Digital Technology Implementation for Students' Involvement Base on 3D Quest Game for Career Guidance and Estimating Students' Digital Competences

Oleksandr V. Prokhorov[1][a], Vladyslav O. Lisovichenko[1][b], Mariia S. Mazorchuk[2][c] and
Olena H. Kuzminska[3][d]

[1]*National Aerospace University H. E. Zhukovsky "Kharkiv Aviation Institute", 17 Chkalova Str., Kharkiv, 61070, Ukraine*
[2]*V. N. Karazin Kharkiv National University, 4 Svobody Sq., Kharkiv, 61022, Ukraine*
[3]*National University of Life and Environmental Sciences of Ukraine, 15 Heroyiv Oborony Str., Kyiv, 03041, Ukraine*

Keywords: Virtual Reality, Quest Game, 3D Model, Career Guidance, Computer Science, Higher Education.

Abstract: This paper reveals the process of creating a career guidance 3D quest game for applicants who aim to apply for IT departments. The game is based on a 3D model of the computer science and information technologies department in the National Aerospace University "Kharkiv Aviation Institute". The quest challenges aim to assess the digital competency level of the applicants and first-year students. The paper features leveraged the theoretical background, software tools, development stages, implementation challenges, and the gaming application scenario. The game scenario provides for a virtual tour around a department of the 3D university. As far as the game replicates the real-life objects, applicants can see the department's equipment and class-rooms. For the gaming application development, the team utilized C# and C++, Unity 3D, and Source Engine. For object modeling, we leveraged Hammer Editor, Agisoft PhotoScan Pro, and the photogrammetry technology that allowed for realistic gameplay. Players are offered various formats of assessment of digital competencies based on the Digital Competence Framework for Citizens (DigComp 2.1): test task, puzzle, assembling a computer, and setting up an IT-specialist workplace. The experiment conducted at the online open house day 2020 proved the 3D quest game efficiency. The applicants estimated a 3D quest, as more up-to-date and attractive engagement. According to the results of the 3D quest, applicants demonstrated an average level of digital competence with some certain items difficulties at 0.5. Several psychometric item characteristics were analyzed in detail that would allow us to improve the item's quality.

1 INTRODUCTION

Augmented and virtual reality (AR and VR) are popular tools to introduce any concept more attractively or interactively. Utilizing AR and VR are most common for medicine, geospatial applications, manufacturing, tourism, and cultural heritage (Frontoni et al., 2019; Lavrentieva et al., 2020) .

The choice of technology and how to apply it, in particular in the higher education field, depends on the research subject, resourcing, and the teachers' and students' competency. The experimental research on digital competency proved: the readiness level to start

digital education is high enough (Kuzminska et al., 2018). Thus, arises the question of creating virtual objects and a methodology on how to utilize them in the educational process. For instance, the paper by Thürkow et al. (Thürkow et al., 2005) explains the experience of utilizing landscapes and excursions as a means of training in geography. Also, the research by Patiar et al. (Patiar et al., 2017) describes the students' experience with an innovative virtual field trip around hotels.

Among the virtual objects' representation formats, gamification gains special importance, since it provides for additional motivation and active participation of the student (Tokarieva et al., 2019; Vlachopoulos and Makri, 2017).

The training games include quests, arcades, simulator games, virtual simulators, and interactive

[a] https://orcid.org/0000-0003-4680-4082
[b] https://orcid.org/0000-0002-2159-5731
[c] https://orcid.org/0000-0002-4416-8361
[d] https://orcid.org/0000-0002-8849-9648

courses (Demirbilek and Koç, 2019; Kompaniets et al., 2019; Vakaliuk et al., 2020). We considered quests to be the most interesting genre among the above mentioned (Barab et al., 2005; Shepiliev et al., 2021). Villagrasa and Duran (Villagrasa and Duran, 2013) analyses the effectiveness of utilizing gamification to motivate Spanish students into studying with a 3D visualization as support for Problem-Based Learning (PBL) and Quest-Based Learning (QBL) to students' collaborative work. Rankin et al. (Rankin et al., 2006) investigated the cognitive and motivational influence of 3D games on studying the second language and creating a digital learning environment for second language acquisition (SLA). At the same time, the transition to e-learning requires additional research on approaches not only for designing virtual objects and digital educational environments to stimulate students' motivation to study (Katsko and Moiseienko, 2018; Ma et al., 2012), but also to assess students' knowledge and confidence acquired competencies (Kuzminska et al., 2018).

The specifics of the paper-based versus computer-based testing results application and comparison became extremely relevant during the COVID-19 pandemic when the majority of students switched to distance learning. In particular, this problem stands out for the high schools (Özalp-Yaman and Çağıltay, 2010; Ita et al., 2014; Garas and Hassan, 2018).

According to previous studies, in particular, Özalp-Yaman and Çağıltay (Özalp-Yaman and Çağıltay, 2010), students' performance does not depend on the testing method – the results showed similar scores for both computer-based and paper-based testing. However, the researchers consider the digital educational environment and the computer-based testing (or e-testing) environment improvements to be perspective. Whereas, the students claim that e-testing has several limitations, such as lack of communication with the teacher, inability to determine the order of test questions, and error analysis sessions. Thus, despite the attractiveness of digital technology, students prefer paper-based testing.

The research on the relationship between students' confidence and self-efficacy is also very relevant during e-learning (Blanco et al., 2020). Students' motivation, cognitive activity, and the desire for self-regulated learning and self-improvement influence their self-efficacy. The degree to which students' self-efficacy skills are acquired and improved, in particular during monitoring and final assessment through testing, varies depending on students' characteristics, and factors related to the testing process and educational environment.

In our opinion, it is possible to make electronic testing simpler for students by combining gamification, case technology, and virtual reality. However, the equally important task is to determine the item test structure that would allow for objectively assessing the knowledge and skills acquired by students.

De Carvalho Filho (de Carvalho Filho, 2009) studied the influence of metacognitive skills and types of tests on students' results, confidence in their judgments, and the accuracy of these judgments. In particular, the study concentrated on how students with different cognitive and metacognitive skills processed four types of test questions (multiple-choice, short answer, single-choice: "yes" or "no", essay tests). The results proved it is impractical to use the same type of test question sets. This claim corresponds to the recommendations of the DigComp 2.1 framework for assessing students' digital competencies, performed by the authors in previous studies (Kuzminska et al., 2018, 2019).

However, due to COVID-19, the question of finding a way to conduct career guidance and advertising campaigns in a remote format became relevant.

Since the career guidance of the future specialist is on-trend today, universities suggest many formats of how students can get to know the university, and use various forms of online communication with applicants. The career guidance is now on-demand, and recommendations on how to pursue a career path, in particular how to prepare for external independent evaluation, or recommendations on informal education, can be beneficial in helping students to manage their education and career. This can influence the students' consciousness and help to improve the educational system's effectiveness, as well as the equation of demand and supply at the labor market (OECD, 2017).

The research *aims* to create a career guidance 3D quest game to estimate the students' competency, and as well, to attract more applicants, and increase the visibility of the department.

2 THE PROJECT IMPLEMENTATION

2.1 Problem Definition

- *Target audience*:
  - applicants: assessing the digital competency level to understand if the applicant is ready to enter the computer science department, career guidance, department promotion;

– first-year students: assessing the digital competency level to adjust the program of education, introducing the department' activities, career guidance;

– developers of the gamified applications: specification to the technical implementation of the gamified application "Passcode".

- *The technical implementation defines the following scope of tasks*:

  – free movement, acting, and selecting players according to the game scenario;

  – analyzing data on the users' actions;

  – assessing users' actions, demonstrating the users' progress;

  – the current score showing and saving feature;

  – utilizing a database to simulate challenges.

- *Expected results of using the gamified application "Passcode"*:

  – enlarging the target audience to provide for career guidance activities;

  – boosting the applicants' motivation to study and providing them with career guidance;

  – assessing digital competency of intendant IT-specialists for further adjusting the educational plans to suit their skills and level of knowledge;

  – assisting in the development of gamified applications that utilize 3D models.

- *Summarizing the numerous study results, we can highlight the main points we considered when formulating the task to develop the gamified application 3D quest "Passcode"*:

  – the impact values on the test results for paper and computer testing are usually statistically insignificant ($p > 0.05$). Thus, there is no significant difference between these approaches, and computer-based testing can grant for objective assessment;

  – to determine the categories of digital competence assessment, we utilized the framework of digital competence of citizens DigComp 2.1, recommended as a system that "takes into account" both cognitive and metacognitive skills of respondents. However, the content of the items test was prepared considering the specifics of the training for future IT professionals;

  – developing the testing environment and building a test in form of a quest with the appropriate logic, tasks, prompts, and voice guidance can reduce participants' concerns about their performance and help receive accurate assessment results;

– the 3D quest game that is based upon the 3D model of the computer science and information technologies department at the National Aerospace University "Kharkiv Aviation Institute" will motivate future students to get acquainted with the university and help them not to feel like being examined or controlled.

2.2 Means of Technical Implementation

To develop our 3D application, we leveraged Unity as the main engine (Finnegan, 2015; Haranin and Moiseienko, 2018). Unity is a cross-platform tool for developing 2D and 3D games and applications that support several operating systems. We developed a game for MS Windows. The main language we use was C#, though we also utilized JavaScript and Boo for simple scripts. Also, we utilized the DirectX library, where the main shader language is Cg (C for Graphics) developed by NVidia.

The input data is not only the users' actions but the current condition of the game world, as the game is a sequence of conditions, where each iteration defines the following one. The artificial intelligence that controls the game characters, random events, and the game mechanics mathematical tool influence the game as well.

The game objects (including the characters, items, etc.) are samples of classes that define their behavior. The game actions (effects, scenes, etc.) are defined by scripts. The game process is defined by the combined action of managers where each controls a certain part of the gameplay:

- GameManager – controls the game cycle and serves as a linker for the elements of game architecture;

- InterfaceManager – controls the user interface, including the graphical interface and the input equipment;

- PlayerManager – controls the main character's behavior and condition (main character here is the one controlled by the player);

- UnitManager – controls the units;

- SceneManager – controls the game levels.

All of the managers are implemented based on the Singleton pattern. They are universal for the whole game, and each exists in a single copy. The managers are called by type. The main game objects base on the Finite State Machine pattern, which allows for easily controlling the game object and controlling its behavior.

The computer game is a complicated system build of separate subsystems integrated into a program architecture. Our game application has the following subsystems: for finding a way for a character; for user graphic interface; for objects interaction and an additional control subsystem.

We implemented the application in several stages and each stage has its tasks (table 1). In addition to Unity, we also utilized the Source Engine. Due to the utilities stated in table 1, we created an application for OS Windows and Android, and also a WebGL library for running in browsers.

2.3 Aspects of Technical Implementation

Creating the classrooms' 3D models was the most complicated part of the development that is why further we describe some implementation details.

To create the classrooms' 3D models, we leveraged separate models of special photos made in advance. Then we utilized Agisoft PhotoScan, which provides for the photogrammetry function (Anuar, 2006). Due to some technology constraints at the moment, building a fully-featured rooms model was a complicated task. Every gleam, as well as translucent materials, causes significant miscalculations. That can be fixed with a flattening spray, though that won't work for rooms, and that costs a penny. Thus, we utilized photogrammetry technology to get objects of correct shapes and sizes (figure 1). Also, we modeled the objects' textures, those we edited via Adobe Photoshop and attached to the models. Using Agisoft PhotoScan we created the model of a classroom and a model of a computer architecture showcase.

Figure 1 demonstrates the 3D-modeled output level of the department rooms. The room modeling was done by brushing geometry, as thus no additional physical attachment model is required.

Figure 2 demonstrates a part of the level, one of the departments' classrooms. Most of the detailed parts were converted into special mdl format for models to allow for optimizing objects in a scene.

The detailed objects in figure 3 were converted into mdl via the proper plugin. After that, we could utilize the graphics power with the model reduction in distance technology – LOD.

When the scene is settled, we can import it into 3DS Max utilizing the WallWorm plugin (figure 4).

3DS Max allows for exporting the scene in FBX format compatible with the Unity engine. In addition to the model itself, it stores data about lightning, materials, and structures.

To make sure that the scene was imported correctly we utilized the projection reflection modes. In figure 5 we can see that the grid is in its normal state.

Unity does not automatically create objects' physical models as it does not allow for brushing geometry. We have to optimize the model in the Unity scene and add a physical model of a connection mesh collider or box collider. The WebGL technology allows for running the project in the Internet browser. This technology is yet imperfect, however, if we optimize the scene it will work well. The mobile systems require the controls to let the user run the game, for the mobile devices do not have keyboards and a mouse pointing device.

Figure 6 demonstrates the controlling elements, the motion controls on the left, and the sight controls on the right.

The home screen interface is a menu that includes options "New game", "Load a game", "Settings", "Exit". After the user loads the game the menu extends with more options. The players can move with the mouse and the keyboard, or via sensor controls. The controls can be set in Settings, in the Keyboard tab. The graphical interface is an upper layer of the graphical system that allows for creating realistic 3D scenes on that basis. These scenes can have their scenario that may be changeable depending on the users' actions.

The game's current version has a static background, though it can dynamically change to another background after each time the player reloads the game. Also, the vital part of the application development process was the scenario creation and quest development.

The scenario development: the game challenges utilize various objects, such as *scripted_sequence* that allows the characters for moving and performing the required actions; *logic_relay* that is used to create the series of events started with some item when it's necessary; *point_template* – a container for storing task objects; *ambient_generic* – used to play audio; *logic_compare* – compares the numbers to decide on what to do next; *info_node* – creates the navigation grid nodes for the non-game characters (the way searching system utilizes the key *info_node* elements), etc. We implemented these elements based on the Finite State Machine pattern, which allows for controlling the game object condition and its behavior. For the quest development there are several algorithms to utilize, though since the game model is 3D, we implemented the way search via the navigation grids algorithm.

The Navmesh or Node Graph navigation grid is an abstract data structure that is usually utilized by AI

Table 1: Tasks and tools for implementation.

| Tasks	Tools
Creating 3D models of rooms	Source Engine, Agisoft PhotoScan Pro, GUI StudioMDL
Editing objects	Hammer World Editor, MilkShape 3DL
Creating the objects' textures	Adobe Photoshop, VTF Edit
Creating levels and lightning for some items	Hammer World Editor
Scenes editing, processing, and exporting to the format	3D Studio MAX, plugin Wall Worm
Scenes optimization Adding the physical model of connection Creating game objects and events Developing the game manager, interface manager, player, units, and levels Scripts writing	Unity
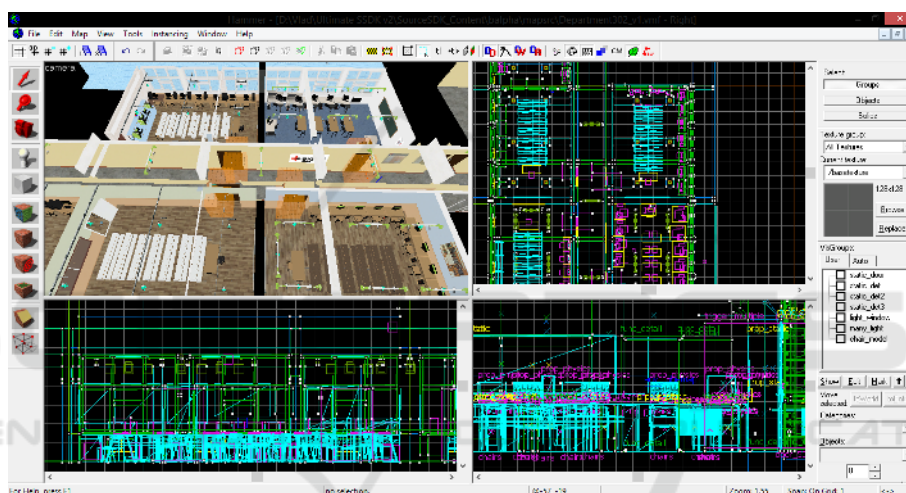
Figure 1: Hammer Editor with a model of department rooms.

applications, to allow the movement agents through big and geometrically complicated 3D objects. AI considers objects that are not static to be a dynamic hindrance. This is another advantage of utilizing our approach to solve the challenge of searching the right way. The agents that can approach the navigation grid do not count these hindrances when building their track. Thus, the navigation grids method allows us to shorten expenses on calculations and makes finding the agents that encounter dynamic hindrances less pricey. The navigation grids are usually implemented as graphs, so we can utilize them for several algorithms defined for those structures. Figure 7 demonstrates the navigation grid utilized to calculate the way for non-game characters.

2.4 Application Scenario

The 3D quest "Passcode" can be downloaded via the following link: https://afly.co/xxn2. To start the quest,

the user selects the language, as the game contains tips and subtitles, adjusts the keyboard settings, and on-demand can go to help for instructions in the corresponding menu section. The article (Prokhorov et al., 2020) provides for a simplified game description used for the pilot mode. We updated the game and added more advanced features in the latest release. Thus, further in this paper, we explain the game scenario and provide a detailed description of all functional elements implementation.

The quest contained different challenges to evaluate different groups of digital competencies according to the Digital Competence Framework for Citizens DigComp 2.1, that is information and data literacy, communication and collaboration, digital content creation, safety, problem-solving (Carretero et al., 2017).

The tasks had different constructs and were not limited to linear tests. This allowed us to assess the various cognitive and metacognitive skills of students who participated in the game.
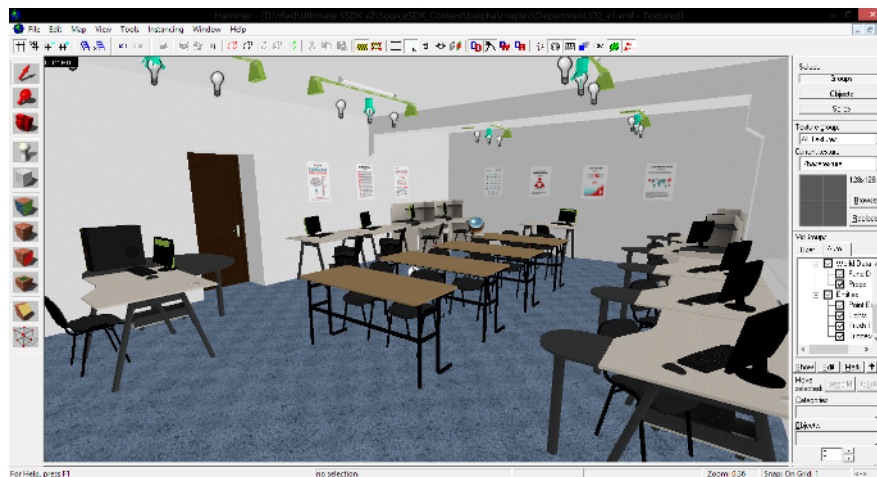
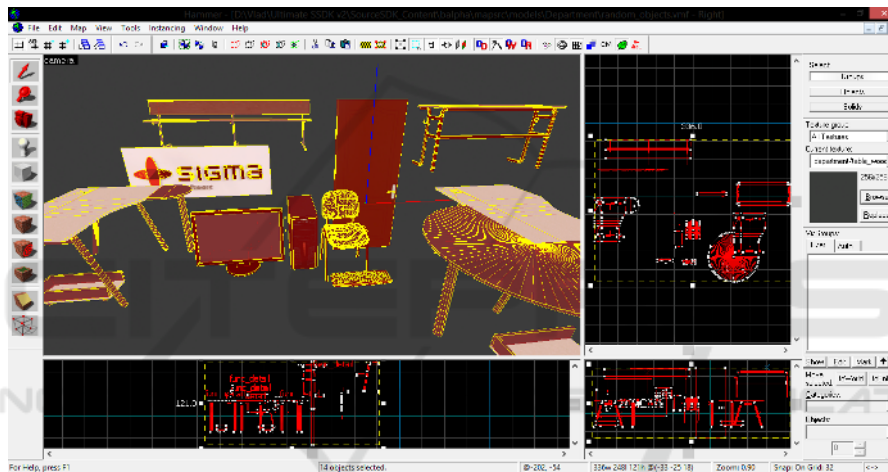Figure 2: Hammer Editor with a model of department rooms.

Figure 3: Hammer Editor with a model of department rooms.

Though, to determine the total score we leveraged the approach typical for the majority of computer grading systems: each task has a time limit, and while assessing the performance we consider both the scores and the time spent on the task.

The task constructs in these cases are complex, though due to multi-platform Unity tooling and optimal subsystems interaction, we implemented the complicated game elements and complex evaluation system.

We should note that the game has two modes – the learning mode and the assessing mode. The training mode provides users with a set of prompts and hints and the function that allows for interrupting or canceling the task at any minute. The player can cancel the task with the appropriate button. Also, during the game, the player can see the information on the statuses of completed tasks. Until all tasks are completed, the user will be suggested a new task each

time he completes or interrupts the selected task. New tasks will appear until the user completes them all and after that game is considered to be over.

The evaluation mode provides for the limited time on each task, and once the time is over the task is interrupted. In this case, the users' scores are based on their performance. If the task was completed to the fullest extent, the user gets the maximum number of points. If the task was completed partially, the user can score half, quarters, or three-quarters of the points. The evaluation mode doesn't have any prompts that help to complete the tasks, only the prompts that navigate the user through the game. The user is free to choose the order to do tasks, and they also can get back to the postponed tasks unless the time for those tasks has not expired yet.

The game has the following scenario: everything starts when the player appears info_player_start; throughout the parent parameter, the
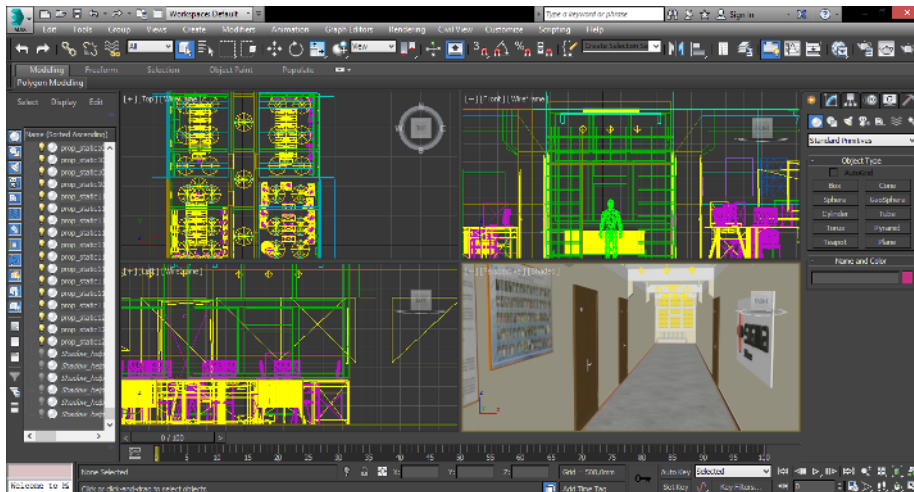
Figure 4: Hammer Editor with a model of department rooms.

Figure 5: Hammer Editor with a model of department rooms.

Figure 6: Hammer Editor with a model of department rooms.
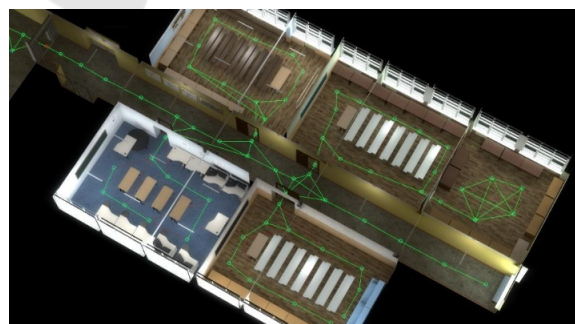
Figure 7: Hammer Editor with a model of department rooms.

env_entity_maker (cam_i_playersstart_maker) is attached. The env_entity_maker (cam_i_playersstart_maker) includes the point_template (cam_inmenu_point_template) container with the point_viewcontrol (cam_menuv1_point_viewcontrol) camera, the func_brush (cam_menuv1_fadebr) that overshadows the menu background and the info_target (player_old).env_fade that transitions the screen from black to normal.

After the player appears, the rigger_teleport (player_start_trigger_teleport) moves him to info_teleport_destination (playerspawn_depstart) – the end of the corridor in the department that has certain coordinates.

The player receives a number of messages env_message: (Department_WelkomeKhaiDepartment), (Department_TasksButtons), (Department_tasksstart_compl) and (Department_interrupt_ task). After 6.5 seconds, logic_auto activates trigger_teleport (teleport_to_buttons) and moves the player to info_target (tele_player_buttons) – the task menu. Before the player can select a task in the menu, env_entity_maker (cam_i_playersstart_maker) leaves the container point_template (cam_inmenu_point_template) in the previous location of the player.

The task menu consists of five func_button (Button_activate _quest_1-5), script_intro (effect_in _menu) shows the camera effect in the menu. Each button activates its corresponding task script. Any of these buttons refer to logic_relay (buttons_common_relay) when activating the task that disables the menu effect, extra sounds, and messages.

We should note that the game is intended for Ukrainian students and supports only Ukrainian and Russian localizations.

Once the task is selected, trigger_teleport moves the player to their previous location info_target (player_old) so that a player can start a new mission.

The entity responsible for the task completion sends a request to the corresponding env_texturetoggle (Texture_Button_activate_quest_1-5), which changes the buttons' state to "completed".

The math_counter (Math_Completed_procent) counts the number of completed tasks, and logic_compare (Compare_Completed_pr1-5) compares and shows the player their performance in percentage via env_message (Completed_pr1-5). Once the player completes the task, they should select the next task from the proposed.

For instance, estimating the level of competence working with data, the users have to answer multiple-choice questions that cover the information competency (Item 1). These tests can have from two to four questions depending on the test. When the user selects an answer, it is supplied with a corresponding comment and highlighted red (for incorrect answers) or green (for correct answers). For both cases, the user receives a text message with the correct answer. After the user completed test questions, the program counts correct and incorrect answers and displays the results in a message, and voices it over. Figure 8 demonstrates an example of a closed test question,

where the user has to choose the correct answer by tapping the number of the computer monitor in the virtual classroom.

The task has the following implementation. In the beginning, the player sees the message env_message (Department_Quest_1_502_goto504) that tells the player an audience to go. Once the user is in the right audience, trigger_multiple (Department_Quest_1_504_as1_triggershowMSG) activates the task.

The player sees the message env_message (Department_Quest_1_502) on the screen, then several buttons appear: func_button (button_que1_1-4), logic_case (quest1_logic_case) and the user should randomly select the first question. For each question, QUE1_1-16_relay utilizes math_counter (quest1_math_voice_number) that announces the question's number, ana func_ brush (QU1_monitor_image *) displays the picture on the in-game monitor.

To estimate the users' competence in problem-solving and communication, we developed the "Find the academic record book" challenge (Item 2) (figure 9). The scenario supposes the user to communicate with the Student character, ask her questions on the educational process and decide where to go to find the academic record book. To provide for an additional challenge, this item randomly appears in one of the departments.

When the user finds the object, he receives a message about discovery and he can go find the academic record book. After he gets the academic record book in his hands, he leaves the department and the challenge is over. The game counts the number of steps the user made to complete the task.

When the user finds the object, he receives a message about discovery and he can go find the Student. After he gets the academic record book in his hands, he leaves the department and the challenge is over. The game counts the number of steps the user made to complete the task.

To accomplish this task, we utilized: info_node, scripted_sequence, npc_template_maker, npc_natasha, env_message, logic_relay, logic_choreographed_scene, filter_activator_name, trigger_multiple, logic_case_ trigger_teleport, fun_tempergetge, info_thanplate.

Let's consider these entities closer. info_node is a node intended for creating a navigation network, required to move non-game characters in three-dimensional space. Each info_node has an ID. For a particular task, such a character is npc_natasha a student who uses the network to move around the level. The more info_node will be used on the level, the bet-
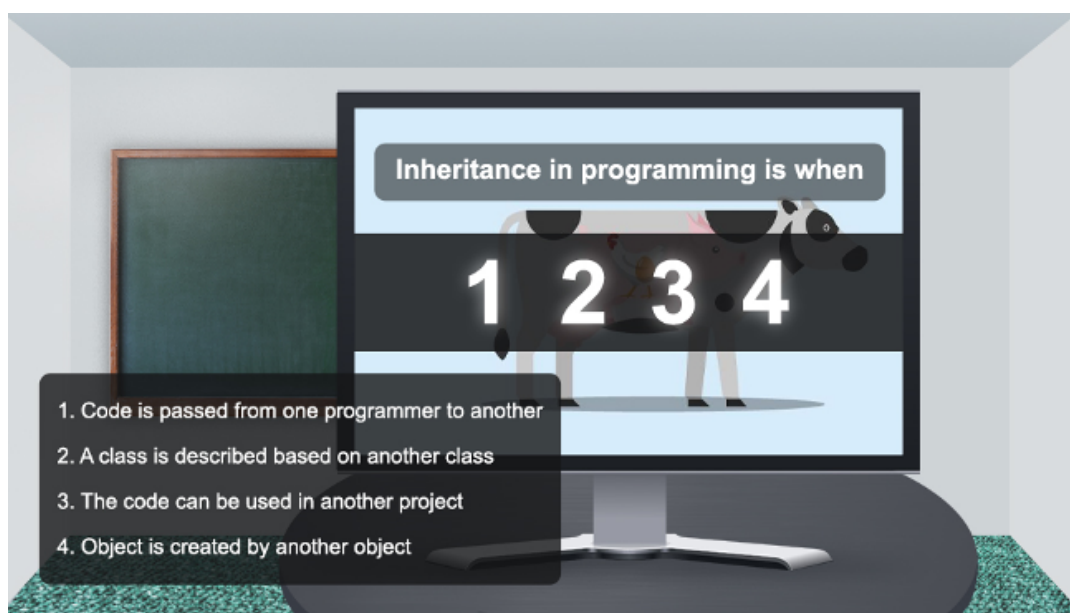
Figure 8: An example of the question from the 3D quest game.

Figure 9: An example of the question from the 3D quest game.

ter the navigation network will be. Though the aim is to build a correct and efficient network, that means that the nodes should be used even for the narrow doorways to connect different rooms in a network. Otherwise, the non-game characters won't be able to walk through the doors because they cannot get from one isolated network to another. Besides, the non-game characters will always choose the shortest way through the network from point A to point B. In case if the character encounters two roads of identical length the character will choose the road with a smaller ID number. The npc_natasha entity uses other entities intended to implement various actions. The npc_natasha entity is a source for cloning. This is a non-game character that is a female 3D model, which implements basic AI functionality. To move around the level this character utilizes the script files with scripts and the navigation network.

Other entities and their purpose are listed in table 2.

The "Clean the classroom" challenge (figure 10) aims to evaluate the user's ability to solve technical problems, follow the rules of safety, and treat the technical equipment and computers (Item 3). The user has to place computers, screens, mouses, and keyboards around the classroom in the right places. The game counts the number of steps the user made to complete the task.

In another classroom, the user has to set up a computer out of suggested elements (the computer cabinet, processing unit, mother card, power source, cooler, graphics adapter, RAM, etc.). This challenge counts the order; thus, the user can't place the cooler before settling the processing unit into the mother card. After the computer was set up, the user is told the number of a room where to take the computer. The task is considered to be complete when the user takes the computer to the given classroom.

Table 2: The entities used for the 3D game scenario implementation.

Entities	Purpose of use
scripted_sequence	required for programming the script scenes with non-game characters. Allows for the characters moving to specified locations, playing animations, and playing sound files.
npc_template_maker	a container for creating a non-game character at the selected moment, for example, if the player wants to repeat a task.
env_message	displays the message at the player's screen. The messages are stored in a text document and can be edited.
logic_relay	triggers the selected chain of actions of the scene level. Can be performed either once or several times.
logic_choreographed_scene	stores a link to a scene file via Face Poser. Scenes contain the advanced combination of character animations, facial animation, and their speech. One scene allows for managing several characters simultaneously.
filter_activator_name	serves for filtering the entities by name. Required in places of various objects interaction. For example, according to the task, the player cannot give the student a chair instead of the record book. In this case, we filter the record book by name using this entity.
trigger_multiple	is a three-dimensional, geometrically constructed trigger at the level, activated when physically encounters the activator. Any entity can be an activator.
logic_case	the trigger required to activate the random chain of events. Utilized for the test tasks.
info_target	a target or a point. The point can locate at any coordinates within the scene. info_target is utilized by other entities as a target or location.
trigger_teleport	it is a trigger for moving entities to a specific point specified in it. The point is defined in the entity info_target.
point_template	an entity that serves to create and clone other entities on call. Mostly used when a player wants to replay a task.
func_physbox	is a three-dimensional entity of the convex shape that behaves like a physical object. For example, the test book in the task.
prop_dynamic_override	an entity that serves to create a dynamic model bypassing the constraint criteria (dynamic/static). This entity can play animations.
ambient_generic	stores the links to the audio files. The entity is used for all tasks, allowing for looping the sounds.
func_door_rotating	serves to create doors that can be opened by the player.
prop_door_rotating	serves to create doors that can be opened by non-game characters. The non-game characters can open these doors if they are closed or block the way.
func_button	the trigger button that a user can press to initiate a certain sequence of actions. Used in-game to select tasks, and for the tests and puzzles that allow for interrupting the task.

For the task we use the following entities: info_target, prop_dynamic_override, prop_physics, trigger_teleport, func_brush, math_counter, filter_activator_name, func_button, ambient_generic, env_message (table 2).

Also, we used the entity math_counter to perform such arithmetic operations as addition, subtraction, multiplication, and division. This entity is applied for counting the player's score or the number of tests.

The next task is to "Assemble the computer" (Item 4). The player is asked to assemble a system unit from various components (figure 11). The player has the

following items: the case, processor, motherboard, power supply, cooler, video card, RAM, hard drive, and side cover. For this task matters the order of actions, for example, you cannot install a cooler until the processor is installed on the motherboard.

Due to the technical aspects, the components must be installed only inside the system unit, but not outside it. That means the user cannot install the processor in the motherboard outside the system unit. Once the system unit is complete, the user is told which audience to take the computer. After the player brings the computer to the right place, the task will be com-
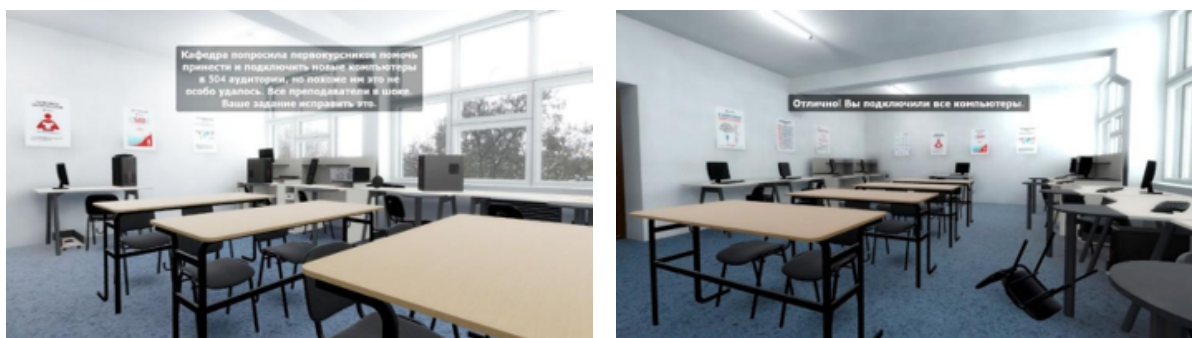
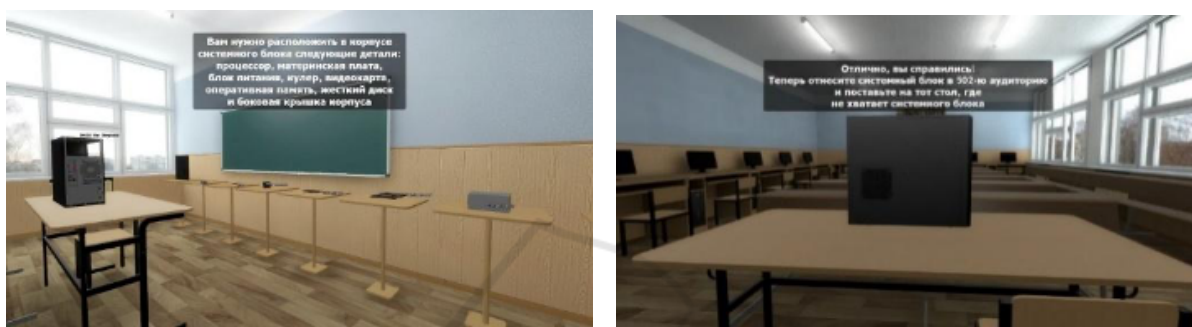Figure 10: The user got the task to settle the classroom and completed it.

Figure 11: The player received and completed the task to assemble the computer.

pleted.

This task consists of the func_detail, point_message, env_message, filter_activator_name, func_button, ambient_generic, env_projectedtexture, trigger_teleport, info_target, logic_relay, func_brush, func_physbox, point_ountericplate (table 2) entities. The additional entities for this task were:

- func_detail – three-dimensional convex-shaped entity used to create walls and structures, has no name and should not be taken into account when creating level scene optimization;

- point_message entity that displays text prompts located in three-dimensional space. Used to suggest component names in a task where the player has to assemble a system unit;

- env_projectedtexture entity used to create a dynamic light source with a shadow. Located in places where it is required to highlight some stage areas for better convenience. Highlights the areas in tasks with assembling the computer block and puzzle games.

To evaluate the users' abilities for self-education and career guidance (Item 5), the user has to put together the "IT specialist jigsaw puzzle". The task is to group 30 suggested elements according to 10 given IT-related occupations: Mobile Developer Android, Mobile developer iOS, Frontend developer, Backend developer, Project manager, Java developer, .NET developer, UX/UI designer, QA tester, Database developer. The number of pieces for each occupation varies from 3 to 6, similar pieces can belong to different occupations. The order in this challenge doesn't matter, and the number of attempts is not limited. The assessing mode has a time limit. The pieces that do not match automatically drops away, denoting the mistake. The challenge is complete after all the pieces are together (figure 12).

During the challenge, the user can get tip messages by clicking the occupation name, and it shows up for 10 seconds. The tips number is limited, and the game counts how many of that user took.

The task with puzzles includes the following entities env_message, filter_activator_name, func_button, ambient_generic, env_projectedtexture, trigger_teleport, info_target, logic_relay, func_brush, func_physbox, point_template, game_textter, englec.

All entities were previously considered for other tasks (table 2), the additional entity here is phys_keep_upright, used to hold physical objects in a defined position, allowing for setting the angle. The entity serves to keep puzzles in a certain position.

The tasks are meant not only to evaluate the users' digital competence but also to learn about the faculty life and educational system as the game models reflect real objects.

Figure 12: The user processing the jigsaw puzzle task.

At the moment, the quest has 5 challenges, though we have an opportunity to make changes to the tasks pull. To succeed, the user has to complete all of the challenges, yet the order can be random. To choose the challenge the user just picks one by clicking on it, and the voice behind the scene explains the message and the point for him to go. As the user reaches the right classroom the voice behind the scene provides detailed instructions for the challenge. When already moving, the quit option becomes available for the user. To disrupt the challenge the user should press the corresponding button in the classroom or use a keyboard shortcut.

Completing each task is always written, its color changes from red to green. During the process, the user sees the score of the challenges he completed. There are certain evaluation criteria, though every task is scored 4 points. The maximum score is 20 points. Depending on the complexity the tasks value differently. The system defines the applicants who scored less than 10 points to have a low level of digital competence, from 10 to 15 points – the middle level, and those who scored above 15 – to have a high level of digital competence. Also, each challenge has no time limits, yet the quest time was limited. Thus, we could evaluate the users' ability to plan their time and decide on the order and timing for the challenges they take.

3 THE EXPERIMENT RESULTS

To evaluate the quest efficiency we held an experiment at the IT championship for the applicants at the computer science and information technolo-

gies department in the National Aerospace University "Kharkiv Aviation Institute", which results are demonstrated in the article (Prokhorov et al., 2020). This paper compares the results of students who passed the quest on a computer and in real life. The analysis proved that the difference in results of two groups of students who participated in the IT championship is not significant, and confirms the results of the previous research (Özalp-Yaman and Çağıltay, 2010; Ita et al., 2014). However, the teenagers were mostly attracted to the 3D game.

In 2020 the championship occurred in the University for the fourth time, and the applicants were suggested the 3D game challenge. Due to the pandemic, all students participated in the championship online, while we calculated their scores and defined the winners (https://www.youtube.com/watch?v=3HRz2GoudeA).

In general, we registered 180 students from 35 schools, though only 116 students participated in the game and completed all tasks.

There were 84 boys that equaled 72% and 32 girls that equaled 28% of participants. To process the overall applicants' results we applied statistical analysis from the R packages (Kabacoff, 2021; Field et al., 2012). We calculated the average for girls and boys. Figure 13 provides for the distribution of the scores. Boys demonstrated better results (average score equal 10.7) than girls (average score equal 9.8), but the difference isn't statistically significant (the Students' criteria equals 1.18 at p=0.23).

To verify that the tasks are valid and applicable to access the applicants' skills in the field of computer science we carried out the psychometric analysis. We defined the task complexity score that demonstrates
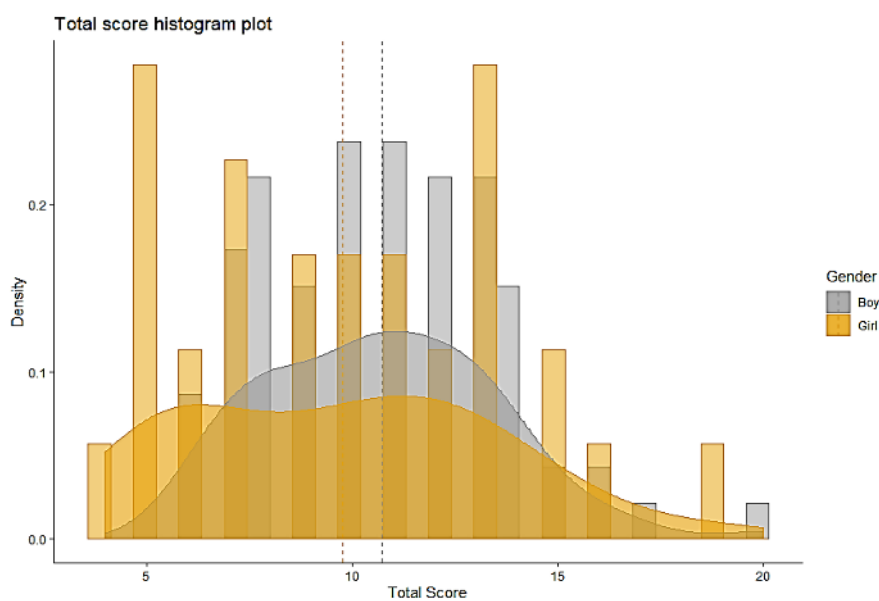
Figure 13: Scores distribution on the 3D game results.

the participants' performance on certain tasks and the coefficient of correlation of tasks to the total score, that characterizes the consistency of test tasks. The obtained results are in table 3.

The results prove that items 1 and 5, those suggested to answer the questions related to the IT industry and to assemble a puzzle were the most complicated in the 3D game (47% and 46% of students accordingly got the maximum scores). This proves that we should carefully approach creating the tests, considering the target audience's cognitive skills and the test intended use.

Items 2-4 appeared to be easier for the students (63%, 52%, and 52% of students accordingly got the maximum scores) since they didn't aim to assess the knowledge but to assess the ability to navigate through the game and concentrate. Thus, in accomplishing these items, students had to demonstrate metacognitive skills.

Though, considering the correlation of scores for these items to the general score, the fiesta item correlates the most (the correlation coefficient equals 0.6). That means that the students who answered IT-related questions better showed overall higher results. The general difficulty on all test tasks is 0.2, that is the middle level of difficulty. The results confirmed that the tasks are reliable and adequate for determining the level of digital competencies precisely for future applicants of the IT departments.

The analysis concluded that the format of test tasks allows not only to determine the level of participants' competencies but also to define the skills

that should be developed. The tests in the format of a game that automatically collects data allow for defining the digital competencies profile for each participant. This profile can be analyzed and compared to a sample "desired" profile to decide on career guidance and training strategy. The profile analysis allows defining the competencies that do not require development, the competencies that require development, and the missing competencies. To provide for an integrated assessment of the participants' competencies, we used the weighting and ranking method. As a result, we received a clear picture of the skills that the participant has already obtained and the skills that should be developed so that a participant could enter the IT-related department and successfully study there.

However, the middle level of the participants' digital competence didn't decrease their interest in our evaluation approach. This fact is important not only for the future IT specialists but also for the departments' occupational guidance process. The students mostly coped with the tasks and provided positive feedback on participating in the game.

4 CONCLUSION

Out of the aim of this research and the particular tasks we faced developing a 3D quest game, as well as the results of assessing the application efficiency in career guidance we came up with the following conclusions.

The game application development technology we

Table 3: Statistics of items.

	Item 1	Item 2	Item 3	Item 4	Item 5	Total
Difficulty	0.47	0.63	0.52	0.51	0.46	0.52
Correlation	0.60	0.59	0.51	0.51	0.43	

suggest can be utilized by 3D models and game developers, in particular for training future IT specialists.

We utilized various technologies to implement the application idea. Leveraging Unity 3D and Source Engine as the main engines allowed for creating a 3D model of a game and its main objects. We edited objects via Hammer Editor and created a realistic department's classroom model with the Agisoft PhotoScan Pro tool and photogrammetry. Searching the right way was implemented via navigation grids, which allow through the geometrically complicated 3D objects.

The game scenario provides for a virtual tour around a department of the 3D university. As far as the game replicates the real-life objects, applicants can see the department's equipment and classrooms.

During the quest development, we considered the requirements to the participants' characteristics, game environment, and utilizing various types of tests with hints and voicing over, that contributed to the accurate evaluation and increasing the students' motivation to acquire the IT-related profession, in particular building the models and researching.

The quest includes several different challenges meant to evaluate the applicants' digital competence connected to the DigComp 2.1 framework components such as information and data literacy, communication and collaboration, digital content creation, safety, problem-solving. The tasks also allow for understanding the applicants' ability to work efficiently and to use computers in real life.

The experiment results prove the 3D quest to be effective. According to the results of the 3D quest, applicants demonstrated an average level of digital competence with a certain item test difficulty at 0.5. This indicates that applicants made a conscious choice of the faculty and they are ready for further study. Our psychometric analysis confirmed the reliability and consistency of the test tasks we developed.

The applicants estimated a 3D quest, as more up-to-date and attractive engagement. Also, they claimed this up-to-date approach would influence their choice of a university. The general results of the test tasks outlined the areas for enhancement and showed what digital competencies the students yet have to obtain.

Thus, our 3D quest application can grow the audience for career guidance activities and improve the public image of the university. Besides, applicants can use this 3D quest to decide on their future occupation.

In addition to campaigning and career guidance, this application can help to teach and test students. To do this, several psychometric indicators of 3D quest tasks were analyzed to allow further improvement for the items' quality.

The prospective research aims become pending due to switching to digital learning. These aims are to create a convenient and effective environment for digital learning using VR and AR technologies, to utilize the application for evaluating the digital competence of the future IT specialists, and adjusting the educational plan for the university's first-year students.

REFERENCES

Anuar, A. (2006). Digital Photogrammetry: An Experience of Processing Aerial Photograph of UTM Acquired Using Digital Camera. Paper presented at the AsiaGIS 2006, Johor, Malaysia. http://eprints.utm.my/id/eprint/490/.

Barab, S., Thomas, M., Dodge, T., Carteaux, R., and Tuzun, H. (2005). Making learning fun: Quest Atlantis, a game without guns. In *Educational Technology Research and Development*, number 53, pages 86–107.

Blanco, Q. A., Carlota, M. L., Nasibog, A. J., Rodriguez, B., Saldaña, X. V., Vasquez, E. C., and Gagani, F. (2020). Probing on the Relationship between Students' Self-Confidence and Self-Efficacy while engaging in Online Learning amidst COVID-19. *Journal La Edusci*, 1(4):16–25.

Carretero, S., Vuorikari, R., and Punie, Y. (2017). DigComp 2.1: The Digital Competence Framework for Citizens: With eight proficiency levels and examples of use. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106281/web-digcomp2.1pdf_(online).pdf.

de Carvalho Filho, M. K. (2009). Confidence judgments in real classroom settings: Monitoring performance in different types of tests. *International Journal of Psychology*, 44(2):93–108.

Demirbilek, M. and Koç, D. (2019). Using Computer Simulations and Games in Engineering Education: Views from the Field. *CEUR Workshop Proceedings*, 2393:944–951.

Field, A., Miles, J., and Field, Z. (2012). *Discovering Statistics Using R*. SAGE Publications.

Finnegan, T. (2015). *Learning Unity Android Game Development*. Packt Publishing, Birmingham.

Frontoni, E., Paolanti, M., Puggioni, M., Pierdicca, R., and Sasso, M. (2019). Measuring and assessing

augmented reality potential for educational purposes: Smartmarca project. In De Paolis, L. T. and Bourdot, P., editors, *Augmented Reality, Virtual Reality, and Computer Graphics*, pages 319–334. Springer International Publishing, Cham.

Garas, S. and Hassan, M. (2018). Student Performance on Computerbased Tests Versus Paper-Based Tests in Introductory Financial Accounting: UAE Evidence. *Academy of Accounting and Financial Studies Journal*, 22(2):1–14.

Haranin, O. and Moiseienko, N. (2018). Adaptive artificial intelligence in RPG-game on the Unity game engine. *CEUR Workshop Proceedings*, 2292:143–150.

Ita, M. E., Kecskemety, K. M., Ashley, K. E., and Morin, B. C. (2014). Comparing Student Performance on Computer-Based vs. Paper-Based Tests in a First-Year Engineering Course. In *121st ASEE Annual Conference & Exposition*, pages 24.297.1–24.297.14, Indianapolis, Indiana. https://peer.asee.org/20188.

Kabacoff, R. I. (2021). *R in Action*. Manning Publications, third edition.

Katsko, O. O. and Moiseienko, N. V. (2018). Development computer games on the Unity game engine for research of elements of the cognitive thinking in the playing process. *CEUR Workshop Proceedings*, 2292:151–155.

Kompaniets, A., Chemerys, H., and Krasheninnik, I. (2019). Using 3D modelling in design training simulator with augmented reality. *CEUR Workshop Proceedings*, 2546:213–223.

Kuzminska, O., Mazorchuk, M., Morze, N., Pavlenko, V., and Prokhorov, A. (2018). Digital competency of the students and teachers in Ukraine: measurement, analysis, development prospect. *CEUR Workshop Proceedings*, 2104:366–379.

Kuzminska, O., Mazorchuk, M., Morze, N., Pavlenko, V., and Prokhorov, A. (2019). Study of digital competence of the students and teachers in Ukraine. *Communications in Computer and Information Science*, 1007:148–169.

Lavrentieva, O., Arkhypov, I., Kuchma, O., and Uchitel, A. (2020). Use of simulators together with virtual and augmented reality in the system of welders' vocational training: Past, present, and future. *CEUR Workshop Proceedings*, 2547:201–216.

Ma, M., Bale, K., and Rea, P. (2012). Constructionist learning in anatomy education. In Ma, M., Oliveira, M. F., Hauge, J. B., Duin, H., and Thoben, K.-D., editors, *Serious Games Development and Applications*, pages 43–58, Berlin, Heidelberg. Springer Berlin Heidelberg.

OECD (Accessed 21 Mar 2017). *Learning for Jobs: Synthesis Report of the OECD Reviews of Vocational Education and Training*. OECD Reviews of Vocational Education and Training. OECD Publishing, Paris. https://www.researchgate.net/publication/266265826_Learning_for_Jobs_Synthesis_Report_of_the_OECD_Reviews_of_Vocational_Education_and_Training.

Patiar, A., Kensbock, S., Ma, E., and Cox, R. (2017). Information and Communication Technology–Enabled Innovation: Application of the Virtual Field Trip in Hospitality Education. In *Journal of Hospitality & Tourism Education*, volume 29, pages 129–140.

Prokhorov, O. V., Lisovichenko, V. O., Mazorchuk, M. S., and Kuzminska, O. H. (2020). Developing a 3D quest game for career guidance to estimate students' digital competences. *CEUR Workshop Proceedings*, 2731:312–327.

Rankin, Y. A., Gold, R., and Gooch, B. (2006). 3d role-playing games as language learning tools. In Brown, J. and Hansmann, W., editors, *27th Annual Conference of the European Association for Computer Graphics, Eurographics 2006 - Education Papers, Vienna, Austria, September 4-8, 2006*, pages 33–38. Eurographics Association.

Shepiliev, D. S., Semerikov, S. O., Yechkalo, Y. V., Tkachuk, V. V., Markova, O. M., Modlo, Y. O., Mintii, I. S., Mintii, M. M., Selivanova, T. V., Maksyshko, N. K., Vakaliuk, T. A., Osadchyi, V. V., Tarasenko, R. O., Amelina, S. M., and Kiv, A. E. (2021). Development of career guidance quests using WebAR. *Journal of Physics: Conference Series*, 1840(1):012028.

Thürkow, D., Gläßer, C., and Kratsch, S. (2005). Virtual landscapes and excursions-innovative tools as a means of training in geograph. In *Proceedings of ISPRS VI/1 & VI/2 Workshop on Tools and Techniques for E-Learning*, pages 61–64. https://www.isprs.org/proceedings/xxxvi/6-w30/paper/elearnws_potsdam2005_thuerkow.unlocked.pdf.

Tokarieva, A. V., Volkova, N. P., Harkusha, I. V., and Soloviev, V. N. (2019). Educational digital games: models and implementation. *CEUR Workshop Proceedings*, 2433:74–89.

Vakaliuk, T., Kontsedailo, V., Antoniuk, D., Korotun, O., Mintii, I., and Pikilnyak, A. (2020). Using game simulator Software Inc in the Software Engineering education. *CEUR Workshop Proceedings*, 2547:66–80.

Villagrasa, S. and Duran, J. (2013). Gamification for learning 3D computer graphics arts WebAR. In *TEEM '13: Proceedings of the First International Conference on technological ecosystem for enhancing multiculturality*, pages 429–433.

Vlachopoulos, D. and Makri, A. (2017). The effect of games and simulations on higher education: a systematic literature review. *International Journal of Educational Technology in Higher Education*, 14:22.

Özalp-Yaman, Ş. and Çağıltay, N. E. (2010). Paper-based versus computer-based testing in engineering education. In *IEEE EDUCON 2010 Conference*, pages 1631–1637.