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Didactic Value of Gamification Tools for Teaching Modeling as a Method of Learning and Cognitive Activity at School

Elena V. Soboleva [1*], Elvira G. Galimova [2], Zhumagul A. Maydangalieva [3], Khalimat Khadzhi-M. Batchayeva [4]

[1] Vyatka State University, Kirov RUSSIA
[2] Kazan (Volga region) Federal University, Kazan, RUSSIA
[3] S. Baishev Aktyubinsk University, Aktobe, REPUBLIC OF KAZAKHSTAN
[4] Karachay-Cherkessian State University named after U.D. Aliev, Karachaevsk, RUSSIA

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ABSTRACT

The relevance of this article is determined by the possibility to increase the efficiency of teaching modeling at schools by means of involving modern gaming and educational platforms in students' cognitive activity. The problem of the study results from the contradiction between the broad potential of the gamification tools to motivate and involve students in modeling, to improve their skills, and the ideas of the general methodology about gamifying the educational process as well as the lack of well-designed techniques and methods of using the appropriate software to teach modeling at school. The purpose of the study is to define the didactic value of the gamification tools used to teach modeling at school and to develop a methodological approach to the structured lesson planning using computer game instruction technology. The article describes the types of schoolchildren activities, which allow the use of gamification tools for modeling, to develop schoolchildren's research skills and the ability to use modern tools to solve theoretical and experimental problems. It describes methodological methods and recommendations on organizing information and pedagogical interaction between the participants of the educational process by applying educational programs available on gaming platforms both at the level of personal communication between the teacher and the student, and at the level of the tripartite "teacher-student-computer" interaction. The results of the study can be used, firstly, to change the techniques and methods of teaching modeling at school; secondly, to improve conventional training programs included in the curriculum for university students of pedagogical departments and faculties; thirdly, to develop and improve specific educational programs in various subjects on the gaming platforms for schools in order to improve the quality of education, social integration, and career orientation.

Keywords: computer game, gamification, tools of gamification of education, teaching modeling at school, activity-based approach to the educational process

INTRODUCTION

Relevance of the Research

The most important condition for the effective organization of the educational process, as it is stated in the works of outstanding teachers and psychologists such as Vygotsky (1999), Galperin (2005), Granitskaya (1991), Rubinstein (2002), Kholodnaya (2015) is creating conditions for students' personal growth, training their cognitive skills and

✉ sobolevaelv@yandex.ru **(*Correspondence)** ✉ elyagalimowa@yandex.ru ✉ maydangalieva@mail.ru ✉ halimat56@mail.ru

Contribution of this paper to the literature

- The study has identified possible ways of applying modern gaming platforms and educational programs to gamify teaching modeling as a methodological tool which can contribute to improving the efficiency of the training process.
- Specific materials which can improve the content and technologies for teaching modeling at school by means of computer educational games (training programs on gaming platforms) are suggested.
- The methodology of gamification in teaching modeling is suggested; it motivates students to become more active in the cognition process, develop their research skills taking into account the specifics of the procedure component of the training process in which computer educational games are used in conditions of forming a new gaming style.
- The study has identified the peculiarities of the preparation process, of conducting modeling lessons which apply gamification tools, the problems connected with assessment of the developed projects by the teacher, as well as the difficulties the teacher may face while using specific gamification tools.

abilities, that is, creating conditions for cognitive development in terms of its value, worldview, intellectual, and activity-methodological aspects.

Studies by modern Russian scientists Leontiev, Lebedeva, and Kostenko (2017), Robert (2014), Trofimov (2017), Tyumeneva and Shkliaeva (2016), Potaturov (2015), Aleshchanova et al. (2017) describe the role and influence of modeling as a training method on the development of the child's thinking. Different systems, methods, techniques, and pedagogical technologies are based on the above idea; they allow the educational process to be organized in such a way that knowledge acquisition and skills acquiring are not its ultimate goal, but serve as instruments for personal development, the child's becoming a cognizing subject, capable of enriching the accumulated intellectual resources throughout life, adapt them to the changing life conditions, and use them to achieve different goals (Ursul & Ursul, 2015). Nenashev, Okulov and Yulov (2012) define modeling as a type of learning and cognitive activity (during which schoolchildren analyze the text of the task, translate information from one representation of language into another, build a model and explore its properties, work with the model to make it more detailed). According to their studies, learning to model creates conditions for intellectual development of an individual:

- didactic potential for a pupil to be active in cognition;
- a possibility to implement the activity-based approach;
- higher level of independence of cognitive activity;
- convergence of the learning process with the process of real cognition.

Pedagogical ideas and technologies for teaching modeling have received a lot of attention in nowadays in the scientific world, when the computer and different information and communication technologies have become included as educational tools in the educational process (Robert, 2014).

Vasenina and Soboleva (2013) have shown that it is possible to combine practical transformational activity (manipulating an object, examining the model) and theoretical activity (mental actions) when teaching modeling, since the examined object is of the informational type: it is a model which is being developed, the computer program (software), the information environment, or the information product created in this environment, i.e. a text document, an electronic table, an electronic database and others. Although these are cyber objects and models, the cognizing individual can influence them, manipulate them, create certain conditions for them, watch the reaction and the changes that occur. What is more, such activities are based on a serious theory, fundamental science, and the more fundamental the knowledge necessary for transformation of the object and obtained in the course of work is, the more interesting and valuable experience it is to work with the object (Yakimanskaya, 2011). On the one hand, transforming information objects and working with the model requires performing complex mental operations, thus close relation of informatics to mathematics and language is manifested. On the other hand, the computer makes it possible to take practical actions, manipulate the object and experiment on the model, which brings informatics closer to practice-oriented disciplines (Chubik et al., 2013).

Synthesis of studying fundamental concepts, principles, and regular patterns with the activity approach to teaching modeling produces the best results if the research model corresponds to the fundamental knowledge which should be acquired in the process of studying the universe associated with the information processes (Mayer, 2016; Rozhina & Baklashova, 2018). A computer program is the most appropriate object in this respect. This information object has a quality of complexity and a high level of abstraction, therefore to develop it, it is necessary to know some fundamental informatics concepts (object, system, structure, model, algorithm, etc.) and methods of scientific knowledge (modeling, experiment). While creating a computer program, the pupils acquire such intellectual skills as structuring, planning, forecasting the results of their activities, searching for information, classifying, reasoning, etc. (Beshenkov et al., 2016).

Gamification is seen as one of the innovative technologies which are going to have a significant impact on education in the most technologically developed countries of the world (Dichev, 2017; Lebedeva et al, 2018), and it is considered one of the new approaches which can bridge the gap between the generation of teachers and the generation of students (Kapp, 2007). It is in these contexts that experts appreciate the universal character of gaming used in the classroom, as homework or final testing, or used as the main learning activity to motivate students, improve their skills and quality of education, including when teaching modeling (McVey, 2013).

Let us highlight the opportunities provided by gamification tools when working with the model which can be useful in training:

- reasonable, strategic and appropriate use of gamification elements when training modeling can create a learning situation characterized by increased student participation, which, in turn, leads to positive changes in the cognitive, emotional and social fields (Brull & Finlayson, 2016);
- gamification elements can actually increase the level of internal motivation, since they help to make boring tasks interesting (Cakiroglu, Basibuyuk & Guler, 2017);
- gamification in working with the model makes it possible to increase the student's engagement in the modeling process. The engagement is seen as the student's attention to the task and the student's absorption in the task, although the tasks are given by the teacher (Maloshonok, 2016; Su, 2017);
- gamification develops problem solving skills by means of a complex system of rules that encourages active research and discovery while learning modeling (Polyakova & Kozlov, 2015);
- gamification makes it possible to "reconsider making mistakes as a necessary part of learning" because a mistake provides an opportunity to try, to practise and improve the model (Sokolowski, Yalvac & Loving, 2011);
- repeated failures in studying the model allow one to learn something different and new (Chou, 2017);
- the social character of gamification environments that allows students to socially identify themselves, increase social activity, and appreciate the achievements which otherwise might have remained unnoticed (Borisenko, Yatsenko & Chernykh, 2016).

Each of these attributes can bring not only undeniable advantages contributing to achieving the goals of the educational process, but they can also have a significant negative impact on the educational process (Grigoriev, 2016). It is important to note that the opportunities provided by the new tool are not created by themselves. It is necessary to select appropriate instructional methods, to change the structure of the lesson in favor of activating the cognition process, implementing the experiment, and organizing the cognitive activity of students on gaming platforms and educational services.

At present, most of the existing games do not meet the requirements of teaching modeling at school, so they can be only partially included in the educational process: at a particular stage of working with the model, or to develop mental processes: thinking, memory, attention and imagination (Aykac, 2015; Duvanov, 1989; Luchenkov, 2016). It should also be mentioned that software developers of programs having the potential for learning modeling, in most cases, do not discuss the form and content of the resources with their end-users: school and university teachers (Babintsev et al., 2016).

The analysis of domestic and foreign studies indicates weakness of the psychological and pedagogical principles of the development and implementation of gamification tools in educational and cognitive activities in modeling. This leads to a problem that manifests itself in the necessity to implement the didactic potential of gaming tools for motivating and involving the students in the modeling task and improving their skills. It is important to expand the understanding of the general methodology for gamifying the educational process and develop the gamification techniques used to teach modeling at school.

Research Goal and Tasks

The goal of this research is to elicit the didactic potential of gamification tools for teaching modeling at school and to suggest a methodical approach to the structured planning of a lesson using the computer game technology.

The main tasks of the research are the following: studying the experience of incorporating the tools for gamifying education into educational and cognitive activities in modeling at school; identifying the types of schoolchildren activities which allow applying gamification tools to teach modeling, developing research skills and abilities to use modern tools when solving theoretical and applied problems; suggesting methodological techniques and recommendations on the organization of information and pedagogical interaction between the participants of the educational and cognitive activity in modeling applying educational programs available on gaming platforms both at the level of personal communication between the teacher and the student, and at the level of the tripartite "teacher-student-computer" interaction.

LITERATURE REVIEW

Many outstanding educators and psychologists, such as Vygotsky (1999), Galperin (2005), Kholodnaya (2015), Yakimanskaya (2011) acknowledge an important role of modeling as an educational and cognitive activity in shaping the skills of identifying the main relations and patterns, manipulating with the properties and characteristics of the object, and combining them as a whole. Robert (2014), Borisenko, Yatsenko and Chernykh (2016) also argue that it is well-developed creative thinking that can enable individuals to easily adapt to the changing conditions and successfully identify themselves and realize their potential in the modern information environment.

Polyakova and Kozlov (2015) as well as Potuturov (2015) demonstrated that the school information-educational environment, rich in computer technologies and software, has a rich didactic potential for the formation of personal qualities and skills mostly required in the modern society. At the same time, many scientists like: Vasenina and Soboleva (2013), Luchenkov (2016), Maloshonok (2016) highlighted an important fact that is, new technical training tools should be used for transition from the empirical type of training based on passive perception of the material to the developmental type of training, in which the main role in the educational process is played by the active cognitive activity of the student.

Modeling as a kind of educational activity receives breakthrough instructional tools in such conditions (Vasenina & Soboleva 2013): as well as software, virtual laboratories, computer constructors and simulators, etc. Robert (2014), Trofimov (2017), Tyumeneva and Shkliaeva (2016) took a close look at the use of information and communication technologies to increase the efficiency of teaching modeling at schools.

Employing the ICT tools for modeling as a method of scientific knowledge makes it possible to enrich and expand the range of objects of study: the computer as technical equipment and a model, the software itself, computer networks, programs, graphics, tables, etc. Robert (2014), Chubik et al. (2013) place a special emphasis on new types of independent educational and cognitive activity which make the essence of modeling: analyzing the text of the task, acquiring information and transforming it from one form of representation into another; creating an information model and working with it, etc.

It is worth mentioning that in teaching modeling with ICT tools, it is necessary to distinguish between the procedure and content components of organization of this educational and cognitive activity (Robert, 2014).

According to Vasenina and Soboleva, (2013), the procedure component of an educational and cognitive activity means that students:

- can identify specific properties of the object of modeling that are essential for the purpose of modeling (the object is understood to be any object, process or phenomenon);
- create a model, which reflects the essential properties of the object;
- test the model in real and artificial conditions;
- find out if the model corresponds to the object of modeling;
- assess the extent to which the purpose of modeling has been achieved.

The content component is determined by the object of modeling which can be represented as:

- an activity as a series of actions which can be formalized (the model is an algorithm described in a natural or formal language);
- economic relations, mathematical patterns (the model is an electronic spreadsheet with formulas and functions, or a database);
- information on an electronic medium in the form of files (the model is a structured system of files and folders on the disk drive);
- events and facts (the model is represented as expressions composed of logical statements and truth tables).

In addition, the right choice of an appropriate software tool is also quite important for developing skills of designing and studying the model. Text processing programs, spreadsheet graphic editors, presentation creation tools, different programming languages and environments are used in teaching modeling at school (Robert, 2014).

At the same time, the requirements of the society, the state and the education system are changing, which is reflected in the educational standards. New challenges require the learning process to be more focused on the personality of the learner and the changes that occur to it during the learning process, but not just on the accumulation of knowledge (Robert, 2014). In practice, however, these challenges are faced in conditions of the traditional classroom lesson system, though enriched with new tools, methods and forms of instruction, but aimed at giving the children a fixed amount of information within 45 minutes of the lesson (Soboleva, Karavaev, & Perevozchikova, 2017). Therefore, there are studies which urge to reorient the process of providing educational information to solve the fundamental task of individualizing the learning process (Grigoriev, 2016; Soboleva et al.,

2017; Ursul & Ursul, 2015). To achieve this, computer games and online game format services are now included in the school system of education (Grigoriev, 2016). For example, the "Uchi.ru" resource in Russia is used to work with numerical information; the gamification tools on the "Yotx.ru" website gives a possibility to work with function graphs, to design mathematical models in the form of formulas; iSpring provides tools to carry out an independent research activity in teaching modeling (Maloshonok, 2016; Soboleva et al., 2017).

Although there are quite a lot of study aids and software packages Soboleva and Karavaev (2017) aimed at employing game elements in educational activities, "Robotlandia" is one the best elaborated resources from the point of view of methodology, gamified modeling teaching, and the formation of appropriate skills (Duvanov, 1989). This training complex offers training at two methodologically worked out levels. A computer, a text, a picture, a text, a graphic and music editor, information interaction space (for example, a chess field) serve as models at the first level. At the second level, children work with more complex information objects: labyrinths, algorithms, programs, black boxes (Bukvoed). Then one can proceed with "AziInformatiki" (Basics of Informatics), an electronic interactive platform for schoolchildren, where cognitive reading is combined with working on numerous simulators, performers, testers and constructors, it is also accompanied by controlling and testing in test rooms, and all these within a single hypertext browser. However, the drawback of this resource is that it is based only on the basic course of computer science; it cannot be applied to teach other school subjects. And unfortunately, it does not meet modern requirements (Grigoriev, 2016).

The revolutionary idea of Papert (1980) that a computer is only a tool which can make teaching (or more precisely, learning) more interesting, fast, and simple allows us to consider the learning environment as a concept of microcosms which are, in fact, models of the real world which children create themselves in a more or less detailed degree (Soboleva, Karavaev, & Perevozchikova, 2017). This idea justifies the necessity to use computers in teaching the humanities at school. Logo environment has been developed to support this idea. The didactic potential of this resource cannot be overestimated: there are tools to model physical phenomena, processes of interaction and activities of several objects, etc. Logo helps to visualize historical events, geographical discoveries, and biological connections. And the most surprising thing is that the gaming resource helps to study such important fundamental concepts as: performer, instruction code, algorithm, method, magnitude. The most valuable idea, in the context of this research, is that this environment allows us to teach children by studying artificial intelligence (Kholodnaya, 2015). The latter is especially important as it helps students to vividly imagine their own thinking processes.

These ideas have been developed in other software educational tools, used in teaching modeling in the game format. Scrath should be mentioned in the first instance (Soboleva, Karavaev & Perevozchikova, 2017). This visual object-oriented programming environment was originally developed to be used in teaching junior and middle school students, but Scratch potentialities are so diverse that it allows teachers to create comprehensive educational programs (Soboleva & Perevozchikova, 2017). The didactic potential of Scratch in teaching modeling can also be realized at any school subject. One can create virtual worlds in literature, physics, music, etc. designing game educational projects (Soboleva, Karavaev, & Perevozchikova, 2017).

The necessity to integrate gamification tools in educational and cognitive activities in order to develop research skills of an individual is discussed in the works by Koroleva (2016), Maloshonok (2016), Polyakova and Kozlov (2015), however the issue still does not have a comprehensive methodological solution.

The first problem faced by a particular subject teacher who intends to incorporate the gaming technology in the educational and cognitive activity is choosing a software tool that satisfies gamification requirements and has the maximum effect in terms of achieving the learning objectives. The solution to this problem is suggested in the work by Soboleva and Karavaev (2017). A detailed analysis of computer services and platforms has been carried out. The following criteria have been taken into consideration: whether it is easy to master (for subject teachers who are not specialists in the technical aspect of the program) and easy to use in teaching; if it has a Russian interface; if the service is paid or free; what is the range of functional capacities of the community. The analysis has identified some gamification platforms and services which more or less correspond to the gamification principles; they are Scratch, Kodu, Quandary, and some others.

Another methodological problem is the necessity for appropriate teacher training with regard to mastering the functional capacities of gamification tools. The solution to this problem is suggested by Soboleva and Perevozchikova (2017) who illustrated it with the case of developing a game educational project in the Scratch programming environment. However, surveys and questionnaires conducted with schoolchildren and students of teacher training faculties have shown that a possibility to work in a software environment with the 3D-game developing tools is of greater interest and a better incentive for modeling (78% of respondents). The results of questioning demonstrate that such modeling environment presupposes realization of the creative potential of students, development of their thinking abilities, a higher disposition to analyze the situation and to a non-standard approach to solving various problems. "Kodu" turns out to be of the greatest interest (64% of respondents) for students. One of the reasons for choosing this gamification tool for teaching modeling is that Kodu Game Lab is a

3D gaming modeling environment that meets the students' needs (https://www.kodugamelab.com). The latter can be used to correctly set the motivation task, to design a system of educational problems. Another reason, as we see it, is that systems of lessons or series of lessons devoted to the solution of a specific modeling problem are inadequately designed from the point of view of methodology.

In Russia, the studies on this issue often only enumerate the main potentialities of the program and discuss some assumptions regarding the use of the visual constructor in the learning process, for example that "learning based on Kodu Game Lab can contribute to the achievement of the educational results" (Chubik et al., 2013). It is also worth mentioning that in the works discussed, Kodu is supposed to be used in out-of-class activities.

Thus, this study is focused on the methodological peculiarities of gamification of the learning process with Kodu Game Lab tools. The developed parts of the lessons are aimed at teaching modeling during lessons at school; therefore they include monitoring of how well the material is learnt through follow-up questions and individual tasks.

Emerson, English, and McGoldrick (2016), Papert (1980), Rogoff and Morelli (1989) highlighted in their works the importance of educational and cognitive activity in modeling in the development of the child's thinking. Different approaches to teaching modeling at school, the didactic problems and methodological experience in different school subjects are discussed in the studies by Akwee, Toili, and Palapala (2012), Edwards & Head (2016), Kubiatko et al. (2010), Manz (2012), Sokolowski, Yalvac, and Loving (2011).

There are interesting developments devoted to learning based on "experimental fumbling", independent discovery by Freinet (1950). Foreign scientists, such as Denning et al. (1989), Papert (1980), Scanlon (2010) and others, have made a great contribution to the description of the influence of education computerization on the intellectual development of schoolchildren, on their cognitive activity. Studies by Kuznetsov and Beshenkov (2005), Papert (1980), Husen and Tuijnman (1991) are of significant importance for understanding the role of the computer used as a learning tool to develop creative thinking; they also stress the importance of developing research skills, admit the didactic potential of training based on working with information models.

In modern learning methodology, a lot of attention is also paid to the description of trends in teaching modeling, studying the changes in the learning process which occur when computer technology is introduced, and the conditions for improving the efficiency of the learning process (Kelly, Koates, & Naylor, 2016). For example, the didactic potential of web-based tools and computer simulations used to teach modeling is described (Aykac, 2015; Jacobson, 2006; Mayer, 2017). A special attention is given to the possibilities created by Internet technologies for organizing the research activities, working with information (Robert, 2014). Information systems which take into account the principles of personalized learning have been worked out. For example, an interactive educational environment paying special emphasis to different cognitive styles is presented in the paper by Hamada and Hassan (2017).

Faiella (2015), Hasegawa, Shibasaki, and Ito (2015) highlighted the necessity to modify the learning process in line with the new challenges to the education system. One of the options suggested is gamification of the educational and cognitive activities (Deterding, Kahled, Nacke, & Dixon, 2011).

Analyzing various definitions of the term "gamification" in foreign studies Deterding et al. (2011), Llorens-Largo, Gallego-Duran, and Villagra-Arnedo (2016), Marti-Parreno, Mendez-Ibanez, and Alonso-Arroyo (2016), one can see the agreement among the scientists who consider gamification as an approach employing gaming functions (elements, mechanics, frames, aesthetics, thinking, metaphors) in non-gaming situations. The term gamification is used in relation to many aspects – the ubiquity or universal character of the computer and video games in everyday life; the necessity to arouse and support students' interest in learning – in order to attract the users and encourage them to achieve more ambitious goals, to follow the rules, and to entertain. Gamified modeling activity is accompanied by active students' involvement in the task, their higher motivation (Su, 2017). In addition, all stages of modeling have a visual representation, so knowledge, skills, thinking of students are developed through the gradual development of the gaming space.

Thus, the use of the described software provides the possibility to incorporate gaming elements into a non-gaming context if there is appropriate methodological support (Deterding et al., 2011). In other words, the teachers get at their disposal a range of tools to enhance the users' engagement; it consists of gaming elements and techniques, and there is no need to change the modeling learning activity itself (Semenov, 2017). In fact, it is gamification of the educational process. Thus, we have determined the potential value of gamification tools in teaching modeling.

Cózar-Gutiérrez and Sáez-López (2016), McVey (2013) gave examples of successful projects of gamification in education. For example, Cózar-Gutiérrez and Sáez-López (2016) describe in detail the methodological experience of using the *MinecraftEdu* constructor. Pennington and McComas (2016) emphasize the positive aspects of computer games which can be used to: train the skills of solving practical tasks, create conditions to develop independence in cognitive activities while modeling, enhance the teacher-student relationship, expand the range of tools for

constructing and studying information models, improving decision-making, and obtaining immediate feedback. Dichev and Dicheva (2017) emphasized the problems of methodological support of gamification of the educational and cognitive activities in the information environment, the necessity to take into account its negative impact on the content component of training (shifting the emphasis from the incentive to acquire new knowledge to the desire to score more points). They considered it important to use a wide range of methods balancing external and internal motivators (Bodnar & Clark, 2017; Dichev & Dicheva 2017) and develop the gamification methodology to ensure that all students in class can acquire and develop the research skills in comfortable conditions (Cakiroglu, Basibuyuk & Guler, 2017; Brull & Finlayson, 2016).

In addition, summarizing the results of numerous surveys and questionnaires, Cózar-Gutiérrez and Sáez-López (2016), made a conclusion that the main methodological problem for subject teachers is selecting a gamification tool, understanding the technical peculiarities of working with computer platforms and services, working out fundamentally new lesson plans (for example, designing the scoring system, looking for methods preventing distraction of students' attention). At the same time, the teachers are insufficiently trained to actively use all the methodological capabilities of modern services and facilities (Dichev & Dicheva, 2017; Kapp, 2007). Since this study thoroughly considers the methodological peculiarities of gamification in teaching modeling by means of "*Kodu Game Lab*", we should note that most of the articles devoted to the use of this visual designer in the training process contain methodological recommendations on using "*Kodu*" in extracurricular activities or working with video lessons (Kelly, 2013).

To maximize the didactic potential of gamification tools for teaching modeling at school, it is necessary to improve the methodology of gamifying learning, taking into account that it is primarily important to focus on those thinking qualities and skills that develop most effectively when working with the text of the task, transforming information from one language representation into another, creating a model, studying its properties and perfecting it.

This approach to teaching modeling will contribute to the development of the following skills of schoolchildren: being able to change the future outcome of the simulated situation depending on the efforts made; thinking of various options for the scenario development, as each scenario is not influenced by the past but depends only on the decisions of the participants of the situation.

MATERIALS AND METHODS

Theoretical and Empirical Methods

The method of analysis of the psychological, pedagogical, methodological and technical literature by foreign and domestic authors whose authority and scientific reputation are recognized by the scientific community has been used to determine the significance of modeling as a method of educational and cognitive activity. To determine the role of ICT tools in improving the efficiency of teaching modeling at school, the method of analyzing the projects developed by subject teachers in the field of teaching modeling at school, as well as scientific and methodological literature on the use of ICT tools in teaching modeling has also been employed.

The method of analysis of gaming platforms and educational services used to gamify the educational process in the context of the state and society requirements, and individual needs has been used to formulate the problems of gamification of education and to describe the specifics of the use of gaming computer technology based on modern software.

The method of systematization and generalization of facts and concepts has provided the possibility to formulate the main ideas of the method of gamification of teaching modeling, to suggest specific recommendations for teachers. The forecasting method helped to determine the didactic potential of modern gamification tools in school education, and to formulate a hypothesis regarding qualitative changes in learning outcomes. The method of mental experiment has been used to verify the ideas of methodology, practical ways and techniques of gamification of teaching modeling as a method of educational and cognitive activity of schoolchildren.

At the stage of the pedagogical experiment, empirical methods were employed: involved observation, questioning, testing, analyzing the outcome of the students' learning and cognitive activity. These methods have allowed the obtaining of information about real changes in schoolchildren motivation, their involvement in the modeling task, an increase in students' activity in cognition, development of research skills and skills of independent work with the model.

Research Base

The results of the research have been verified, generalized and implemented by:

- delivering the course in Technology of Creating Training Programs for students trained in the field of 02.04.01 Mathematics and Computer Sciences (first year of the Master's Degree) based on the materials developed by the authors; the course has been run since 2012, first at the Vyatka State University (Russia) and Kazan (Volga region) Federal University (Russia), Karachay-Cherkessian State University named after U. D. Aliev (Russia), S. Baishev Aktyubinsk University, Aktobe (Republic of Kazakhstan) (since 2016);
- delivering the course in Theory and Methodology of Teaching Computer Science for students trained in the field of Pedagogical Education (Informatics and English, 3-4 years of studies) based on the materials developed by the authors; the course has been run since 2010, first at the Vyatka State University (Russia) and Kazan (Volga region) Federal University (Russia), Karachay-Cherkessian State University named after U.D. Aliev (Russia), S. Baishev Aktyubinsk University, Aktobe (Republic of Kazakhstan) (since 2016).

Research Stages

There were three stages in the research.

At the first stage, an ascertaining experiment was carried out: the state of the problem of using modern gaming platforms, educational services for gamification of educational and cognitive activity in modeling at school was studied taking into account the state, society, and individual requirements. To do this, we carried out the analysis of psychological, educational, methodological and technical literature, computer educational games, gamification software in order to identify possible organizational forms of employing the gaming services and platforms in school education. In addition, the analysis of the methodological experience of teaching modeling at school, of using ICT tools to organize modeling activities was conducted to determine the didactic potential of the gamification tools in regard to teaching modeling.

The second stage was devoted to the development of methodological recommendations on the organization of information and pedagogical interaction between the participants of educational and cognitive activities in learning modeling in which training programs on gaming platforms are used, both at the level of personal communication of the teacher and the student, and at the level of tripartite "teacher-student-computer" interaction. The instruments that have a didactic effect and are mostly consistent with the idea of gamification of teaching modeling at school were selected. The discussion of the research results has been carried out in the form of reports at conferences and seminars at various levels, which provides for consistent improvement of teaching methods in computer science, physics and mathematics in practice.

The third stage was run in parallel with the second one; during it the experimental teaching was conducted according to the suggested methodology of gamification of teaching modeling, which takes into account the positive experience of domestic and foreign designers, serves as their development and aims at eliminating various methodological, technological and practical contradictions. In addition, a pedagogical experiment is being carried out, the results of which have already confirmed the efficiency of the developed methodology in improving the quality of the practice-transformational (manipulating an object, studying the model) and theoretical activities (developing mental actions).

RESULTS

The Fundamental Principles of the Methodology

Most often, the following logic of exploring the gamification tools in regard to teaching modeling is observed: students are asked to perform a series of tasks that are not connected by a common idea. The main goal of such classes is studying the interface, getting to know the basic concepts of the environment, mastering the tools and their functional capacities. This allows one to create a general understanding of the modeling environment, gain experience in creating a model and implementing it by means of the program, and develop the skills of working with the ready-made models with a quite large number of various tasks (Soboleva, 2012).

At the same time, the drawback of this approach is that students can experience considerable difficulties in developing their own game space due to lack of relevant experience. This results from the fact that the student cannot combine various practical skills obtained in solving the set of unrelated tasks, as they solve each set of tasks in isolation.

The methodological recommendations on creating one's own game space are suggested to help students acquire experience in educational and cognitive activities in order to develop the modeling skills. The key idea is to conduct a series of lessons in which students develop and implement an interactive video game in a particular school

subject. The study describes a series of lessons that can be used to teach modeling in the school courses of both Mathematics and Physics. Methodological recommendations are formulated without going deep into the programming process, without giving the detailed instructions and descriptions of the properties of objects. This approach is explained by the fact that the aim of the study is to disclose the didactic potential of gaming tools for teaching modeling, but not to study the programming characteristics of the "*Kodu Game Lab*" environment. The subject teachers can develop independently a detailed guide for preparing the lesson notes for the series of lessons taking into account their own experience and resources.

The idea is as follows: there are 5 race tracks on the playing field, and there is an object in each field. When the game starts, the racer shave to cover a certain distance, then stop; the player is asked to calculate the parameters of each racer's movements and take a small test.

So, the students have to create a game in which 5 objects will compete in speed, and the players will compete in the knowledge of the Physics laws and the correctness of mathematical calculations. The students are offered a ready-made idea of the world, aimed at gaining the modeling skills while studying the motion characteristics (trajectory, speed, time, measurement units). The theoretical concepts which are being worked at in the process of modeling the world are fundamental for understanding the scientific reality. Moreover, the students get acquainted with the basic concepts of the visual modeling environment, the gamification principles; the didactic potential for the development of creative thinking and research activities is realized in the process of implementing this project.

The Lesson Series

Lesson 1. Getting acquainted with Kodu visual environment

Step 1. Studying the main terms

Step 2. Starting to model a new gaming world

At the first lesson, the basic terms and the environment interface are studied, and examples of the ready-made worlds are explored. The students get registered at the start of the application and try to create their own game space (landscape). They create a model of the terrain of a suitable size, and they also simulate the race tracks.

After some of the features of *Kodu Game Lab* have been investigated: the interface has been studied, the skills of adding a character have been acquired, and peculiarities of the movement control and of turning to a certain side have been learnt, the following questions can be offered for discussion:

What are the characteristics of the path / the landscape?

How can you choose the landscape type? How can you delete a part of the landscape? How can you change the material type used to design the landscape? Perform each of the above commands.

How many material types are there?

How are the paths along which the objects move displayed? In which environment mode can you see the paths?

How can you make the object perform certain actions?

How can you add another landscape type to the terrain you already have without changing it? Perform this command.

How can you change the terrain you already have without modifying its size and borders? Perform this command. Assess the results you have.

Lesson 2. Filling in the gaming space

Step1. Adding the game characters/objects

Step 2. Modeling the controlled motion of the objects

Step 3. Working with the timer

Once the paths are ready, one can add the objects. Not all the characters can move in *Kodu Game Lab*, and all moving characters have quite different movement speed.

After adding a character and setting the characteristics (color, speed), the students start the game, and observe the movement of the object. At the first step of the lesson, the object moves along the preliminarily indicated paths, so the students cannot control it.

At the second step, students begin to model the movement of the objects. According to the task, they have to work so that the characters begin moving along their paths immediately after the game starts. To do this, the user should gain the skills of modeling the conditions ("when") under which the character must perform certain actions ("do").

After that, the students start the game again and in the process of studying the model they find out that it is necessary to limit the time of the characters' movement. The timer is used for this purpose in the *Kodu Game Lab*

environment. It starts at the moment the game starts, which is quite consistent with the conditions of the task. This way of controlling the movement is called "rule". When working with the model, students can set several rules for each object. After that the following questions can be offered to students for consolidation:

Which instrument helps to set the object trajectory?

How many colours can you set for a character?

Can I change the speed of the character? If so, how can it be done? What other settings can you change?

What instrument is used to program time? How to set the time, which is not defined in the corresponding menu item? Perform this command.

Lesson3. Adding the scorekeeper

Step 1. Making the scoring rules for one object

Step 2. Modeling the game strategy

The timer, which was studied at the previous lesson, will help in designing the scoring system for each racer. To do this, students come up with a rule, write it in the environment language and examine the resulting model.

When the model is verified, it turns out that the racers pass a certain distance during the set time and stop, and the score changes. For example, for some characters 5 seconds are enough to reach the end of the path, turn back and start moving back. While working with the model, the students understand that this situation needs to be corrected to simplify the calculation. It may be necessary to expand the terrain in the game and increase the length of the paths. While studying the model, it may also be useful to understand that after changing the size of the game space and the path length, you can add a landscape, fences and other elements of the environment to the game. The importance of the second step is in the fact that students in practice come to the conclusion of the necessity of the score keeper as a way to determine the end of the game which can have two possible outcomes: winning and losing.

To consolidate, the following questions can be discussed:

Why should scoring be made in the program only once?

Why is it necessary to specify the colour of the path in the program of the object? Change the program so that there are two paths of the same colour. What happens to the movement model in this case?

In combination with what element of the environment can the timer become a stopwatch? What do you need to set to do this in a computer model? Perform this command.

Can you make the racers move exactly 5 seconds?

What instruments do you have to use to finish the game at a certain score? Devise your own rule and set the score value.

Are the same rule elements used in the cases when the player wins or loses in the game?

Lesson 4. Making a dialogue with the player in the form of a test

Step 1. Creating additional conditions for the convenience of calculations

Step 2. Holding a dialogue with the player

Step 3. Calculation of the test results

The logic of research at the first step may start with the following problem: to calculate the speed, it is necessary to know the time and the distance the object covers during this time. We have made the racers move exactly 5 seconds. But what distance do they cover during this time? To find this out, using the environment tools you have to devise a scale with divisions to calculate the distance. Then, in the process of working with the model, you have to start the game to calculate all the values on the basis of which a test for the player will be made up. After the necessary calculations are made, one can proceed with the second step –making up a test which will help to assess the achievement level of the students. When the player is ready for testing, he presses the space bar, after which the test starts. Each answer influences the total number of points, and, depending on the result, the game ends with either a victory or a defeat, and for the student this is a corresponding mark for the lesson.

The idea is to add a new object to the gaming field (revising what was learned earlier) and select (analysis, comparison, reasoning) the appropriate location. It is also necessary to consider the condition added in the previous lesson –the racers stop 5 seconds after they start to move. This fact will make it possible to make the transition from demonstration to calculation. The test starts to run immediately after the player presses a specific key (for example, the spacebar).

In order not to complicate the task, only two options can be offered to answer each question: true and false. When you click the number corresponding to the correct answer, the game adds a point to the score and offers the next question; when the wrong answer is given, one point is subtracted and the next question is offered too. It is not difficult to implement this.

The next step in the study is to refine the model so that the game responds to the player's answers in the appropriate way.

Thus, it is possible to continue an independent dialogue between the player and the game. It is useful to ask a problematic question to continue studying the model: can the same keys be used when answering different questions?

Case study:

Biker moves along the brown path. What is his speed if the distance between the red marks is 10 m and the width of each red mark is 2 m?

24.4 km/h

6.8 km/h

How many meters per second is the speed of the Plate (black path) less than the speed of the Puck (green path)?

20 m/sec

24.8 m/sec

As one can see, each new answer option should have a new key. In this case, it can be either a digit key or a letter key; the main thing is not to get mixed up when describing the reaction of the game to pressing a particular key. After the game is finished, the procedure for evaluating the test results is simulated. The students can be offered to model this stage of the task themselves. For example, the information model might look like this: if a player gets more than 101 points (or exactly 101 points), then he has answered correctly at least three questions out of five, which is a satisfactory result. The result of less than 100 points indicates that there have been two out of five correct answers at maximum. And this result is unsatisfactory, so the player has to make motion recalculations.

The following questions can be offered to consolidate the material:

- Why shouldn't the same key be assigned to several answers to different questions?
- Try to predict the actions in the game in the situation when an interval of 20-30 points is taken to evaluate the result.
- Trace this section of the program. What will happen to the score after the introduction of these lines?
- At what point does the timer start counting time? In what units is the time measured?
- What is the difference between "above" and ">=" in the "score" selector? In which cases should the item "above" be used?
- Change the colours of the paths in the computer models of all the characters. What happens in this case? Cancel the changes.
- Why is 5 seconds an optimal time interval for this game?

Other Variants of the Game Space to Teach Computer Modeling

At present, unfortunately, schoolchildren, starting with primary school children, show a rapid decline in the interest in literary reading. To solve this problem, teachers use various non-traditional teaching technologies to improve motivation and cognitive interest in the subject (Koroleva, 2016). Introduction of software tools will be especially effective for primary school children if it is combined with play activities. Thus, modeling skills can also be obtained within the framework of a humanitarian subject course. There is an example to gamified simulation training of 2-4 grade schoolchildren by means of the game "Wise Apples" in the "*Kodu Game Lab*" environment.

The game is quite simple: there are two characters on the playing field, *Plate* and *Kodu*, and the player controls the movements of the latter. *Plate* flies along its own trajectory and produces apples of red and green colours at regular intervals. At the beginning of the game, the player is asked the question: "Why do you think the sea is salty?" And he is offered to read a fairy tale to answer this question. The task of the player is to collect apples, thus increasing the score, and every other ten points of the game open a new fragment of the tale.

The idea of the world "Columbus's Odyssey" can be suggested for History (Geography) lessons. The game simulates Columbus's traveling when he discovered America. The information model should simulate the activity of the Player controlling the Ship. At the beginning of the game the ship is located on the water near some island. During the game, the traveler collects the coins, following the route. When a certain amount of coins has been collected, the player gets a story about the adventures of Columbus, or a story describing some discoveries.

Biology (Environmental Studies) lessons can be accompanied by a game that involves modeling the movement of characters through a forest and its surrounding areas. Initially an object is situated in a forest surrounded by trees. Controlling the object, the player finds small nonmoving things which are randomly scattered –"garbage"

(broken branches, dry leaves, household waste). Students get information about the Red Book plants and animals after they have collected a certain amount of "garbage".

Pedagogical Support of the Gamifying Educational Environment

Having finished the work with the world designed by the teacher, the students should devise and implement their own educational project by means of the Kodu environment. The project is understood as designing and creating a computer model of the game space, developing the landscape of the world according to the plot and adding characters to it. The world is modeled for educational purposes. The main methodological problem is to come up with one's own idea of a game educational video that could be modeled. The greatest difficulties are experienced at the initial stage, when the authors have to create an image – a model of the future game world. We offer several instruction techniques to trigger creative thinking:

It is possible to take a ready-made plot and use it in a fictional world. For example, you can study the laws of Physics working on the Earth with X-Men comic book characters.

It is possible to use the plot and the game world of a fairy tale or some other literary work. For example, geometric objects can be studied while going through the twelve labors of Hercules.

Nevertheless, even after such work, some students may still experience difficulties in formulating the modeling project tasks. Therefore, the teacher should have variants of possible plots and ideas of the worlds so that the students have the right to choose.

Problems Connected with Assessment of the Game Space

The next methodological problem is connected with the necessity to evaluate the modeled game world. The fact is that it is very difficult to unambiguously evaluate the creative activity, aesthetic taste, creative thinking, and imagination.

The approach offering a solution to this problem is described in the article by Soboleva and Perevozchikova (2017). The authors suggest a methodology for assessing the whole process of creating a game world from coming up with the idea of an information model of the project plot to implementing the computer model by means of the software environment. The following categories are used as criteria: idea of the game world, information model, computer model, design and educational potential.

In the context of this research, the most valuable are the criteria associated with formalizing the task (information model) and implementing the computer model by means of the environment tools.

The following criteria can be singled out in the category of "Creating an information model of objects and processes to solve the problem": defining the goal of modeling, identifying the properties of the objects which are essential with regard to the goal of modeling, sufficiency of the objects to design the model, and description of the information model in a formalized language. Each criterion is described in **Table 1**.

The next category is "Implementation of the computer model by means of the environment tools"; the following criteria can be taken into consideration here: efficiency of the model, implementation of certain objects and their actions through a system of rules, interactivity, and rationality. Each criterion is described in **Table 2**.

The described variant of evaluating the game world, created to acquire the modeling skills by means of gamification, is one of the attempts to solve the methodological problem of the teacher to give an appropriate mark for creative work of the educational and cognitive character. Of course, the complexity of the plot, the multilayer character of the world may require more criteria. The value of this variant lies in the desire to offer a holistic approach (from the plot to the result), as the learning and cognitive activity in modeling starts with inventing the idea of the world, which is then formalized and implemented with the tools of the environment in the form of the game space.

Thus, the suggested approach to the structured organization of educational and cognitive activity in teaching modeling at school using the computer game technology is a reflection of the structure of students' cognitive activity and, in turn, is reflected in the structure of the lesson (lesson series) which is based on students' experimental and practical-transformational activity with information objects. It makes the basis for the accumulation of theoretical knowledge, and is focused on developing a new way of thinking, finding not just a non-standard solution but the one that is strategically verified and suitable to be applied in the real world.

Each lesson always starts with revision and includes a series of tasks and exercises that help students to establish a link between the previously studied material and the new one. They also contain questions that enhance thinking activity. The structure of each lesson consists of several steps, completing which, the students create a finished video game.

Table 1. Creating an Information Model of Objects and Processes to Solve the Problem

Criterion	Value	Description
Defining the goal of modeling	Low	The goal of modeling is not correctly defined
	Medium	The goal of modeling is defined correctly in general, but there is some misunderstanding in respect of the result of the problem solution (for example, restrictions on the result)
	High	The goal of modeling is correctly defined and the results of the task are clearly understood
Identifying the properties of the objects which are essential with regard to the goal of modeling	Low	There is no understanding of which properties of the given objects and phenomena are essential to achieve the goals
	Medium	Not all the properties of the objects and phenomena essential for achievement of the goals are identified
	High	All the essential properties of the objects and phenomena are identified and correctly described
Sufficiency of the objects to design the model	Low	Not all the objects and processes essential for achievement of the goals are identified
	Medium	There are more objects than necessary to design a model
	High	All the objects necessary to design a model are identified and correctly described in accordance with the task requirements
Description of the information model in a formalized language	Low	There are three gross errors: - violations in the sequence of the steps of the activity and their representation in natural language; - not all the dependencies between the original data and the result are represented; - inaccuracies in the representation of a statement or a Boolean expression
	Medium	There is one or two of the errors described above
	High	All separate steps which constitute the activity are represented as a sequence of actions in the natural language (an algorithm as a model of the activity) All dependencies between the initial data and the result of the solution of the problem are represented as a statement or a Boolean expression

Table 2. Implementation of the Computer Model by Means of the Environment Tools

Criterion	Value	Description
Efficiency of the model	Low	There are gross errors in the description of the model properties and characteristics of the objects by means of the environment tools.
	Medium	The program on the whole runs well, however there are some inaccuracies in the model implementation.
	High	The computer model is implemented without mistakes.
Implementation of certain objects and their actions through a system of rules	Low	The objects are added but their properties are not set. The player cannot control the movement of the object.
	Medium	The rules are only set for some objects. Some rules are incorrectly set. The range of conditions is limited to 2-3 rules.
	High	All blocks and operators, environments are reasonably used. The set of objects is optimal. Working with the rules and the timer is correctly organized. Various conditions are used. Control is transferred in a proper way.
Interactivity	Low	The user cannot influence the characters' actions and their movement.
	Medium	The user can control the game world, but his influence is limited.
	High	The model is completely interactive
Rationality	Low	The commands are in general correct, but their choice is not optimal.
	Medium	On the whole, the commands and their sequence are given correctly but some algorithms should be improved.
	High	All the commands, objects, and rules correspond to the information model and the conditions of the task.

The new methodology of the use of play technologies in teaching modeling takes into account the ways of providing the pedagogical support of the cognitive activity of students aimed at their intellectual development and implemented by means of computer educational games via improvement of information and pedagogical interaction between the participants of the educational process and organization of the cognitive activity in the course of a computer game.

DISCUSSIONS

As the literature review has shown, modeling is both an efficient instructional method and one of the most important methods of scientific knowledge. Due to new requirements of the state and society to the education system, mastering methods of solving practice-oriented tasks involving the information resources of the society have become one of the main tasks of education. The problem solution always starts with modeling: constructing or selecting a number of models. It can be a model of the content of the problem, a model of the object, a model of the solution, or a model of the problem solution process. The use of computers and other technical means has not only enriched the didactic potential of the modeling method with regard to enhancing students' cognitive activity, but also increased the significance of information models in the scientific description of reality.

The gamification tools used in education can successfully integrate into the interactive school educational environment, and in particular in training modeling. The literature review shows that the studies on teaching modeling at school using ICT tools consider only some aspects of the problem discussed. The efficiency of using computer services and platforms is manifested in the fact that new tools enrich modern education with tools for implementing new types of educational activities and supporting the functioning of the traditional types of educational activity at a whole new level. For example, practical-transformational and experimental activity with an information object in the game space at a lesson performs a motivating role and increases the visual expression, which is important in studying abstract theoretical concepts. Employing gamification services in independent research will provide the educational and cognitive activities with the tools for consolidating knowledge in the game format, for deepening and expanding the understanding of the information object. All this can happen when you employ the technology, which is based on schoolchildren's needs. But the most important thing to remember is that the nature and content of educational and cognitive activities should not be changed.

The results of the research can be used:

- to develop the methodological system of training teachers to use the gamification tools in teaching modeling at school;
- to continue working on methodological concepts of teaching modeling as a method of educational and cognitive activity making use of other gamification tools;
- to improve the traditional teaching techniques included in the compulsory curriculum of pedagogical departments at universities.

CONCLUSION

The tested and evaluated application of gamification platforms and services, based on the analysis and the experience of using didactic computer games, the practice of their creation, has made it possible to suggest a methodological approach to realizing the didactic potential of gamification tools in teaching modeling at school. The study has made it possible to give valuable methodological recommendations for organizing a structured lesson (a lesson series has been developed) using computer game technology. The suggested technology for the use of computer games in educational and cognitive activities in modeling:

1) contributes to the process of systematization and generalization of the results of previous studies on teaching modeling at school, supports the use of ICT tools to improve the quality of education;
2) takes into account the didactic potential of the new generation game software services and platforms: expanding the educational content; supporting individualization of learning; offering new types of educational activities; offering new tools to enhance the cognitive activity and involvement; changing the direction and quality of interaction between the participants of the educational process.

The article also describes methodological methods and recommendations for organizing information and pedagogical interaction between the participants of the educational process via educational programs on gaming platforms, both at the level of personal communication between the teacher and the student, and at the level of the tripartite teacher-student-computer interaction. These methods and recommendations can help to individualize the influence on the intellectual development of the student by means of the precise diagnosis of its condition and selective control measures.

The paper suggests recommendations regarding the logic of teaching modeling. The didactic potentialities of the use of gamification tools in teaching modeling at school to activate cognitive activity of students are described in a specific context. They are: increasing the cognitive interest; organizing the students' activity when acquiring different action modes; offering opportunities for active experimentation, implementing research and creativity elements; enhancing independence of an individual in cognition; individualizing the pedagogical guidance for the intellectual development of an individual.

Thus, the suggested methodological approach reflects the specifics of the procedure component of teaching with the use of computer educational games in the conditions of developing a new game style of thinking and recognizing the intellectual development of an individual as a priority objective in determining the strategy and tactics of education. The findings presented in the article can be of practical use for school teachers who employ computer games to teach modeling.

The research results can also be used in teaching students whose future professional activity is connected with information technologies, as gamification of educational and cognitive activities can serve as an integrative approach combining didactic potential for improving the quality of education, social integration, and providing career guidance. It is confirmed by not only the increase of motivation and involvement of students in solving modeling tasks and developing educational game projects, but also the fact that students themselves initiate research activities offering their topics of interdisciplinary projects for modeling and gamification tools to implement them.

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