Gamification Approach to the Creation of Virtual Laboratory Works and Educational Courses

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Abstract: Despite the problems of obtaining educational information in e-learning have been successfully solved, the problem of the development of laboratory work remains relevant, especially under quarantine conditions. Preparing high-quality virtual laboratory work is a time-consuming task, especially for the natural sciences. E-learning laboratory work types are mainly remote and virtual. Two scenarios have been investigated in detail: 1 Adaptive Interaction with Virtual Devices. 2-Gamification with simulation and 3D graphics. Implementation of animations and interactive game scripts not only simplifies and accelerates student preparation but also provides concentrated learning. The article presents the results of comparative analysis of created virtual laboratory works using data of real measurements, models, 3D graphics and interactive adaptive scenarios. The advantages and benefits of gamification in laboratory work to improve the learning process are discussed. The immersive learning environment has been demonstrated to make it much more effective to interact with virtual objects and tools for the researcher. Automatic methods of operation, especially with sophisticated and unique equipment have been implemented. This provides an opportunity to interact more effectively with virtual laboratory objects and instruments.

Keywords: Virtual Device, Virtual Laboratory Activity, Remote Labs, Computer Based Support, Cognitive Activity, Adaptive Model, Visualization, Interactivity, Gamification

1 Introduction

In recent years, a new way of utilizing games in education has appeared and it is called gamification. The term was created by Nick Pelling back in 2002, but it was not until 2010 that gamification itself became well known and embraced [1-3]. The definition of "gamification" is using for the application of game mechanisms in

nongaming environments. The main goal of this approach is to strengthen the processes and experiences of those involved through motivation and engagement [4]. One of the problems of modern education is the lack of motivation for students to learn natural sciences. Therefore, teachers trying to use new computer technologies and approaches to provoke students' activity and motivate them to participate in learning. The appropriate solution, in this case, is the application of game elements in the learning process. Gaming is now being used as a learning medium to educate students in many different disciplines and the educational community has begun to explore the effectiveness of gaming as a learning tool [5].

The purpose of this work was to reveal that the advantages of the gaming industry, such as interest, immersion in the gameplay can and should be conducted into the learning process.

The practical significance of the work is to use real data of high-tech equipment with a combination of interactive gaming scenarios to perform simulation subroutines behavior.

This approach with the implantation of a special system of awards, competitions and ratings, based on the use of game elements in the educational process, increases the motivation of students for participation and activity [6].

2 Background

The idea of using game elements in non-game contexts to motivate and increase user activity. The historical origins of this term concerning its predecessors and similar concepts are formulated in [7]. It is suggested that gamified software gives an idea of new gaming phenomena. Such digital, serious games can be defined as "any form of interactive computer gaming software and full games for non-entertainment purposes".

Gamification directly related to knowledge and skills affecting students' behavior, commitment and motivation. It can lead to improved knowledge level and skills [8]. In [9] a theoretical model is offered that explicates the dynamic interrelationships among learners' problem representation, motivation (i.e., interest, competence, autonomy, relatedness, self-determination, and self-efficacy), and engagement.

Findings of this study suggest that learners' motivation determines their engagement during gameplay, which in turn determines their development of complex problem-solving competencies.

Findings also suggest that learner's motivation, engagement, and problem-solving performance are greatly impacted by the nature and the design of game tasks.

The gamification approach is also important for interactive lecture-demonstrations and virtual laboratory works development.

Gamification uses only some game elements instead of the entire game and focuses to design features such as badges, levels and leaderboards. As elements can be used personal elements (badges, levels, time constraints) and social elements (competition, cooperation, sharing achievements) [10].

Using these elements can lead to a successful gamification strategy [11]. There are eight core drives in human motivation: Accomplishment, Meaning, Empowerment, Ownership, Social Influence, Scarcity, Unpredictability, Avoidance.

A 5-step model for gamification instructions is described in [12]: Understanding of the target, audience and context, Definition of learning objectives, Structure of the experience, Identification of the resources, Application of the gamification elements.

The first two steps are basic to any educational design. Structuring the experience includes the development of the stages with own learning objectives. There are many different types of games, making it difficult to give a precise definition of the game [13]. However, games can largely be defined by the following characteristics:

- Rules. Games are activities that have rules that are different from everyday life. These rules generally exist to define the scope of the player's choice of actions throughout the game.
- Feedback systems. Much of a game's interactivity relies on its feedback system, which is often instant.
- The consequences of a player's actions are usually presented immediately on taking the action.
- Goals. A game's goal, or victory condition, are clearly defined and unambiguous. Often games have several mini-goals which yield points towards the ultimate goal, that of victory, but in nearly all cases the path to victory is clear and known to all players.

Concentrated learning is a technology of the organization of the educational process, which involves the students mastering a large amount of educational information without increasing the amount of study time by changing the mechanisms of its assimilation, information structure, forms of its presentation [14].

The main basis of the method is the idea of the holistic perception and understanding of the student throughout the training course in the short term. It is achieved, firstly, by a concentrated study of one subject in the short term - this is immersion - and, secondly, by repeated four times during the study of such immersion at a higher level - from oriented to creative.

Coupled with new approaches in education and particularly gamification this presents opportunities for new forms of assessment that may provide a more accurate picture of students' achievements. The design of authentic assessment tasks is becoming increasingly important as education moves away from moribund classroom-based approaches to more authentic learning.

Virtual laboratory works (VLW) and simulators are the important initial step in the STEM (Science, Technology, Engineering and Mathematics) training. Students must have practical experience with real equipment [15]. VLW is a computer program that allows performing experiments and getting results without using real laboratory installations and instruments [16].

The interactive model of the laboratory setup, including virtual instruments and tools, was described in VLW, which involves the mathematical modeling, can be considered a virtual simulator [17, 18, 19]. Computer support of the educational process provides opportunities for independent activities of students and their work in classrooms and laboratories.

Therefore, it allows stating that further improvement of the programs of VLW by adding the elements of a real experiment with gamification approach and instrumental errors, diversifying model of investigation and taking into account the principles of didactics enable the creation of VLW that are very similar to real ones [20].

There are many projects for the development of VLW in natural science. Laboratory work for cloud electronic learning environments with algorithms and methods for protecting information between devices using combined communication channels and embedded systems is discussed in [21].

Electronic laboratory work in medicine using data exchange in cloud environments, computer-aided analysis with real-time visual monitoring is described in [22]. The main aims are the development, testing, implementation and distribution of educational modules, teaching methods and pedagogical strategies based on the use of virtual devices in various fields of science (physics, chemistry, biology) to help students get through the availability of virtual tools in classes.

Virtual instruments combined with dynamic models of physical laws allow simulating learning skills in a virtual lab, for instance, TEALSIM [23, 24]. But all of these projects don't use the gamification approach and don't motivate students to the educational process.

The main objectives of the research are the presented VLW on natural science with modeling of dynamics of physical processes and some studies of gamification in IT educational courses for providing the highest standards of e-learning.

3 Methods

3.1 Interactivity and interdisciplinary approaches

To improve methods of virtual laboratory work wide use of interactivity with the implementation of the principles of interdisciplinary approaches to learning is required. In the case of laboratory work, the essence of these approaches is to diversify ways of virtual laboratory work on each step, the presence of self-control and methods of evaluation of results. During laboratory work, students have to fulfill a task of conscious choice and means of experiment operation. This may be the choice from the available list of virtual instruments and conditions of the experiment. An adaptive model scenario of the virtual electronic laboratory work is shown on Fig. 1.

Methods of visual interaction, methods of modeling and data collection have been also implemented for virtual laboratory development.

Results. Realization of VLW, examples of created VLW and modeling of virtual measurements were presented in [19, 20].

3.2 Software system for VLW

Games and the game's elements are included in the education process and educational software systems, to ensure the interest and participation of students. It means that game mechanics,rewards and group tasks remain the core-teaching tools. In a result of our research, a number of VLW have been developed. As an example, we will discuss VLW of modern Semiconductor Physics and Nanoelectronics. Laboratory work based on automated research installation [19].

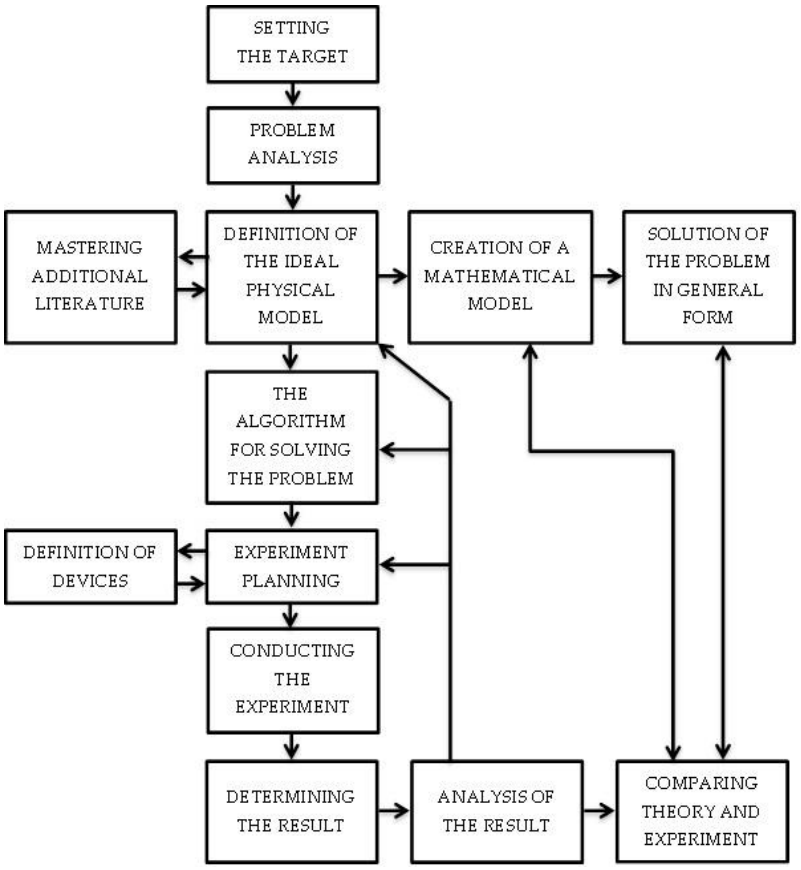

Fig. 1. Block diagram of the algorithm of functioning of electronic laboratory work.

3D-scientific visualization is used to illustrate complex schemes. The developed simulator interface is completely identical to be used in the real hardware (Fig. 2).

The number of research efforts can be fixed by the tracking system and game's elements such as incremental progression, instant feedback, status and visibility, collective responsibility, leaderboards, rankings. All of them affect the final assessment.

Each question has an individual rating and weight coefficient, which helps to track the level of practice on the topic. For the scenario, the complexity of the game's levels is to be taken for the test results. The introduction of gamification in a laboratory workshop allows us to create a clear sequence of implementation, a clear number of iterations and the number of iterations of student error corrections in feedback with the teacher. This approach provides a simple understanding of the accumulation of points for the implementation of the stages of practical and laboratory work, the assessment of the individual student rating when performing work in a group of students. This allows you to create a transparent system for assessing courses with laboratory and practical work.

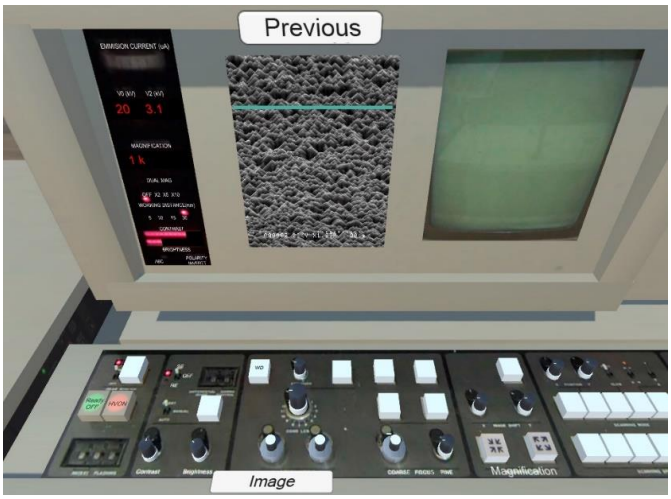

Fig. 2. Interactive 3-d model animation module.

3.3 Game simulators for educational process

At Kharkiv National University of Radio Electronics, was created the "GameDev Lab" game development laboratory for providing students with knowledge about game design, programming, AI systems in games and for learning courses creation with a gamification approach created virtual laboratory works based on games for students of different ages for getting them new skills in different areas.
"Safe Laboratory" (Fig. 3) is based on UE 4, Visual Scripting System Blueprint, C ++, platform - Mobile AR platforms.

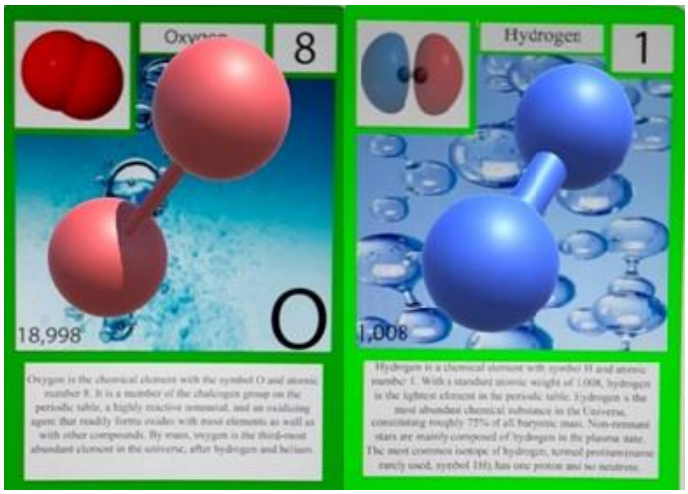

Fig. 3. Safe Laboratory Interface.

This application is gamification of chemistry laboratory work for students using augmented reality technologies, is using in the labs for first-year students on modeling chemical reactions, because it gives visual clarity for better understanding and carrying out chemical experiments and simulations of chemical phenomena, after studying the theory, the student is asked to answer several questions on topics.

AR technologies will make it possible to reduce the cost of laboratory and practical work, and will also make them safe and interesting. In addition, it will provide an opportunity for distance learning for people with special needs, specifically student with the special needs could use distance-learning platform for getting access to virtual laboratory, to the educational process and making and pass exercises without visiting university.

Besides, the student must complete laboratory work and practical assignments using this application. Using it, the student can get the right result in different ways, especially in assignments where it is necessary to obtain different chemicals in chemical reactions.

The student as well as the teacher can see their rating and level of knowledge on each topic. This allows you to find topics that have not been thoroughly studied and to get recommendations from the teacher on what else to work on.

This approach differs significantly from the different types of testing, as it has several ways of implementing and obtaining the correct results when performing practical and laboratory work based on the theoretical knowledge that the student possesses. Each task has its rating and weight factor, which helps to track the level of preparation on the topic.

“Great Way” is application based on Unity3d, C#, platform - Android, iOS. The application helps students to acquire additional knowledge in agile technology, form the basic skills of the economy and to develop memory. The player repeats the signals coming from other semaphore towers, trying to transmit a packet of messages faster than they are delivered. The game allows developing memory and forming the basic skills of economics.

“Fragile World” is an application based on UE 4, Visual Scripting System Blueprint, C ++, platform -Windows PC. The application develops logical thinking in the player, the basics of economics knowledge, methods of constructing the optimal strategy, minimizing risks and maximizing profits. It is based on the classic party RPG with turn-based battles.

A “Great Way” and a “Fragile World” are used in laboratory work on economics for students who simulate various economic models and engage in business planning taking into account risk and profit assessment.

All these applications have as the main goals to give new knowledge and skills to the students of different ages and motivate them to involve in the study process. The games we developed refer to the following sections: physics, chemistry, economics and information technology.

The highlight of these games is not the entertainment component, but the involvement of students in the learning process. These examples are part of the laboratory works that are used in the educational process for students. These laboratory works are an integral part of the virtual laboratory of training courses in physics, chemistry, and economics.

The use of gamification approaches within the framework of VLW allows simplifying the process of teaching students and understanding complex processes and phenomena, motivates students to perform activities, and also allows introducing a simple and clear assessment system for completed tasks.

All applications were created within different projects by the university specialists, IT companies' staff and implemented as pilot courses in the educational process for students.

The study was conducted in the different faculty where were implemented these courses in the 2018–2019 academic year.

The sampling method was purposeful sampling. The main reason for choosing the working group was that they had already taken these courses, and the questions used in the gamification applications are about chemistry, physics and economy for students.

The main game elements were implemented in these courses: stating goals and objectives (how to complete mission and take more points); student participation (restart points and some possibilities); assessment (points and additional opportunities for reassessment); feedback (progress bars, warnings); cooperation/collaboration (Teams, social interaction, competition, communication ways, helping others).

In the design of an environment, these game elements used to engage students in the instructional process we have used using outcomes and certified methodologies of Tempus Project "A Network for Developing Lifelong Learning in Armenia, Georgia and Ukraine" such as Design of LLL programs, LLL Monitoring Model, Course Evaluation Template for estimation of quality assurance [25].

The result of the student's questionnaire presented some benefits of gamification for 500 students: increase of motivation 79%, observation of other students' learning 92%, the permanence of the learning process during the course 84%, time-saving 85%, collaboration in groups 91%, rivalry/competition 86%, the attractiveness of technology 100%, consolidation of learning 100%.

As negative aspect, we received answers from 21% respondents who did not feel increasing of motivation. It related with that these courses use applications are based on some technology and gamification approach, the technological problems have affected to the educational process.

Table 1. The methods of assessments support by the game elements

Game elements	Support for educational process
Challenges	Demonstration of the capacity to apply knowledge and perform specific tasks
Choosing different ways	Demonstration of knowledge and skills regarding decision making
Opportunities to complete tasks	Development skills or knowledge
Teams	Promotion of collaborative work and group problem solving
Progress bars	Provision of information on student progress toward the attainments of goals

4 Conclusions

Under quarantine, universities have to switch on-line laboratory activities. It is almost impossible to do with sophisticated equipment, without virtual laboratories or simulators. It allows students to continue research and experimental studies in compliance with quarantine requirements and appropriate social distance. Visualization of laboratory work allows us to ensure the educational process without loss of quality and time, and also allows students to acquire additional practical knowledge in a virtual laboratory.

During the classes in the virtual science laboratory, students' motivation for the learning process was increased. The developed software has helped students improve critical thinking and problem-solving skills. It has been found that game scripts and 3D visualization of complex phenomena and processes provide an opportunity to interact more effectively with virtual devices and activate the student's mechanism for memorizing new knowledge.

Gamification is a tool to encourage students to master knowledge level. Virtualization of training experiments in laboratory work using computer graphics makes it possible to simplify the learning process and make it more evident and adaptive due to the gradual complication of exposure, especially when previous images are stored and subsequent ones become more complicated.

The results demonstrated the potential of using gamification techniques in promoting learners' motivation, engagement, and performance, mainly by establishing a comparative learning environment that influences how a student learns, not necessarily the context in itself. This includes creating an interesting statement among students that encourage them to be more engaged with the learning task, thus increasing their interest and motivation. Understanding how gamification techniques affect the behavior of learners can help researchers and instructors to select suitable techniques for their students.

This understanding is vital for context's designers where they need to choose the suitable gamification interventions that can stimulate students during the discussion session. In addition, it is important for students to be instructed about the application of the gamification approach before they engage in the discussion. Previous studies seem to provide poor guidance to future researchers about the suitability of gamification techniques for achieving a certain learning objective. Providing enough knowledge about these issues is vital to understand the role of gamification in education.

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