Game based learning with artificial intelligence and immersive technologies: an overview

Yulia Yu. Dyulicheva[1], Anastasia O. Glazieva[1]

[1]V.I. Vernadsky Crimean Federal Univerity, 4 Vernadsky Ave., Simferopol, 295007, Crimea

Abstract

The usage of serious games with AI and immersive technologies in education is considered in the paper. We discussed the development of serious educational games with adaptability and personalization based on recognition of the images, human emotions, speech, and intelligent agents usage for the simulation of "being there" effect of a human opponent, and control of the complexity of game levels and game contents. We investigated some tools for teachers and students to allow the creation of the educational games based on AI and immersive technologies without programming skills existence: Aurora Neverwinter Nights toolset, eCraft2Learn tool with visual programming on Snap!, Scratch with AI abilities, Metaverse Studio for AR applications development with computer vision models using Google AI, CoSpaces Edu and EV Toolbox constructors for immersive apps.

Keywords

educational games, AI in education, immersive technologies in education, AR/VR constructors with AI modules

1. Introduction

Game-based learning is the perspective direction in education because the younger generation is involved in computer and mobile games from early childhood and this kind of activity began to be perceived as a normal thing. The games in education are not required adaptation from the younger generation, cause to positive perception and desire to use games for further learning [1]. Serious games are widely used in education, but they are aimed not at entertainment, but at achieving concrete educational goals [2].

There is no single definition of a serious game. Following [3, 4, 5], by serious games we mean digital games with some simulation of processes oriented to knowledge acquisition, its improvement and problem-solving, including the harnessing of innovative technologies, in particular, virtual environment. Games of this kind can help create new curriculums for the adaptation of the learners to the digital age.

Computer games are considered as perspective interactive digital or virtual environments, that allow getting immersive experience and practical skills through engagement, the interest of

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dyulicheva@gmail.com (Y. Yu. Dyulicheva); gameresearchanastasia@gmail.com (A. O. Glazieva)

https://researchgate.net/profile/Yulia-Dyulicheva (Y. Yu. Dyulicheva)

0000-0003-1314-5367 (Y. Yu. Dyulicheva)

players, and feedback with them [5]. As shown in [6], educational computer games contribute to the improvement of cognitive and social skills.

Modern serious games must satisfy a number of requirements: aimed at problem-solving, must have a spirit of innovation, take into account the personal needs and preferences of the player and his goals, improve cognitive, analytical, mathematical, communication skills, promote the development of new technologies, develop creativity and skills management, ability to take initiative, etc. [7]. For example, Nand et al. [8] considered the characteristics that attract and retain the users in the games and how such characteristics can be used for the development of educational games. So, as a result of the survey, it was revealed that realistic graphics, different levels of difficulty, and feedback in the form of scoring are important for the players. Abdellatif et al. [9] investigated the qualitative characteristics (game design, user's satisfaction, usability, usefulness, understandability, motivation, performance, playability, pedagogical aspects, learning outcomes, engagement, user's experience, efficacy, social impact, cognitive behavior enjoyment, acceptance, user interface) of serious games in the field of education with the help of game Robocode for the teaching of programming and discussed the directions for improving the game that students are noted.

Important features of the development of serious games are the focus on obtaining certain knowledge and skills from students. The development of serious games requires the use of machine learning methods to solve such practically important problems as image recognition, speech-based text recognition, etc. [10]. The recognition of the players' emotions is of particular importance, as it makes it possible to track those parts of the game that cause boredom, fear, etc. Recognition of players' emotions can be used to personalize content in educational games, and the natural language processing techniques in conjunction with neural networks are used to develop dialogues with the learners in real-time and create the effect of the tutor presence for support organization during learning [11]. Tracking and assessing the emotional state of the learners during the use of serious games are important tasks aimed at studying both the emotions themselves and assessing the emotional experience gained during training since it is precisely such emotional experience that further affects the activity and volition in the learning process based on games and is of interest from the point of view of developing educational games aimed at personalizing learning. Anolli et al. [12] considered different approaches for assessment of the emotional state of the player based on facial emotion recognition, voice analysis, and gesture recognition (assessment emotions based on body language analysis).

The purpose of the paper is to study the possibilities and prospects of using immersive technologies and artificial intelligence for gamification of the educational process and tools for the development of educational games based on these technologies.

2. Related works

Serious games in education aim at the acquisition of basic knowledge and skills and academic performance improvement. As shown in table 1, serious games are widely used in police, business, diagnostics, aircrew for educational purposes. Their main distinguishing feature is the focus on the educational aspect and active learning, and the main advantage is maintaining the student's interest-based in cognitive curiosity, plot intrigue, reward system, interactivity,

feedback and gaining professional skills and knowledge through experience of problem solving and high motivation [13].

Table 1
Areas of the serious games usage

Research	Area	Goal	Target group	Results
Binsubaih et al. [14]	Police	Learning of the typical traffic accident investigation experience	56 police officers	Advantages: effective learning, performance improvement, interactive environment for learning Disadvantages: difficulties at the beginning of interaction with virtual environments for students that have not any experience with 3D technology
Martín and Aznar [15]	Business	Learning of business information analysis	58 students	Learning improvement through experience to get different useful skills in the subject area
Chourabi et al. [16]	Information System	Data Modeling, UML learning	24 master I students and 3 teachers	UML understanding and improvement of data modeling skills
Gaggi et al. [17]	Diagnostic	Identification of people with developmental dyslexia	24 children	Classification of children with respect to risk group for developmental dyslexia
Mautone et al. [18]	Aircrew	Aircrew Training	14 male	Improvement of performance and accuracy of carrying out the FMS preflight programming in the proper sequence
Lämsä et al. [19]	Inclusive Education	Reading and math learning for people with disabilities	-	Organizing of special educational support

3. Review of serious learning games

3.1. Games with Artificial Intelligence and for Artificial Intelligent learning

The rapid development of the gaming industry puts forward new requirements from players – the presence in the game of the "being there" of a human opponent, the presence of levels with complex enemies behavior, a variety of scenes, and unexpected dynamically changing scenarios, the replacement of a human enemy who has left the game with an intelligent enemy bot, etc. This led to the need to integrate artificial intelligence modules into games and, in particular,

machine learning based on the use of intelligent agents, including human behavior simulation in games according to styles and skills acquired in games by intelligent agents [20]; the usage of the deep learning, for example, the usage of the value and policy networks for the game Go to generate different random games for self-play [21] and multilayer perceptrons for developing intelligent bots simulated human behavior [22]; the usage of the genetic algorithms for the search of the effective strategy organization without total check of all possible alternatives [23] and simulation of real player behavior playing, for example, in Mario game with the help of genetic operations, fitness function, and subject area knowledge to optimize actions of the player [24].

The criteria for evaluation of users' engagement and their interest is an open problem in game development [25], but some researchers propose methods for assessment based on machine learning. For example, Tadayon and Pottie [26] investigated the ability of the hidden Markov model for student performance assessment after educational game usage.

Serious games are enough effective in education, but require the effect of support presence when learners find it difficult. As support, virtual and intelligent characters are used in games. They are created, for example, with the help of agent-based technology [27].

There are two directions in game-based learning: the development of learning games with artificial intelligence and learning games to teach and learn artificial intelligence itself. Examples of games for AI learning are ArtBot – a game for learning the basics of reinforcement learning and supervised learning methods. It allows investigating how the bot is trained. Machine learning for kids game allows demonstrating the possibilities of machine learning algorithms, and how they transform input to output and can be considered as an introduction to machine learning for kids [28].

3.2. Adaptive learning games

Personalization, personification and adaptability today cover all areas of human activity from Internet technologies, medicine, and economics to education [29, 30] and are associated with understanding human behavior, emotions, states, experiences and desires, cognitive processes.

Development of dynamic adaptive educational games focused on offering educational content, difficulty level, game scenarios, assessment of acquired skills, etc. taking into account personification is one of the innovative approaches in the gaming industry and education. Personification is viewed as a tool for developing adaptive games aimed at understanding the players, their personal needs in order to engage and retain their interests. Many scholars investigate how users or homogenous groups of users interact with the content of the game. The model of educational games based on real-time dynamic adaptivity taking into account learning styles, performance, player's behavior, and profile with personality traits are investigated in [31]. Serhan et al. [32] detected the target groups of players with similar preferences, proposed the serious game development with adaptive learning content for such group, and considered the idea of personal hints in the game depending on rating scores.

Adaptivity in game-based learning is considered as the systems' ability to change learning content according to users' preferences and characteristics [33]. Such type of game's customization usually is based on users' learning styles and tracking their behavior during games (for example, users' eye tracking, face and its emotions recognition, etc.). The game development

based on behavior tracking has to take into account users' affective states changing during the game and the ability to predict users' emotions in the future to generate adaptive content. Lopez and Tucker propose to use the recognition of facial expression in real-time mode for motivation, experience, and performance improvement in the game with the help of SVM algorithm [34]. The search for a balance between skills and game difficulty is a very important factor for serious games development.

Zhu and Ontañón [35] discussed open problems connected with AI usage for personalized serious game development, for example, such as modeling of individual player behavior because often it is not enough to get observed data for the prediction of the users' behavior.

The most well-known approaches for developing adaptive games in education are the use of learning styles that reveal preferences about the way information is perceived (visually, verbally, with the help of "brainstorming", while observing someone, etc.) and machine learning algorithms for embedding adaptive content, taking into account the current behavior of the player and the skills he has acquired. Khenissi et al. [36] found that students with a predominant style of Active in the Felder-Silverman model prefer action games, students with a predominant style of Sequential prefer games based on puzzles. Thus, when developing serious games in education, it is possible to offer educational content adapted to specific target groups.

Some examples of the serious adaptive game in education are presented in table 2.

3.3. Serious learning games with augmented and virtual reality

Augmented and virtual reality technologies aimed at providing interactive experiences in the study of abstract concepts are showing promising results in the field of education. If we add to the interactivity and clarity of learning in a playful form, then this kind of approach can increase the involvement and interest of students. Games with flashcards for entertaining learning of the alphabet, numbers, and words, developed on the basis of Unity, Vuforia, Blender, InkScape are widespread [10].

The interesting direction of immersive technologies is the use of such technologies for hints appears as support in the learning process. Dyulicheva [39] proposed to use hints for students that have trouble in mechanics learning; the hints for people with special needs during learning are discussed in [40]. Drey et al. [41] considered the application of adaptive hints in a virtual environment based on analysis of player behavior.

Game-based learning with immersive technologies is effectively used for teaching and learning mathematics, foreign languages, physics, chemistry, biology, astronomy, etc. AR/VR with gamification is widely used in rehabilitation when people learn to control their body from the start and AI modules are applied for quality assessment of performed exercises by patients [42].

Some examples of serious learning games with immersive technologies are presented in table 3.

3.4. Tools for learning games development with AI and immersive technologies

The usage of serious games in education as their development by students with the management of teachers facilitates to positive effect in education [45]. Annetta et al. [46] noted that serious

Table 2
The examples of the serious games with adaptivity in education

Research	Area	Game genre	Type of content with adaptivity	Specialties	Adaptivity Base	Target group	Results
Soflano et al. [37]	Basics of SQL	3D Role-Playing Game (RPG)	Presentation of learning materials	Game with three modes: non-adaptive, out-of-game (based on questionnaire before game) and in-game (based on historical data) adaptive modes	Felder-Silverman learning style usage	120 higher education students	The learning effectiveness increasing for GBL and strengthening of effectiveness through adaptivity mode
Hooshyar et al. [38]	Computational thinking	maze	Situations in game, feedback, hints, learning materials	Bayesian network usage for decision making of hints or feedback creation for user support	Historical data	79 students in an elementary school	Improvement of students' learning attitude

games with immersion in a virtual environment contributed to the self-education of students, stimulated them to learn additional materials, and also developed collaborative skills through interaction with other students or instructors when they created their own games. Carbonaro et al. [47] proposed an approach based on supplementing and adapting the finished game "Neverwinter Nights" by students without programming skills for deeper immersion in the studied subject area. Immersive technologies and artificial intelligence make it possible to transfer the teacher from the role of a passive observer to an active participant who directly interacts in a virtual environment with the subject of study and even creates virtual objects himself and determines how to interact with them. The learner gains important skills through the study of microworlds. A student now is not just a user of a computer game, he is also its developer, who must achieve a certain educational goal. The student's participation in game development contributes to his self-expression, the development of creativity, and self-education.

The development of tools with interactive and visual software development tools leads to the emergence of new teaching methods and to rethink the possibilities and learning outcomes

Table 3
The examples of the serious games with immersive technologies

Research	Area	Game title	Immersive technology	Specialties	Development tools	Target group	Results
Cerqueira et al. [43]	Mathematics (Learning basic functions and their graphs)	FootMath	Augmented reality	3D football to score goals with the help of different function graphs. It uses real teaching scenarious	Unity, Vuforia	22 middle school teachers	The interest and engagement improvement
Afyouni et al. [42]	telerehabilitation	RehaBot	Virtual reality	Personalization based on analytics of quality of therapy exercises performance and 3D motion tracking using for rehab bots development	Unity	10 patients with neck pain	Usability and effectiveness experimental proof of online physiotherapy
Zarzuela et al. [44]	kids and handicapped people learning	--	Augmented reality	Different types of activities	Unity3D, Cinema 4D, Vuforia SDK	5 kids	Knowledge improvement in some field (animals learning)

based on the integration of AI and immersive technologies into education. Consider the tools that teachers can use together with their students to develop educational games with AI modules and/or immersive technologies:

1. Computer role-playing game creation with BioWare Aurora Neverwinter Nights toolset when students play the role of historical character, journalist, ecologist, economist, etc. for expanding the skills of scientific research, or writing story with facts, or creation proposition for save of environment, or studying the conditions of life in some historical epoch is discussed in [47]. Another example of educational game creation for adaptive teaching of SQL base with Aurora toolset is described in [37]. Aurora toolsets allow develop different scenes and characters based on usage of the tiles and library of creatures, create and assign dialogs to characters of the game, and set actions and organize interactivity with characters. Spronck et al. [48] describe the possibilities of introducing adaptive elements into games based on the role-playing game “Neverwinter Nights” using AI and dynamic scripting development.
2. Tool eCraft2Learn allows developing projects with AI blocks and abilities with block visual programming with the help of Snap! [49]. AI blocks are used to create custom projects

involving speech, image recognition, and neural network application development. Any project allows you to add various sprites and functionality based on AI blocks. Study projects contain applications with gesture and speech recognition for learning words in other languages, gaining skills in arithmetic operations with numbers, acquaintance with works of art, and more. For example, you can study the pronunciation of numbers in different languages and the pronunciation of a phrase that a parrot will recognize using AI blocks with the help of Snap!, as shown in figure 1.

3. The block-based visual programming language Scratch with AI abilities is used for learning basic concepts of AI and own games creation with AI. For example, kids easily can create their own chatbot with Alexa functionality, games with hand-written text recognition, games with voice and video recognition [50]. Estevez et al. [51] proposed to use Scratch to understand the principles of cluster analysis algorithms and the functioning of a neuron and a simple neural network. The introduction of tools for visualization of difficult-to-learn concepts into the educational process and familiarity with basic machine learning algorithms in a game form contributes to the growth of students' interest, their involvement, and the study of advanced information technologies.
4. Studio for the creation of AR applications, in particular, AR games with visual tools like storyboard [52]. The button "Create experience" on the web page allows creating a workspace named as a storyboard page with the ability of characters and dialogs, many scenes such as, for example, inserting of photo and video portals, blocks into the scene as shown in figure 2.
   MacCallum and Parsons [53] considered the perspectives of Studio usage for learning. The authors point out a number of benefits of using Metaverse in education:
   - simplicity and availability of Metaverse in terms of use by both teachers and students, the ability to embed various resources into scenes;
   - Metaverse supports locating and overlaying AR content for exploring the environment and conducting experiments in physical space, proposing hypotheses by students and confirming or refuting them using 3D model tracking;
   - Metaverse allows you to embed pre-trained computer vision models using Google AI and combine the capabilities of immersive technologies with the capabilities of recognition of images, texts, environments, and objects.
5. CoSpaces Edu – interactive development environment for educational AR / VR applications with built-in scripting language CoBlocks for block visual programming. The teacher, together with the students, implement project-based learning, creating AR / VR applications for studying the history of Egypt, Minecraft worlds, different simulators for physics learning, puzzles and mazes, games for acquiring computing skills, etc. [54].
6. EV Toolbox – AR / VR constructor for creating scenarios by means of visual programming based on the marker and markerless tracking technologies [55].

Examples of the use of tools CoSpaces Edu and EV Toolbox in the classroom at school and university are given in the paper [57]. In particular, the development of a virtual gallery for the study of animals, an application for learning English based on the use of block programming in CoSpace Edu, and the development of an application based on marker technology for studying the history of the university using the EV Toolbox was demonstrated.

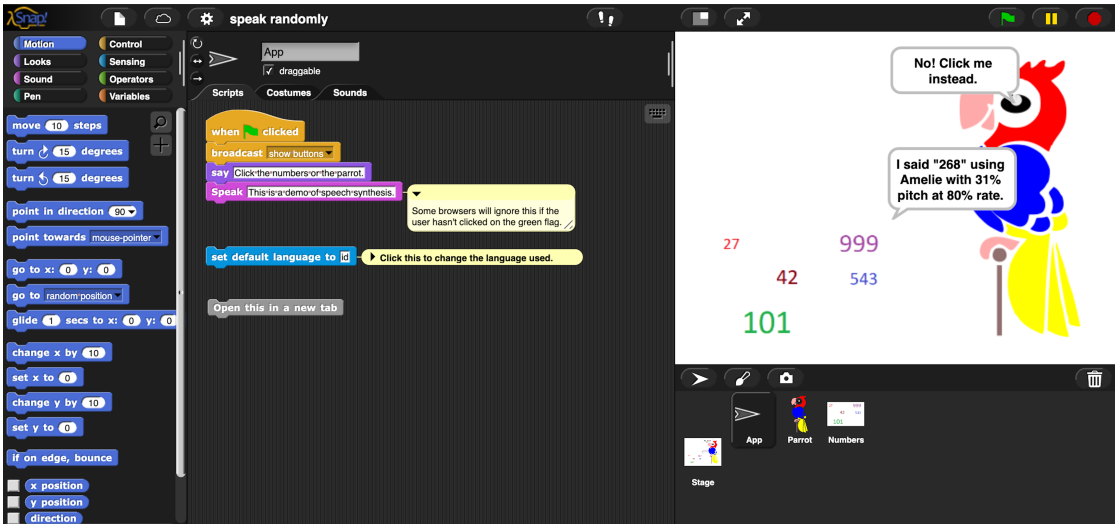

Figure 1: The example of project with AI blocks for speech recognition and block programming on Snap! [56].

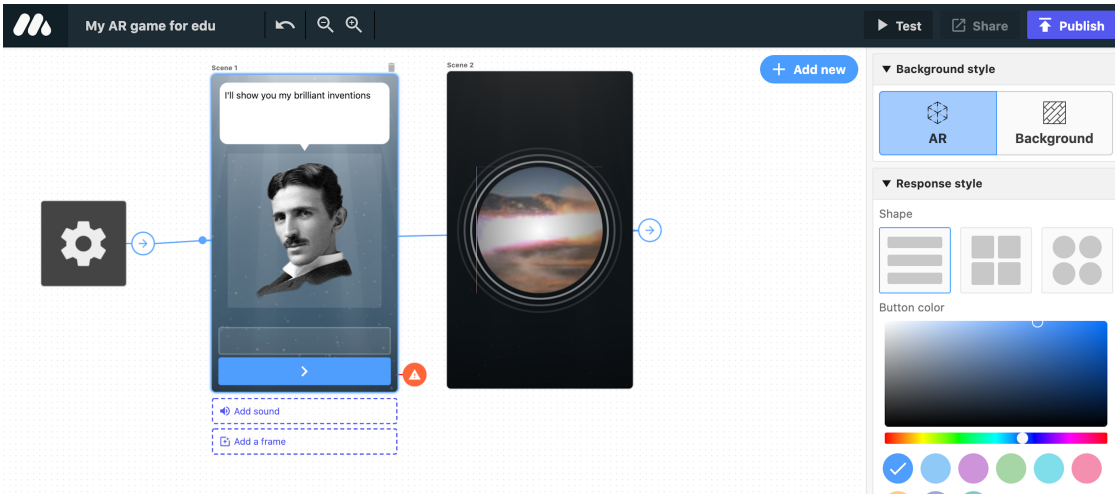

Figure 2: The example of AR-game creation about knowledge of Tesla' inventions.

4. Conclusion

Artificial intelligence and immersive technologies are powerful tools for educational games development. New constructors without programming skills existence open perspectives for the creation of new curriculums for game-based and project-based learning.

A promising area for further research is the study of the development principles of educational games based on immersive technology together with machine learning.

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