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### 3D COMPUTER GRAPHICS IN THE DEVELOPMENT OF KNOWLEDGE CONTROL SYSTEM IN THE DGBL APPROACH

Nowadays there is a tendency to lose interest in learning among student. Therefore it is important to find a way to diversify the ways of information transmitting and checking its comprehension using the information technologies. The most effective and promising approach is the use of computer games in education – Digital Game Based Learning (DGBL). Games in education can be used to facilitate the information comprehension, as well as to test the student knowledge in the knowledge control systems. Paper discusses development of knowledge control system using 3D computer graphics in the Digital Game Based Learning approach. Main directions in the organization of knowledge control are considered. Method of standardized control in quiz mode is chosen as the basic one. Analysis of the foreign experience, recent research and publications in Digital Game Based Learning domain is conducted. It is noted that the effect of using of DGBL is not unambiguous. Some researchers report about negative effect on students' learning performance mostly in early studies. Other studies showed improving of motivation and students' learning achievements. Methodology of using digital games in the educational process including basic functions, approaches and features (students' age, specificity of the discipline, game genre, capabilities of the selected basic 3D modeling system) is presented. Classification of digital games in educational process is shown. Features of the development of knowledge control systems using 3D modeling are considered. The purpose of the research is to consider the development of a knowledge control system using a game form for students of secondary educational institutions. The article is intended for teacher of educational institutions and specialists in DGBL approach.

**Key words:** 3D graphics, computer game, Digital Game Based Learning (DGBL), knowledge control system, quiz.

**Introduction.** Education cannot stand by and do not change in a society where most industries are becoming computerized. Computer technology and electronic tools are slowly but surely finding their way into educational institutions, especially after COVID-19 pandemic. Since nowadays there is a tendency to lose interest in learning among students, it is important to find a way to diversify the ways of information transmitting and checking its comprehension using the information technologies. The most effective and promising approach is the use of computer games in education – Digital Game Based Learning (DGBL). The adaptation of learning to games reached a new level with the development of digital media. This is a new digital way of information comprehension, built on the enjoyment of the learning process through the game.

**Task statement.** Games in education can be used to facilitate the information comprehension, as well as to test the student knowledge in the knowledge control systems. Checking of the learned material is an integral part of the educational process.

There are two main directions in the organization of knowledge control:

1) The student's actions are evaluated using systems based on knowledge, i.e. in expert-learning systems. The knowledge level is determined during the dialogue between the teacher and the student and is based on knowledge of the subject area and assessment rules.

2) This approach is to assess the student's knowledge using answers to a specialized set of tasks. Judgments about his knowledge are made according to these answers. Systematic testing of students' knowledge is mandatory in this approach. This method is used quite often, as it has a number of certain advantages:

- the results are obtained in numerical form, which allows for their mathematical processing;
- small amount of time spent on checking.

Testing is an effective method of knowledge checking with standardized control. Testing systems can be similar to tests, quizzes, surveys, and can also have a different appearance: plain text, interactive, using various graphics and animations [1].

*Object of research* is using of 3D graphics in knowledge control systems.

*The purpose of the research* is to consider the development of a knowledge control system using a game form for students of secondary educational institutions.

**Analysis of recent research and publications.**

The use of a game form of learning allows you to increase the motivation to study, combine theoretical and practical skills, as well as apply individual and collective work, thereby providing a comprehensive approach. In the game process information is memorized at a subconscious level, so learning of theoretical material and acquiring of practical skills take place at the same time.

Learning games have 3 main functions:

- instrumental: formation of certain skills and abilities;
- gnostic: formation of knowledge and development of students' thinking;
- socio-psychological: development of communication skills.

Each function corresponds to a certain type of game: the instrumental function can be expressed in game exercises, the gnostic function – in didactic ones, the socio-psychological function – in role-playing games. It should be noted that learning games use not only the game method per se. During the game, you can use group and individual work, common discussion, conduct testing and surveys, create role-playing situations. In other words, the game organically combines various methods: brainstorming,

method of critical thinking developing through reading and writing, questionnaires, sociometry, etc. [2].

However, the game method has some specificity in pedagogy. In the learning process, the game is often used as an auxiliary element, a supplement to the theoretical material and cannot act as the main learning method.

Several factors should be taken into account when creating an interface:

- students' age;
- specificity of the discipline;
- game genre;
- capabilities of the selected basic 3D modeling system.

The results of the application of learning games are discussed in numerous studies of world experts. Filter “digital-game-based-learning” in Scopus shows rapid increasing of number of publication annually (fig.2).

*Influence of the DGBL on the learning achievements*

The effect of using of DGBL is not unambiguous. Some researchers report about negative effect on students' learning performance mostly in early studies [3-6]. Other studies showed improving of motivation and learning achievements [7-10]. Hung et al. [7] compared DGBL approach, e-learning approach, and traditional instruction in learning of the elementary mathematics course and found that DGBL group surpassed the other two groups in learning achievements, while the learning achievements of

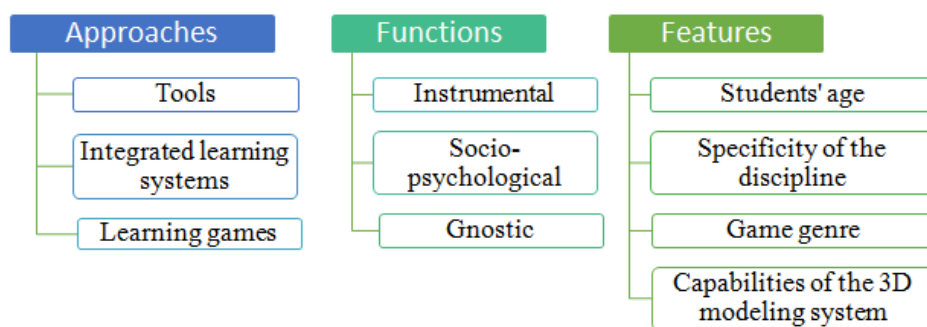


Figure 1. Methodology of using games in the educational process

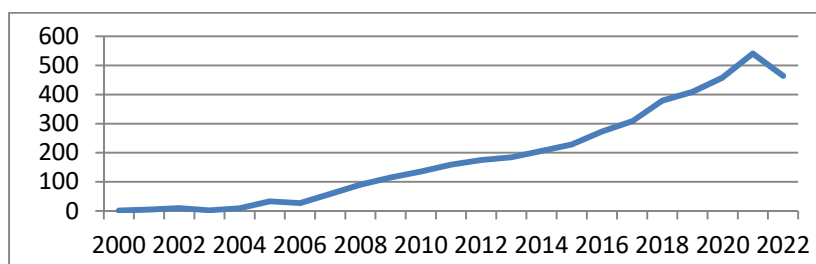


Figure 2. Number of publications in Scopus by the “digital-game-based-learning” filter

the e-learning group and the traditional instruction was at the same level. Interview feedback of DGBL group showed the better engagement in the learning process that may be the reason of better mathematical achievements.

– *Review of the DGBL publications*

It was conducted several meta-analyses (of games in STEM education in [11], of serious games in [12], influence of video games on students’ mathematics achievements in [13]; effectiveness of digital game-based science learning, Gameplay design and Game-mechanism design in [14]) and systematic reviews (30 studies on mobile games in [15], 798 articles in STEM education in [16]). Wang L.-H. et al [11] analyzed 33 studies on the topic with 36 effect sizes and 3894 participants and made conclusion that using digital games could be effective method for STEM education to improve students’ academic performance. But teachers should adequately consider learning purposes and methods of integrating games into STEM classroom. Riopel M. et al [12] reported that learning achievements with serious games were slightly higher in domains of declarative knowledge, knowledge retention and procedural knowledge.

– *game-based learning in certain academic field.*

There are publications connected with foreign languages learning, medical and nursery learning, artificial intelligence and machine learning, STEM courses, particularly mathematics and physics, etc. Giannakos M. et al [17] made review of games used in artificial intelligence and machine learning education, Qais Batiha et al [18] investigated environments used in object-oriented programming including Turtle Graphics, Alice, BlueJ, Greenfoot, Snap!, and NetsBlox, tested their effectiveness with special interview. They pointed out use of Block Programming and collaborative learning to simplify the first approach to programming can reduce and eliminate syntactic difficulties for students, increase

confidence and improve learning performance. Other review on using Games in Learning Programming is represented in [19].

– *games in test control systems.*

For test knowledge checking, one can use the free game-based testing platforms Kahoot and Quizziz, which work in the mode of the competitive multiple-choice quiz and automatically grade students. The advantage of the systems is the competitive mode of the quiz. The programs are compatible with video conferencing systems like Zoom or Microsoft Teams, with Google Classroom and allow students to take the test simultaneously, scoring points and receiving prizes, for example, streak for more correctly answered questions in sequence. The better player’s streak is, the more points he gets for the next correct answer.

A literature review that studied the effect of using Kahoot in the learning process based on 93 quantitative and/or qualitative studies is presented in paper [20]. Researchers found that Kahoot have a positive effect on learning achievements compared to traditional learning. It is noted that one research pointed out reducing classroom dynamics using Kahoot over five months while other studies reported about improved classroom dynamics and better interaction between teacher and students. All studies noted improved reducing student anxiety and increasing of students’ engagement and confidence.

**Main research materials.**

*Stages of computer game development*

Each game goes through a long development process. Quite often, a whole team of people is involved in this process, in which everyone is responsible for a specific stage of work. The number of participants depends on the scope and complexity of the work.

Modern games go through almost the same development stages, with differences depending on the genre and complexity of the game (fig. 3).

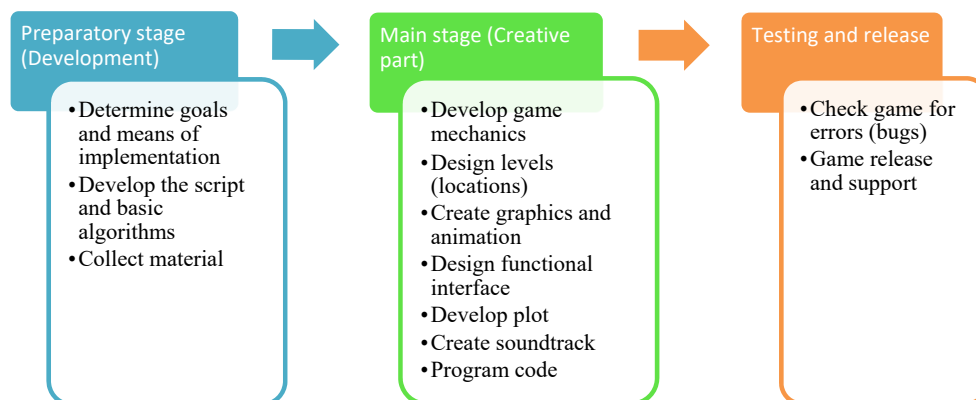


Figure 3. Stages of computer games development

1. Purpose (definition of the project goals, genre and theme).

At this stage, you need to plan the game – clearly to select genre and, starting from this, to create its concept. Genre determines the main actions performed by the player, and setting is responsible for the environment theme. Setting characterizes the belonging of the game to any plot theme or a specific virtual world. The most popular settings are: fantasy, post-apocalyptic, science fiction, medieval, comics and anime.

2. Implementation means (choice of materials and tools).

Program code is the game frame. Therefore at this stage language programming is chosen and program code is written, which can operate 2D or 3D-world objects, add images and sounds. In our time, software modules (game engines) are being developed, in which the basic functions have already been implemented, in order to build graphics, sound, objects and their movement.

3. Game mechanics (development of game rules, objects and their control; creation of artificial intelligence).

Game mechanics is a set of rules whereby the game will function. Each action has its own rule, which ensures the game logic. This stage includes the development of objects and their control, object interaction, influence of players on the items, assignment of keys that will be controlled by the main character or object, and actions that will take place after pressing certain buttons. It is also necessary to take into account the physical properties of objects and give them characteristics corresponding to the physical laws of the real world. Depending on the genre of the game, it is necessary to develop an artificial intelligence that will be responsible for the behavior of secondary characters.

4. Levels (composition of created objects on locations).

Environments are formed where models are located and previously created rules are applied.

5. Graphics (creation of 2D or 3D models, animation, backgrounds and special effects; game menu and screen design).

Images of players, game objects and backgrounds are developed. Based on these images, models and animation for them are created, backgrounds are drawn. Special effects are added that use the movement of particles and light filters.

6. Plot (history in game).

As a rule, computer game is built by some kind of scenario. The role of scenarios is especially strong in role-playing, adventure games and in mixed genre games.

7. Sound (creation of sound effects and music).

A sound accompaniment design is equally important in the game development. Background melody sets the main mood, and sound effects add reality to the process.

8. Testing.

At this stage, project build takes place and correctness of game components is checked.

9. Issue.

The last stage is game release and its further support [21].

Before starting work, you need to determine the genre in which the game will be created. The range of existing genres is quite large, so you can choose a direction to begin with, and later in the development process clearly what exactly you want to see at the end.

Figure 4 shows a complete list of existing genres of computer games. As the main criterion for the distribution of genres, we choose actions that are most often performed in games of this genre and the number of elements [22].

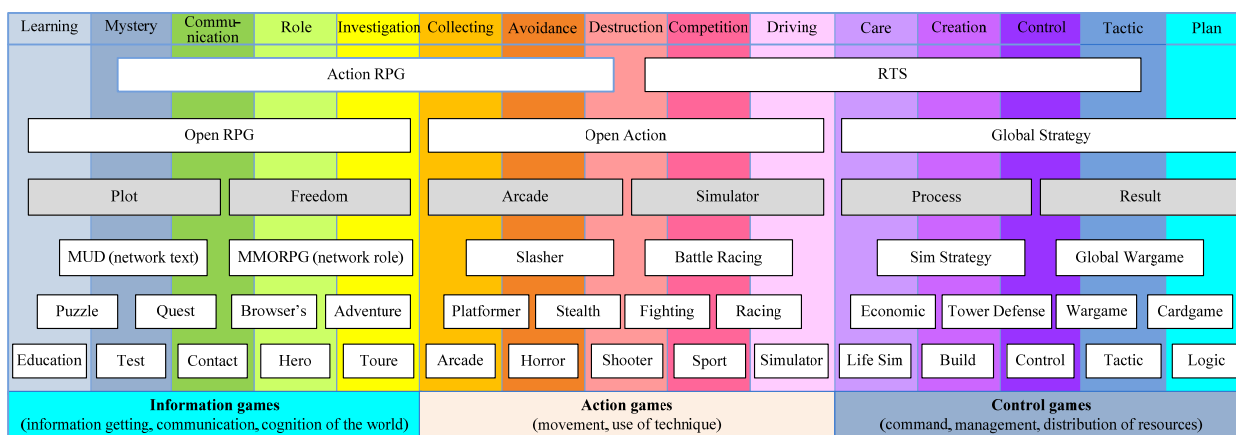


Figure 4. Genres of computer games

The games are divided into three main genres:

- action games;
- information games (role-playing);
- control games (strategy).

The main thing in action games is the body movement which is controlled by the player. Body can be a model of a person, animal, equipment, etc. Such games are known for their dynamics and help players to develop their reaction speed. The best example would be action movie games. They occupy the largest segment of the global game market and are the most popular. The standard scenario for such a play: character control, which can be driven by various special tricks, to reduce enemies. Through its popularity, such games are the most innovative, they use 3D-graphics and special effects and technologies.

Information games are responsible for the transfer of information in any forms to the player. They include learning world through the environment, comprehension of educational material or acquiring skills through communication. The range of such games is quite large, but role-playing games are considered the Golden mean. That is, these are games in which it is possible to take on the hero role and to live his life. Such games are appreciated for their atmosphere, plot and detailed game world.

Games aimed at the development of resource management and administration skills are called control games. The essence of the game is to plan and manage events and resources to gain advantages in the future. This type includes all games of the strategy, economic, logical and tactical genres. It is often assumed that some genres of information and control games are similar to each other, but one important difference must be kept in mind: information games

must be solved by relying on the knowledge received in the game, unlike control games. Here you need to come to a result, relying only on the ability to plan each of your further steps in detail.

All games within each group are very similar to each other, but have certain differences. The game in the knowledge control system belongs to the genre of information games and contains a certain riddle that the player must solve, that is, it is an elementary genre of a riddle – a test. It can be a kind of quiz, similar in principle to the well-known game «Who wants to become a millionaire?», but have a completely different interface or be part of a quest, at each stage of which the student receives different tasks or questions.

Variants of computer game classification are represented in fig. 5.

*Stages of creation of 3D animation*

The process of creating 3D graphics is quite complex and is therefore divided into certain stages. Depending on what work is being done and what the developer wants to see at the end, the number of stages can vary. In general, there are 10 most common stages of creating a 3D animation project (fig. 6).

Let's consider in detail each stage of a 3D animation creation:

1. Concept and storyboards.

3D animation creation starts with idea conceptualization and storyboard creation. A storyboard is a sequence of illustrations showing a story in two dimensions: time and interaction (images and transitions between them).

2. 3D modeling.

Modeling involves creating props, environment, and characters. In 3D computer graphics, 3D

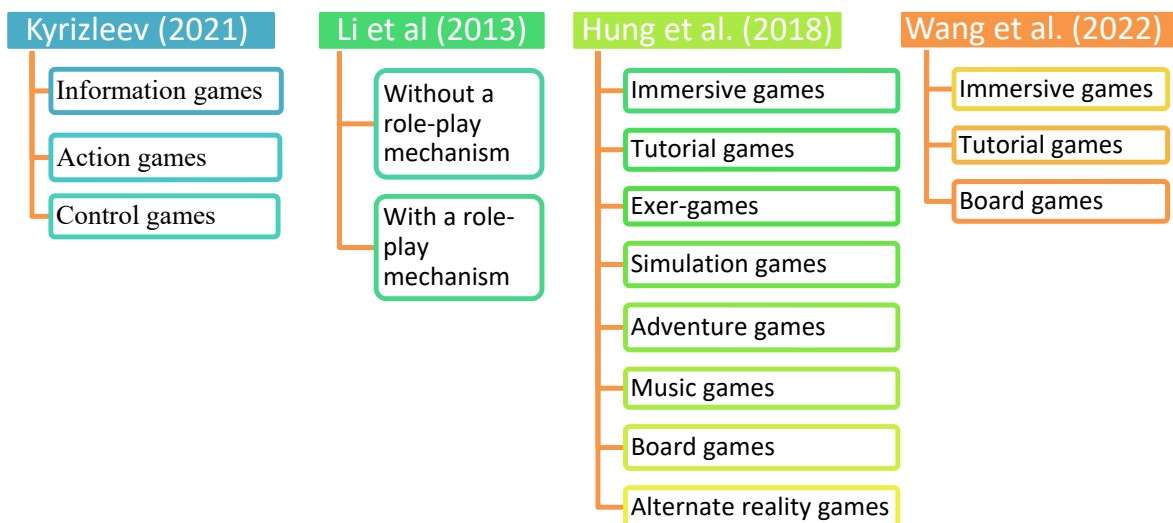


Figure 5. Computer game classifications

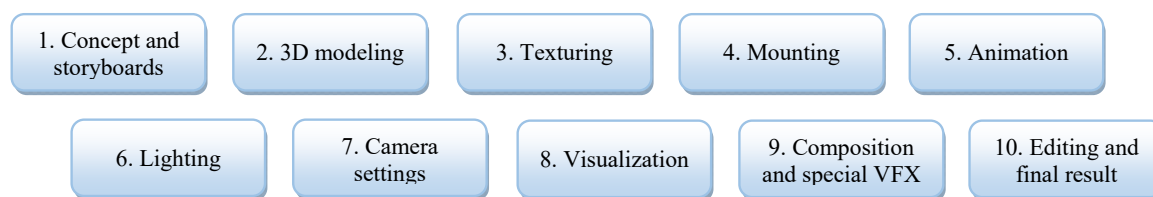


Figure 6. Stages of creation of 3D animation

modeling is the process of developing a mathematical representation of any object surface in three dimensions using specialized software. 3D modeling software is a class of 3D computer graphics software used to create 3D models. 3D models, in this case, are digital images of physical objects. Three-dimensional models, as a rule, consist of a polygonal mesh and a surface texture. A polygon mesh is a «shell» consisting of different surfaces of a three-dimensional object. This shell consists of three main components: vertices (points), edges (lines) and faces (planes). A surface texture is basically an image applied to the surface of a polygon mesh. A texture can be as simple as a solid color or as complex as a high-resolution photo. The texture will be applied to the surface using specific instructions. These textures can have physical properties that interact with light to create effects such as shadow, reflection, transparency, etc.

There are different types of 3D model creation. The most important one are:

- polygonal modeling creates an object of any complexity by combining different groups of polygons;
- spline modeling creates 3D objects using splines, i.e. curved lines;
- NURBS modeling is a technology for creating 3D objects using special curves called B-splines;
- 3D-sculpting or digital sculpture, is an imitation of the 3D model “sculpting” process, i.e. deformation of its polygonal mesh with the help of special tools – brushes, brushes.
- industrial modeling uses creation of models from solid figures or surfaces.

### 3. Texturing.

While 3D model creation 2D image can be overlaid on it using programs like Photoshop to represent texture, color or design. This process is called mapping. Mapping is used, for instance, for hair texture creation.

### 4. Model skeleton and skin covering.

Rigging is the process of establishing a controlled skeleton for a character intended for animation. Skinning is the process of attaching a 3D model (skin) to a molded skeleton so that the 3D model can be manipulated using skeleton controls [23].

### 5. Animation.

Animation is the process of capturing a three-dimensional object and moving it. Animation has several various types: keyframe animation, placing objects on splines and setting them to a curve path, or importing motion capture data and applying it to the skeleton.

### 6. Lighting.

Lighting along with textures, camera angles, etc. can bring to life a scene. 3D light is a virtual object developed to simulate working of lighting in real life.

### 7. Camera settings.

In 3D one can create one or more cameras, locate them in 3D space, and use settings to simulate focal length, field depth, and other camera features.

### 8. Visualization.

Image rendering is usually the last step in the 3D production pipeline, and, may be, the most important part.

### 9. Composition.

Visualization is added to compositing programs for editing, finishing and adding special effects. Composition includes special effects, scene expansion, environment creation, replacing the background with footage shot in other place or artificially generated. Music is added to the graphic.

### 10. Editing and the final result.

At the last stage, developers make sure that all objects are synchronized and their work and performance are correct. Project is compiled and exported to required format [23].

*The system of knowledge control using computer graphics for students of secondary education institutions*

At National University “Yuri Kondratyuk Poltava Polytechnic” a system for knowledge control using computer graphics for learning of programming by students of secondary education institutions was developed.

The knowledge control system development toolkit is responsible for game logic, display of graphic objects on the screen and allows the user to interact with the created environment. The game engine is the game core, that is, the basic software on which all other components of the game are built. There are two types of of game engines using in game development:

- 1) use of ready-made software;
- 2) own implementation.

Table 1

Elements of the game environment

Component	Definition	Example
Object	3D models located in the game	Landscape, natural environment, buildings, train, railway track, characters
Scene	Place or world where main actions take place	Cirty, mountains, desert, beach, swamp, glaciers
Actions	Movement of objects according to the specified parameters	Movement of the train along the railway track
Interaction with the user	With help of quiz	Clicking a computer mouse to give an answer

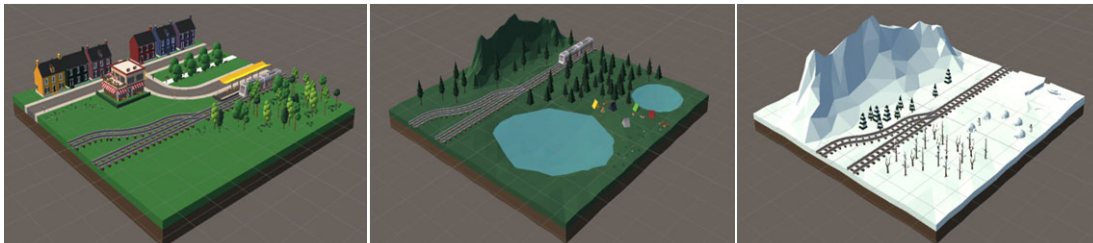


Figure 7. Game scenes created using computer graphics in knowledge control system

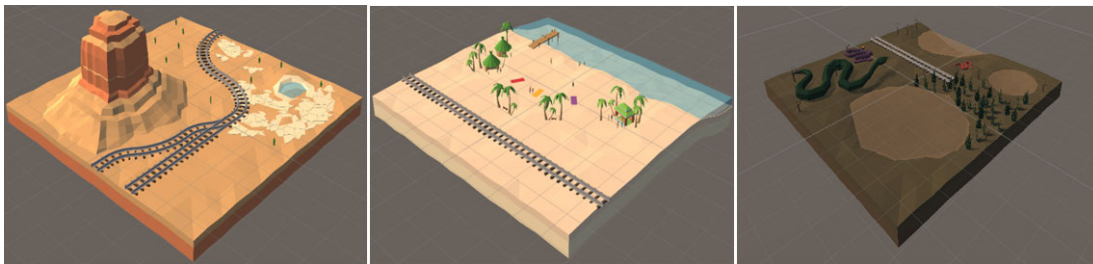


Figure 8. Game scenes created using computer graphics in knowledge control system ()

The first variant provides a significant reduction of development time, since the implementation of most tasks of a low complexity level is already realized. It greatly simplifies the process and allows people with lower programming skills to get involved in development. Therefore, Unity 3D was chosen as the software that will support the use of 3D graphics and C# programming language.

The central element of the project is the Game object, because it is the container for all other game logic, which sets the physical state in the game space and interacts with systems of the code calling. Therefore, it is the foundation in all games created on Unity 3D. Scripts are responsible for the implementation of functionality and logic is set of modules that are specified using software code.

The elements of the game environment are presented in table 1.

It was decided that the game would provide a multiple/single choice quiz, set of characters that react to answers and give prompts, and a set of different scenes, between which the train would move depending on the answers to the quiz questions. Each of these scenes has been created with a specific theme and has a different set of models. The main game object is the train and the railway tracks along which it moves.

The view of the scenes is presented in fig. 7–8.

**Conclusions.** The work considers the use of computer graphics in knowledge control systems within the Digital Game Based Learning approach. Game forms of knowledge control systems allow to increase the general interest and engagement in learning among students of secondary educational institutions and improve the academic performance of such learning.

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### **Гайтан О.М., Колесник Д.Д. 3D КОМП’ЮТЕРНА ГРАФІКА В РОЗРОБЦІ СИСТЕМИ КОНТРОЛЮ ЗНАНЬ ПРИ DGBL ПІДХОДІ**

У наш час спостерігається тенденція до втрати інтересу до навчання серед учнів, тому важливо знайти спосіб урізноманітнити способи передачі інформації та перевірки її сприйняття за допомогою інформаційних технологій. Найбільш ефективним і перспективним підходом є використання комп’ютерних ігор в освіті – Digital Game Based Learning (DGBL). Ігри в навчанні можна використо-



увати для покращення сприйняття інформації, а також для перевірки знань учнів у системах контролю знань. У статті розглядається розробка системи контролю знань з використанням тривимірної комп'ютерної графіки при підході до навчання на основі цифрових ігор. Розглянуто основні напрямки організації контролю знань. В якості основного методу обрано метод стандартизованого контролю у вигляді вікторини. Проведено аналіз зарубіжного досвіду, останніх досліджень і публікацій у сфері навчання на основі цифрових ігор. Зазначається, що ефект від використання DGBL не є однозначним. Деякі дослідники повідомляють про негативний вплив на успішність навчання переважно в білти старих публікаціях. Інші дослідження відвідали збільшення мотивації та покращення навчальних досягнень учнів. Представлено методу використання цифрових ігор у навчальному процесі з урахуванням основних функцій, підходів та особливостей (вік студентів, специфіка дисципліни, жанр гри, можливості обраної базової системи 3D моделювання). Показано класифікацію цифрових ігор у навчальному процесі. Розглянуто особливості розробки систем контролю знань з використанням 3D моделювання. Мета дослідження – розглянути питання розробки системи контролю знань в ігровій формі для учнів загальноосвітніх навчальних закладів. Стаття призначена для викладачів навчальних закладів та спеціалістів з підходу DGBL.

**Ключові слова:** 3D графіка, комп'ютерна гра, Digital Game Based Learning (DGBL), система контролю знань, вікторина.