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Formation of economic and ecological competences of students in the context of learning the concept of sustainable development in a game form

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Abstract: *Today, the ecology issue is relevant and important. Combining the study of environmental and economic aspects in educational institutions in a game format will give a significant result. If we talk about the massive use of such products in education, there are currently no special board games, or they are developed locally. The study* ***purpose*** *is to develop a special software package that is an "Green Economy School" program extension and adapts it to the interactive lesson format. The following* ***methods*** *were used: analysis of literature sources, comparison, and sociological survey on the optimal graphic format, construction of algorithms, three-dimensional modeling. As a* ***results*** *of the work, the economic and environmental board game "Green Adventure", which is part of the educational and developmental program "School of Green Economy", was adapted for use in online mode. This was implemented by the Unity software using the C# programming language. The possibility of using the development in distance learning by students of grades 3-5 is a significant difference from existing analogues. The developed vertical slice of the program implements all the key mechanics that allow it to be used for testing in educational institutions. After receiving the results of the testing, we will either continue development and add all the locations of the playing field, or, if students do not like some aspects of the developed complex, we will modify the work of the software complex, depending on the feedback from the players.* ***Conclusions:*** *based on the sociological survey results, the vector graphics was chosen. A 3D-map model of the developed complex prototype was created. The algorithms were realized in the C# programming language. A program prototype*

was developed, which includes the package basic mechanics. In the Unity, a software package prototype was created for use in the format of an interactive lesson, containing a closed map of the game and several locations that can be improved. In the future, the developed complex will be tested in educational institutions of Kyiv among 3-5 grades students using a special methodology. The testing results will determine the effectiveness of the proposed software package and identify package aspects that need to be redesigned or improved. The results can be applied to digital education programs that promote sustainable development and green economic thinking among primary school students.

Keywords: *education for sustainable development; ecological competence; economic competence; ecological-economic thinking.*

Формування економіко-екологічних компетентностей здобувачів освіти в контексті навчання концепції сталого розвитку в ігровій формі

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***Анотація**: Сьогодні питання екології є актуальним та важливим. Поєднання вивчення екологічних та економічних аспектів у закладах освіти в ігровому форматі дасть вагомий результат. Якщо говорити про масове використання таких продуктів в освіті, то наразі спеціальних настільних ігор немає, або вони розробляються локально. **Метою** дослідження є розробка спеціального програмного пакету, який є розширенням програми «Школа зеленої економіки» та адаптує його до інтерактивного формату уроку. Були використані такі **методи**: аналіз літературних джерел, порівняння та соціологічне опитування щодо оптимального графічного формату, побудова алгоритмів, тривимірне моделювання. За **результатами** роботи економіко-екологічна настільна гра «Зелена пригода», що є частиною освітньо-розвивальної програми «Школа зеленої економіки», була адаптована для використання в онлайн-режимі. Це було реалізовано за допомогою*

програмного забезпечення Unity з використанням мови програмування C#. Можливість використання розробки в дистанційному навчанні учнями 3-5 класів є суттєвою відмінністю від існуючих аналогів. Розроблений вертикальний зріз програми реалізує всі ключові механіки, що дозволяють використовувати її для тестування в закладах освіти. Після отримання результатів тестування ми або продовжимо розробку та додамо всі локації ігрового поля, або, якщо учням не сподобаються деякі аспекти розробленого комплексу, модифікуємо роботу програмного комплексу залежно від відгуків гравців. ***Висновки****: на основі результатів соціологічного опитування було обрано векторну графіку. Було створено 3D-модель карти прототипу розробленого комплексу. Алгоритми реалізовано мовою програмування C#. Розроблено прототип програми, який включає базові механіки комплексу. У середовищі Unity створено прототип програмного комплексу для використання у форматі інтерактивного уроку, що містить замкнену карту гри та кілька локацій, які можна вдосконалити. У майбутньому розроблений комплекс буде апробовано в закладах освіти м. Києва серед учнів 3-5 класів за спеціальною методикою. Результати тестування дозволять визначити ефективність запропонованого програмного комплексу та визначити аспекти, які потребують переробки або вдосконалення. Результати можна застосувати до програм цифрової освіти, що сприяють сталому розвитку та зеленому економічному мисленню серед учнів початкової школи.*

Ключові слова*: освіта для сталого розвитку; екологічна компетентність; економічна компетентність; еколого-економічне мислення.*

Problem statement. Nowadays, the issue of ecology in the world is very relevant and important. Therefore, from an early age, children should understand the complexity and problems of this topic, as well as ways to improve the environmental situation through responsible consumption of resources, use of renewable energy

sources, etc. At the same time, the importance of proper financial management should not be neglected so that when performing a particular activity, one can make a profit, not get into debt or go bankrupt. That is why children should at least learn economic competence at a basic level. These two aspects of our lives are very closely connected, and this connection should be reproduced in the educational process in educational institutions. The work is the first to develop an education-by-gaming software package that integrates economic and environmental competencies into a single educational model.

Analysis of recent research and publications. The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries – developed and developing – in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth [1].

Within the framework of the general concept of sustainable development, V. Radkevych defines sustainable development of Ukraine as a process of balanced socio-economic and environmental progress aimed at meeting the needs of the current generation without compromising the ability of future generations to meet their own needs. [2]. The implementation of these goals is facilitated by the Strategy for Sustainable Development of Ukraine until 2030, which defines the main principles for economic growth, improving the quality of life of the population and preserving natural resources for future generations. Among them, the authors highlight in particular economic sustainability, which enables the creation of conditions for stable economic growth; support for innovative and high-tech sectors of the economy; increasing the competitiveness of the national economy through the development of small and medium-sized businesses, industrial clusters and export-

oriented enterprises; development of a circular economy and the introduction of resource-saving technologies, as well as environmental sustainability, which contributes to: protection and restoration of natural resources, in particular water and land; reduction of greenhouse gas emissions and combating climate change; transition to renewable energy sources, ensuring energy efficiency in all sectors of the economy; waste management and reducing their negative impact on the environment; development of a "green economy", which creates a balance between economic growth and environmental protection [2].

In the work of I. Chekrii it is indicated that people should have formed key competencies for life. A person acquires these competencies by acting in difficult situations, when learning from his own experience. Interdisciplinary competencies are key and necessary for all students of different ages around the world. Related economic, social, political and environmental challenges require education to form responsibility and creativity in young people. UNESCO scientists are convinced that education for sustainable development is a set of tools, methods and techniques that stimulate students to make informed decisions, act responsibly, contribute to the development of economic stability and form a just society for present and future generations, while respecting cultural diversity [3].

According to I. Dubovich and G. Lesiuk, achieving the Sustainable Development Goals requires profound changes in the behavior and way of thinking of humanity. To create a balance between economic, environmental and social challenges, humanity must first possess such knowledge, skills and values that enable the implementation of sustainable development. Education is crucial for achieving sustainable development. However, modern education largely focuses on economic growth and, as a result, the spread of consumer behavior. Today, education for sustainable development is increasingly seen as an alternative tool for organizing teaching and learning in a way that allows schools, vocational and technical educational institutions, universities, communities and the private sector to respond

to the challenges of the 21st century. Effective implementation of education for sustainable development requires adequate support from all countries [4].

At the global level, the specialized UN organization UNESCO has been actively and effectively engaged in the development and transformation of education since its foundation. In addition to UNESCO, several organizations, centers, and platforms have been created to promote the development of education. For example, the UN Economic Commission for Europe created the International Decentralized Network "Environmental and School Initiatives" to exchange successful experiences and best practices in the field of education in general and in education for sustainable development in particular. In 1948, representatives of governments and environmental organizations created the International Health Union, which includes a commission on education and communications. The commission develops teaching and education methods for all segments of the population aimed at raising awareness of the importance of preserving biodiversity. In addition to international, national institutions were created [5].

A. Dzhurilo's work indicates that education for sustainable development is a focus of many countries, including European ones, as an important aspect of education. In the European Union, school curricula for sustainable development usually consider the goals and principles of sustainable development, such as social justice, economic efficiency, and environmental sustainability.

Curriculums in EU schools can include many areas, including the following:

- Environmental education:
  - Studying the principles of ecology and natural sciences.
  - Understanding the impact of human activities on the environment.
  - Encouraging students to take action to use resources rationally.
- Economic literacy:
  - Understanding basic economic principles and their impact on society.
  - Emphasizing economic responsibility and the rational use of resources.

The EU can also implement specific programmes and initiatives to support sustainable development in education. Another important aspect is the introduction of interactive teaching methods that allow students to feel their responsibility for the state of the world and stimulate them to participate in solving global problems [6].

In Ukraine, as in the whole world, there is a program for sustainable development that meets the needs of the present and does not harm the future. In other words, this is development that will preserve the resources of our Earth and help prevent these global problems. Ukraine is the 55th country that joined and signed the Strategy for Sustainable Development in its state. The goal of modern preschool education in Ukraine is the formation of a multifaceted, developed personality who can act and live in the present in a changing environment, which is focused on education for sustainable development [7].

Education for sustainable development of preschool children in Ukraine is based on the manual "Preschoolers – Education for Sustainable Development" by Doctor of Pedagogical Sciences N. Havrysh and Professor, Doctor of Pedagogical Sciences O. Pometun. [8]. A great contribution to education for sustainable development was made by O. Vysotska, who in 2011 published the scientific and methodological manual "Education for Sustainable Development" [9].

Currently, gaming technologies are often used in the educational process to facilitate students' learning, for example, the use of educational board games during lessons. This improves students' ability to learn, increases attention, etc. It also encourages children to engage in discussions, which makes it easier to learn complex concepts. Combining environmental and economic aspects at the basic, school level in a game format will have a significant impact originally on primary school students, although it can also be effective for high school students.

One such project is a board game created by National Taiwan Normal University [10-11]. This development combines economy, ecology, and social problems that players must solve at the same time. However, the game is aimed

exclusively at high school or college students due to the complexity of the rules. If we talk about the massive use of such environmental and economic products in education, there are currently no special board games for primary school, or they are developed locally for a particular educational institution and are not publicly available. At the same time, an economic and environmental board game “Green Adventure” has recently been developed by authors [12]. This development combines economic and environmental aspects and teaches children in grades 3-5 in an interesting and understandable format.

Existing researches does not consider the possibility of creating an interactive game complex based on Unity programming as a tool for educating primary school students.

Highlighting previously unresolved parts of the general problem. However, all the abovementioned analogues can be used only during offline education, which is not always convenient today, when many educational institutions work remotely. Therefore, the idea came up to use the board game “Green Adventure”, previously developed by authors as a basis and expand it to the level of a training complex that can be used both in online and offline learning.

Formulation of the objectives of the article (task statement). The aim of the work is to develop a special software package that is an extension of the educational and developmental program “School of Green Economy” and adapts it to the interactive lesson format to form an economic and ecological competences of students in the framework of learning the concept of sustainable development and to verify the pedagogical effectiveness of the complex through testing in Kyiv schools.

Presentation of the main material of the study. At the beginning of the work, a social survey was conducted among students of grades 3-5 on the optimal format of the graphics of the proposed software package. The survey was conducted in the schools of the Holosiivskyi district of Kyiv, which were closest to the author’s location. A total of 200 children took part in the survey. As a result, 76% of

respondents chose to use vector graphics, while 24% chose to use pixel graphics. Based on the obtained results, the use of vector three-dimensional graphics was chosen, and a certain number of assets for the complex were created by the author, which clearly depict the locations of the playing field and their modifications.

To create the models, three-dimensional modeling software Blender was used. The models themselves are made in the low-poly style, in other words, with little details of objects. This is both done so that the application can run on old devices with low computing power and provides a more cartoonish image of the playing field locations and their improvements, which is aimed at better perception by children. The Unity engine was chosen to create the core of the complex, considering its advantages and disadvantages [13-14].

The first stage of development was the modeling of the basic map of the board game. All models are created using the 3D modelling software Blender. The creation of each model of the playing field location begins with finding examples of a similar location in real life or by artistic means (photo, painting, etc.). This is done by searching on Google Images.

After that, a mock-up of the future model is made using primitive geometric shapes such as a ball, cube, pyramid, etc. Next, certain final colours are added to the model for a clearer understanding of the final result. After that, the primitive shapes are changed to more complicated ones, i.e. those with a slightly more complex geometry, and smaller details of the overall model are also added. The last stage is to modify small details in the overall model, such as the location of objects on the model, their size, and the assignment of colors to each object.

Next, a copy of the full location of the playing field is made, which is supplemented with new individual elements. These elements are determined by future improvements to the location, which are provided by the improvement tree, which will be discussed below. After that, the models are imported separately into Unity, so that the model can be changed at the time of the location improvement.

Finally, the models of the game board locations are arranged in the form of a map and link models are made between them, which visually reproduce the tracks.

The map of the prototype of the developed complex consists of 10 locations of the playing field, fair, 2 risks, environmental and tax inspection. All 3D models were made by authors. Also, each location model has a track of the same color for the entire map, which reproduces the general route of the players' movement during the turn. The flowchart with the algorithm of the player's move is shown on Fig. 1.

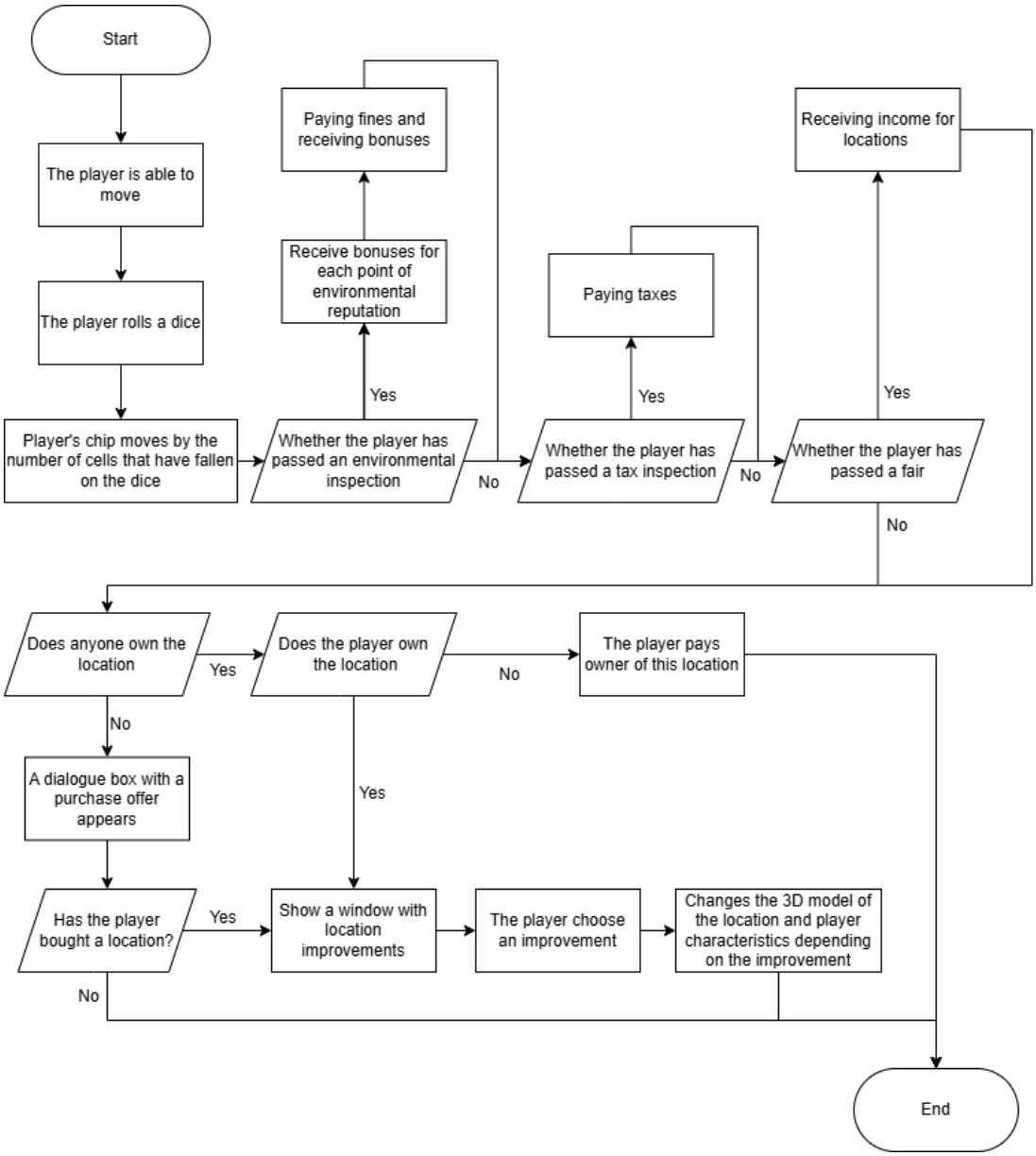

Fig. 1. Flowchart with the algorithm of the player's move

Source: authors

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All algorithms of the game, i.e. all actions of players in the complex, are realised by means of the C# programming language. The software system implements several mechanics, namely: player movement on the playing field; purchase and improvement of the playing field locations; operation of government agencies and the fair, player characteristics (amount of money, environmental reputation, rewards/fines, profits).

There are several phases which switch sequentially during one player's turn: movement phase; action phase (buying and improving locations of the playing field, receiving bonuses and fines from government agencies, etc); the phase of waiting for your turn. During his/her turn, the player presses a key (or a button on the screen, if it is a smartphone) and rolls an imaginary six-sided dice. Next, the player's chip model is automatically moved by a certain number of steps indicated on the dice. At the same time, the animation of the chip movement is displayed on the screen. To move chips to the correct points, special invisible objects are placed on the entire game map. Each location of the playing field has its own object, the position in three-dimensional space of which is recorded, and an arc is drawn between the initial position of the chip and the final cell.

After that, the player gets to the location of the playing field. If the location is not already owned by another player, a dialogue box appears with the price for the location, in which there are several options, namely to buy the location if the player has enough money, or to skip this location if the player does not want to take ownership of it. If the player does not have enough money, a text appears informing them about the lack of money. If the location is already owned by another player, the player is automatically charged a certain amount of money, which is added to the location owner's balance as payment for environmentally friendly (or not) products and services produced at this location. At the same time, if a player, after a certain number of map laps corresponding to one year of the game country's history, gets to a location owned by that player, he or she can make improvements to that

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location according to financial capabilities and a special improvement tree.

For each location, there is a special tree of improvements that can be used to modify this location. After purchasing or entering a location of the playing field owned by this player, a special interface appears with one or two buttons implemented in the form of cards which describe all the characteristics of the improvements and show the image of the improvement in a form understandable for children. When you select an improvement, the three-dimensional model of the location changes, i.e. the previous model of the location is hidden and the model prepared for this particular improvement is shown, which is pre-positioned on the game map at the location position, but invisible until you switch.

During the development of the complex, some aspects of the improvement of the board game locations were also redesigned compared to the basic version of the board game. This was done to port the board game better to electronic devices and to improve the environmental focus of the game. In particular, a return mechanic was created. The mechanic works by allowing some improvements to return a location to some previous state of improvement. This allows the player to go back if they realize that their previous actions were wrong or simply decide to change their improvement strategy. If the player continues to improve the location in the direction of environmental degradation, the mechanics of confiscation are provided. In this case, at a certain level of improvements, the location can be confiscated, and it will again be available for purchase to any player except the one from whom it was confiscated, which is provided as a punishment for unfair attitude to the environment and the use of government resources. However, all the financial results gained by the player when using and improving this location are not confiscated. The money spent on the purchase of locations and their improvement goes directly to the government and can not be returned. As a result of location improvements, player characteristics are updated.

Let’s take a closer look at the player characteristics developed in the complex.

In total, the developed system includes five player's characteristics: the amount of money on the player's balance; the level of environmental reputation and economic trust, which are indicators of the player's environmental friendliness during the game; ownership of the playing field locations; profits received after the fair, received for environmentally friendly (or not) products and services produced at locations owned by the player; economic bonuses or fines that are paid by the player during its activities.

All of them are represented by integers so that children have no problems with calculations and planning their actions. Only ownership is represented separately by special icons. With the help of these icons, each player records which locations of the playing field are in his or her ownership and at what stage of improvement they are. This is done to enable the selling or exchanging locations between players.

During the gameplay, the player passes through special locations. When moving, the player's chip jumps through these locations without stopping at them, except for the Risk location, which the player can get to with a certain probability. When passing through each of these locations, certain events clearly defined for each location occur. When passing an environmental inspection, the player receives bonuses or fines. For each new level of environmental reputation, the player's subsequent profits increase by 10%. If the player's environmental reputation has become negative as a result of his actions, the following profits are penalised: for each level of negative environmental reputation, profits are reduced by 10%. The value of 10% was chosen to be convenient for children of primary school age, as it is quite simple to calculate by dividing the number by 10.

During the fair, the player is credited with profits for the functioning of the locations of the playing field that are in his or her ownership. There may be no profit from the locations or it is a one-time payment for the provision of a certain service, or it may be recurring, i.e. the player will receive profit during each passage of the fair. All this information is specified when purchasing and upgrading locations. The

total value of the profits from all locations is used to calculate the taxes that the player must pay. The profits from the fair are immediately credited to the player's balance, but after passing the tax office, taxes must be paid.

When passing through the tax office, a dialogue box appears, requiring the player to pay a certain tax on their profits, namely 10%. The player has to calculate his or her own income and the amount of taxes to be paid. However, in this window, the player can write down how much he decides to pay to the tax office. If the player pays less than the required amount, they will be issued a penalty for tax evasion equal to the full amount they should have paid in taxes immediately. If the player pays the required amount or more, the amount of money that he or she wrote in the dialogue box will be debited from the player's bank.

A participant can get to the Risk location by rolling a virtual dice and moving around the playing field. Upon entering the location, the player is randomly given a card with a positive or negative message. Risk cards form a certain set that is randomly shuffled before the start of the game. The developed system implements three main types of messages: moving forward or backward on the map to a certain number of locations; receiving bonuses or rewards; paying additional fines or taxes. These messages are based not only on the economic aspects of the game, but also on the probability of certain environmental events.

In case of passing the fair, the profit from all player’s locations is added to the his or her balance. After passing the environmental inspection, a bonus is added to the player's balance for environmental friendliness, as well as an increase in the level of environmental reputation. At the tax inspection, the player is charged with the amount he or she has decided to pay in taxes, with possible penalties for not paying them in good faith. Upon entering the Risk location, the player randomly receives a positive or negative message that affects his or her characteristics.

All the mechanics and features described above were based on a single player playing the game. At the same time, an important aspect of the developed game is

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its multiplayer, i.e. the participation of many players in the game at once. The software package is designed for several players, and therefore the question of choosing a multiplayer architecture arises. Let us consider four main existing models, namely: P2P (Peer-to-Peer), Player-host, Relay, Dedicated server [15]. Each architecture has its pros and cons. Based on the results of the comparison, it was chosen to use the Relay method, namely Unity Relay, which does not require any funds at the initial stages of development, but when entering the market and increasing the audience, it will require a certain subscription price, so currently Unity Relay is the best option. The disadvantages of this method are not important for the developed software package, namely the prevention of unfair play and modification of the package during the game, because this can be controlled by the teachers when using the educational software package for children in grades 3-5.

The implementation of the chosen method in the Unity environment is carried out using the Fish-Net networking solution. It was chosen because of its active support by developers, a large number of features, and a friendly community. With the help of Fish-Net, namely the FishyUnityTransport module, Unity and Unity Relay are connected. Next, Unity Relay is configured and the host and player are realised. The C# programming language is used to create a code for the host to create a server on his device and then connect the player to it using a special code. The design is created in the form of two buttons, Host, which starts the process of creating a server on the player's device, and Connect, which has a field for entering the connection code.

Currently, a vertical slice of the application has been created, i.e. a working prototype or alpha version of the application containing a closed map of the game, all government agencies and several locations of the country that can be improved. This version of the application can be used to evaluate the effectiveness of its use for use in educational institutions. Approbation of the prototype of the developed software complex as a component of the educational and developmental program

"School of Green Economy" is planned to be carried out in the educational institutions closest to the authors, i.e. in the Holosiivskyi district of Kyiv. For this purpose, groups of 10 children of grades 3-5 from different classes and schools are selected for a larger sample (20 groups in total). Next, agreements are signed with their parents on the participation of their children in the testing of the developed complex. After that, the students are given a vertical slice of the software package, i.e. a prototype in which most of the mechanics of the software package are implemented. The team of authors act as hosts who monitor the progress of the game. Students play the game several times under the supervision of teachers.

Assessment of learning outcomes is conducted after the end of the last game with a special survey to determine the skills, abilities and knowledge acquired, the emotional feeling of the game and the wishes of the participants. A special questionnaire will be used for the survey after testing in educational institutions. It is planned to test the developed software package in educational institutions of the Holosiivskyi district of Kyiv.

Conclusions. The study is dedicated to development of a special software package that is an extension of the educational and developmental program "School of Green Economy" and adapts it to the format of an interactive lesson to form an economic and ecological competences of students in the framework of learning the concept of sustainable development. A sociological survey was conducted among students of grades 3-5 on the optimal format of the graphics of the proposed software package, which is part of the educational and developmental program "School of Green Economy". According to the survey results, the use of vector graphics was chosen. Unity was chosen as the development environment for the software package. A 3D model of the prototype map of the developed complex was created in the 3D modeling program Blender by the author. An algorithm for passing the turn of one player, which consists of three phases: the phase of movement, action and waiting for his turn, has been developed. The developed algorithm is implemented in the C#

programming language. The movement of the player's chip across the playing field by rolling a dice and automatically moving the chip across the field was implemented. The existing game location improvement tree, in particular by creating a link-based return mechanic was improved. Five different player characteristics have been introduced and their dynamic change depending on the player's actions has been implemented. The functioning and influence on the player's characteristics of four special locations was implemented. Based on the analysis of possible variants of multiplayer system architectures, the Player Host method was chosen as the most optimal method for the developed software package. A methodology for prototype approbation of the developed complex in educational institutions of Kyiv for pupils of grades 3-5 was developed. After testing the software package, a comparative analysis of the level of environmental and economic awareness of students before and after learning in a gaming environment will be conducted.

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