projects, students gain computational thinking skills. They learn how to use computers to solve problems of an applied nature, make informed decisions with the help of digital resources. In the digital age, it is necessary to develop students' computational thinking since it is an important competence that determines success and professional personal fulfillment in the modern technological society.

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