

Is a Board Game Suitable for Teaching Complex Natural Systems? Yes

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Abstract: The quality of people's daily lives is dependent on the functioning of natural systems - ecosystem services. These services are essential for social and economic development of our society and for ensuring the well-being of humans. This dependency is not easily understandable, as it is non-linear. The use of games has been proven a successful method in teaching complex systems. Games can improve, besides knowledge, students' social and academic achievement, promote students' motivation, improve their critical thinking and co-operation skills. In this research we assessed how an ecosystem services themed board game „End of the World Begins in Kurtna“ supports students' ability to understand the relationship between humans and nature. We evaluated the game's potential as an educational tool to foster better comprehension of the concept of ecosystem services. To validate the game's usability and learning value, game sessions were conducted with more than a hundred students. To collect their knowledge about both ecosystem services and nature, their attitudes towards the game and their subjective assessment of their own knowledge, pre-test and post-test questionnaires were used and the data was analysed using mixed methods. The results present that the game enhances the understanding of relations between humans and nature and helps to notice causality related to the subject. The game makes players perceive the human impact on nature and creates a positive attitude towards protecting the natural environment. The majority of respondents found the game to be interesting and engaging. Since interest and engagement are closely related to motivation we conclude that the game also has a positive effect on learning motivation. We conclude that board games can be suitable means for understanding complex terms such as ecosystem services. The game is applicable for enriching natural science education and is a good supporting material for teaching. However, since we did not measure knowledge retention over a long period of time we cannot confirm the game's ability to enable deeper understanding of the subject.

Keywords: ecosystem services, board game, natural sciences, GBL, educational games

1. Introduction

Ecosystems provide us with services necessary for people's well-being and for the social and economic development of society (Costanza et al, 1997; MEA 2005). The environment and nature, including ecosystem services, have complex ways of operating and are therefore not linear (MEA, 2005). However, it is difficult to convey knowledge about nonlinear and complex systems to students in a linear way (through words and sentences). One possible way to enhance the understanding of complex systems is through educational games (Castronova & Knowles, 2015). Games have become increasingly popular, with more and more games being used for educational or training purposes (Jesmin & Ley, 2020). The role of educational games in the learning process has been studied in the past and is a common strategy in the classroom to increase student engagement (Ke et al, 2015). For example, in Estonia game-based learning (GBL) is widely used in classrooms (Jesmin & Ley, 2020). This paper provides an overview of an Estonian ecosystem services themed board game „End of the World Begins in Kurtna“ which is designed for educational purposes. The goal of this research is to assess the potential of the game to provide students with knowledge about nature and promote understanding of the concept of ecosystem services. Therefore, the game „End of the World Begins in Kurtna“ has great potential to be an important educational tool in natural sciences education.

Education in ecosystem services could be an effective means of conveying knowledge about the importance of different ecosystems and people's dependence on these complex systems. Ecosystem services framework can be used to learn about the structure, functions and different assessment methods of ecosystems as well as the impact of human activities on these self-regulating natural systems (Torkar, 2016).

2. Context

2.1 Ecosystem Services

Ecosystem services (ES) are widely acknowledged as goods ecosystems provide to humans. These goods can be provisional (food, freshwater, fuel, medicine), cultural (recreation, aesthetic value) or have a regulating or a supporting purpose (pollination, climate regulation, soil formation, biogeochemical cycle). Millennium

Ecosystem Assessment (MEA) defines ecosystem services as the benefits humans receive from nature due to certain conditions and processes (MEA, 2005). The second most common approach is the TEEB (The Economics of Ecosystems and Biodiversity) definition describing ecosystem services as „the direct or indirect contribution of ecosystems to human well-being” and looks at benefits and services separately. However, the concept of ES is relatively new. The concept was first mentioned by scientific literature in 1981 and only gained public attention in the late 1990s (TEEB, 2010). Understanding how ecosystem services relate to biodiversity, social and economic aspects aid in developing more sustainable and nature-based solutions (Burkhard & Maes, 2017). The complex environmental issues we are facing today require an educated public (UNESCO, 2017).

2.2 Game-Based Learning

Involving students in classroom activities has become increasingly difficult over the years. As a result, there is a need to implement other teaching strategies that improve student engagement, such as game-based learning. GBL is often associated with computer games but can be applied to non-digital games as well. Game-based learning often conveys „serious” subjects through games and allows the player to gain new knowledge and skills (Laamarti et al, 2014).

Previous research (Hsiao et al, 2014; Anastasiadis et al, 2018, Zainuddin et al, 2020; Yu et al, 2021) has found that engagement, interest and motivation are closely related and they play an essential role in improving players’ learning ability, acquisition of knowledge and help enhance factual knowledge and cognitive skills. Educational games provide players with a safe space to learn through trial and error (Zeng et al, 2020) as they are merely models of real life. Game-based learning can have other advantages like providing immediate feedback to player’s actions (Toda et al, 2019) and creating a more positive attitude towards their knowledge, skills and learning in general (Sitzmann et al, 2010).

There are not many ecosystem services related games, however, there are plenty of ecology-themed tabletop games (e.g. Parks (2019), Photosynthesis (2017), Endangered (2020), Canopy (2021)) and several ecosystems and climate-related board games. Some have been researched and proven to have a positive impact on players’ knowledge. Eisenack (2012) found that a climate change themed board game „Keep Cool” prompts discussions and facilitates better understanding of a complex subject and its terminology. Phoomirat et al (2018) concluded a board game about green roofs helped players understand the benefits and ecosystem services these roofs could provide and inspired some of them to do additional research on the subject. Gitgeatpong & Ketpichainarong (2022) researched the ability of an educational board game „Mangrove Survivor” to help teach interspecies relations in mangrove systems and the environmental impacts affecting the habitat, concluding that the game created a positive perception and can be an effective learning tool and assist in understanding.

2.3 The Board Game

„End of the World Begins in Kurtna” („Maailmalõpp algab Kurtnas” in Estonian) focuses on ecosystem services and is an educational role playing board game which shows the impact of economic activities on our natural environment. The game takes place in Kurtna Lake District, which is a part of the Alutaguse National Park located in the North-Eastern Estonia. The Kurtna Lake District is unique for its diverse landscapes, abundant lakes of thermokarst origin, diverse ecosystems and habitats for protected species. It is also a transitional zone between densely populated and heavily industrialised oil shale mining region and a sparsely inhabited territory with large forests and mires. North-Eastern Estonia is heavily affected by human activities. The lakes of Kurtna have been deteriorated by peat milling, mining of oil shale, sand mining from the Pannjärve quarry and by excessive groundwater intake to provide drinking water to the nearby towns. Due to these anthropogenic activities lake levels have dropped, water chemistries and lake ecosystems have changed. (Terasmaa et al, 2014; Vaasma et al, 2015; Vainu et al, 2020)

All this makes the Kurtna region an ideal example of showcasing conflicts between economic needs and ecosystem services. The game „End of the World Begins in Kurtna” uses those real-life problems in Kurtna Lake District as an example to illustrate both the positive and negative impact humans have on ecological balance. Each decision and action taken by the player affects the course of the game and determines if the in-game world is moving towards sustainable management or the end of the world.

The game has been created with the help of Tallinn University students as a part of two interdisciplinary collaborative projects (LIFE). The LIFE project is a part of all study courses and it focuses on project- and problem-based learning. The designing process brought together students from different fields of study (e.g. educational

technology, environmental management and pedagogics) providing a diverse background for developing the game. The goal was to create a fun and educational board game for introducing ecosystem services. The designing process took two years and the game's latest version was released in 2019. The game has a total of 22 authors, including the project supervisors Jaanus Terasmaa and Triinu Jesmin.

2.3.1 Learning Value

At the heart of the game is a player whose task is to achieve the goals set in their role. Players' actions in the game have direct and indirect, immediate and delayed effects on the environment. Some actions do not appear to affect the environment at first. However, the impact can manifest gradually and the consequences of one's actions (both positive and negative) may cause a domino effect, similar to real-life settings. The domino effect can change the course of the game, make achieving goals more difficult or even end the game. This helps to bring to players' attention when managing ecosystem services and natural environment in general, both in the game and in real-life situations, sustainability takes precedence over short-term solutions. According to the creators of the game, depiction of causality in the game helps to illustrate cause and effect between nature and man and in nature in general, and improve analytical abilities. Castronova & Knowles (2015) also propose that educational games help to understand causal relationships and improve the development of new skills and knowledge.

Players' success is dependent on the actions and decisions made by other players. The cards in the game are designed to provide a fun and engaging way for players to interact and commence in non-verbal communication with each other and with the ecosystems on the gameboard. As suggested by Pornel (2011) social interactions play a part in making educational board games engaging for students. To avoid the „end of the world” players need to communicate, collaborate and make compromises. In addition to emphasising the importance of cooperation, this could also help enhance players' communication skills. Teachers also use games for improving students' social skills and willingness to cooperate (Jesmin & Rinde, 2018).

Another learning value of the game is to bring the concept of ecosystem and sustainability to players' attention. Understanding the balance between healthy functioning of ecosystems and their ability to provide us with necessary resources, societal, and economical needs could help players to grasp the concept of sustainability better (Burkhard & Maes, 2017). The game also teaches players more about the biota and environmental problems present in the Kurtna Lake District. Seeing the environmental problems, consequences of human activities and exploring possible solutions, the game could encourage players to be more environmentally aware, considerate towards nature and realise the importance of sustainability.

2.3.2 Game Mechanics

The game board (Figure 1A) includes lakes, fields, shrublands and local ecosystems such as grasslands, forests and swamps. The board is divided into 30 hexagonal fields, each with its own ecosystem. Each hexagon has different features and requirements for interacting with them in the game (Figure 1B). The game includes 6 different types of cards: Role Cards, Ecosystem Service Cards, Action Cards, Development Cards, (+) Cards and (-) Cards. Other elements of the game are the Doomsday Clock, scoring tokens and game pieces. The recommended number of players is 4-6.

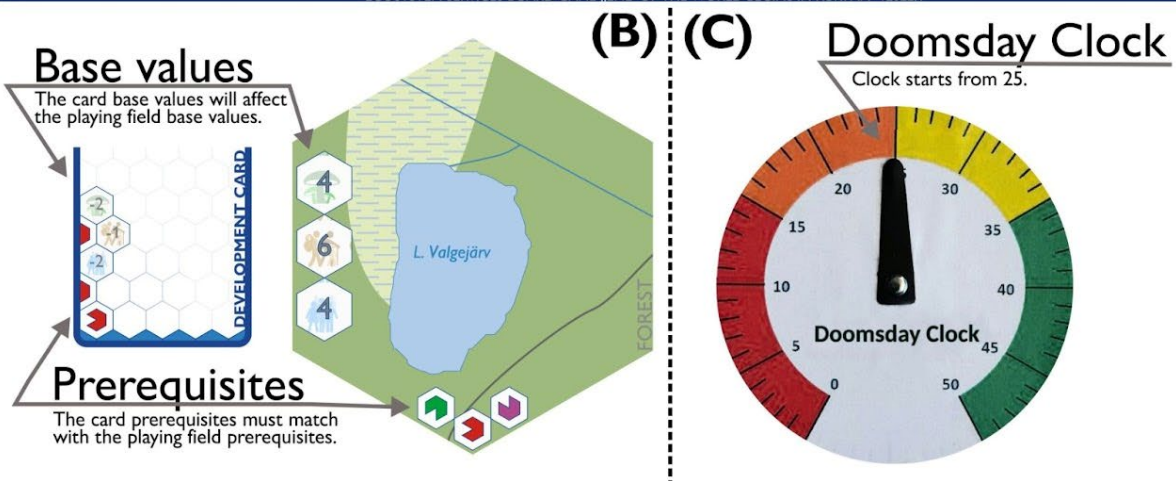
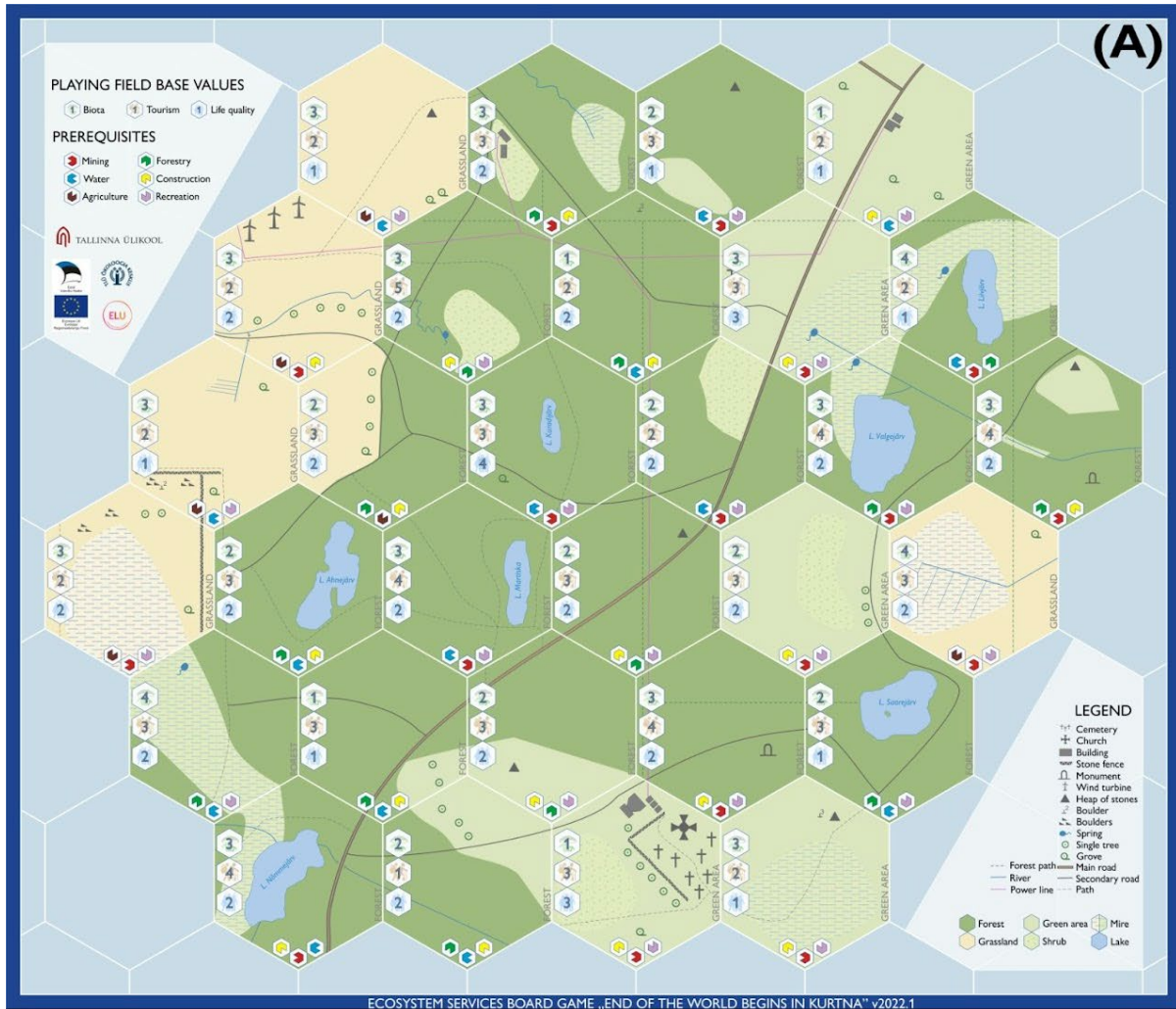


Figure 1. The board of the game „End of the World Begins in Kurtna” (1A), playing field (1B) and Doomsday Clock (1C)

At the beginning of the game, each player draws a Role Card. The goal of the player is to complete the task indicated on the Role Card without making the „world end” (except for the role of the „Apocalypticist”, whose sole task is to make the world end). The first person who achieves their goal, wins. Additionally, each player will draw 2 Activity Cards, 2 Development Cards and 2 Ecosystem Service Cards. The number of cards can be changed to make the game more challenging or to provide variety. Development Cards enable players to engage in economic activities, Ecosystem Service Cards can be used to provide nature with ecosystem services and improve its condition, and Action Cards describe other human-related activities that impact the game’s world

and other players (Figure 2). (+) and (-) Cards illustrate consequences of different actions and can create a positive or a negative domino effect.

- Development Cards: Players can create different facilities (e.g. wind parks, camping sites, different mines, adventure parks, groundwater extraction sites) and engage in other economic activities (e.g. grazing, cutting forests, growing crops) to enhance local economic activity. Building activities and increased tourism has a negative impact on nature and decreases the score on the Doomsday Clock.
- Ecosystem Service Cards (ES Cards): These cards provide the game's nature with ecosystem services. Service cards have a positive effect on nature and help to improve both living conditions and stabilise the environment so that it is more resistant to human impact and allows continuation of economic activities.
- Action Cards: These represent a wide range of other different socio-economic activities and events (e.g. accidents in mines, renovations, planting trees, wildcrafting, fires, economic crisis, cleaning). However, most of these actions have a negative effect on nature.

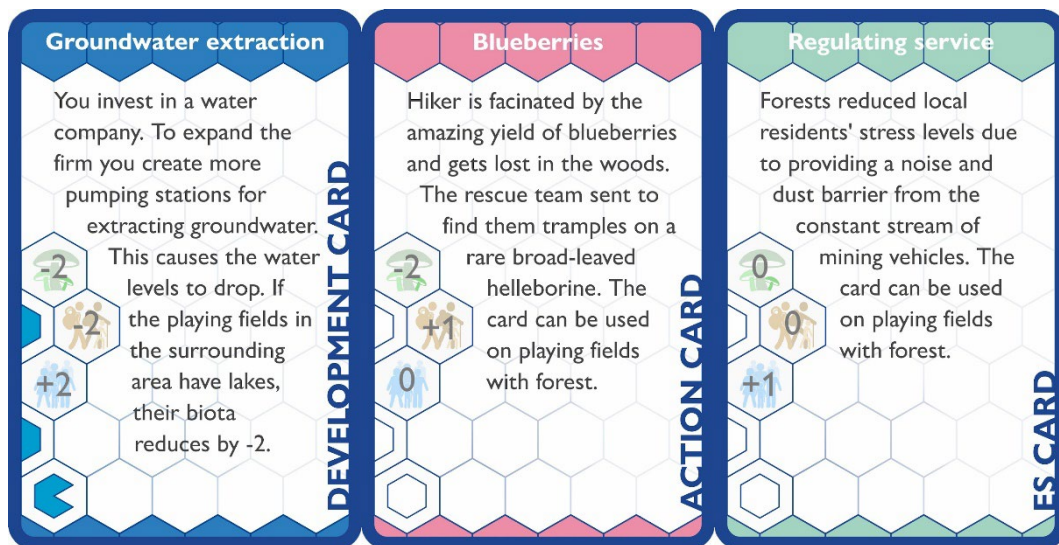


Figure 2. Examples of game cards: a Development Card, an Action Card and an ES Card.

All cards affect the base values of the playing fields and consequently, the score on the Doomsday Clock. The clock (Figure 1C) is an indicator of the well-being and resilience of ecosystems, thus keeping track of the state the nature is currently in as well as informing players of their impact on the game's ecosystems. After using a card the new values of the affected hexagon(s) will be calculated immediately. The change in values either increases (the clock moves towards the green zone) or decreases (the clock moves towards the red zone) the clock's score. If the Doomsday Clock reaches zero, the world has ended and the game is over.

3. Methodology

The sample (N=84) consisted of young people of different ages (i.e. voluntary work groups) between ages 12-26. They took part in game sessions and filled out a questionnaire consisting of a pre-test and a post-test. Each group of players attended an educational game session of about 2 hours. The game session consisted of an introduction to the purpose of the activity, a substantive introduction (very short review of ecosystems and ecosystem services), a breakdown of the rules, active playtime and answering the pre- and post-test. Active playtime was between 1-1.5 hours on average and the introduction part took around 15 minutes. A total of 6 game sessions were conducted and 16 different groups played on up to 4 boards simultaneously (4-6 players per board).

A web-based questionnaire consisting of a pre- and a post-test was used to collect the data. The pre-test was conducted before the introduction of the subject and the game, post-test was taken by the players immediately after the end of the game. The pre-test consisted of 7 questions and the post-test included 9 questions, both open-ended and closed-ended questions were used. The questions concerned participants' knowledge of ecosystem services and nature in general (e.g. „What do you think ecosystem services are?“), their attitudes towards the game (e.g. „This game sparked my interest“; „This game was engaging“), subjective assessment of

their own knowledge (e.g. „The game made me understand the relationship between nature and man better”; „I could explain to my peers what ecosystem services are”).

To analyse the data collected from the game sessions, combined use of qualitative and quantitative methods were used. Descriptive and inferential statistics were used for closed-ended questions and qualitative content analysis for open-ended questions.

4. Results

We categorised the results into three different groups according to the theme of the questions. We also assessed how the content of the game overlaps with learning goals set out in the Estonian national curricula and determined the game supports the general competencies, learning objectives, organisational guidelines and cross-curricular topics.

4.1 Relations Between Humans and Nature

Post-game, the players considered human influence on the natural balance to be greater than before playing the game (Figure 3). The opinion of 23 people moved by one step and the opinion of 2 people moved by two steps towards a higher value. In self-assessment, all of these 25 respondents reported it became clearer to them what ecosystem services were. Additionally, more than half of the players agreed the game made them understand the relationship between man and nature better (i.e. 65% of respondents agreed or mostly agreed; 30% were hesitant). The players who answered „agree” or „mostly agree” also found humans’ impact on nature to be greater than the players who answered „mostly disagree” or „disagree”.

The open-ended question „Why do you think biodiversity is important?” that was present in both questionnaires, received noticeably more human-related answers in the post-test (37%) than in the pre-test (21%). For example, in the pre-test 15% of players mentioned how biodiversity is important for nature itself due to abiotic factors and organisms depending on each other. In the post-test this category did not receive any responses and instead players mentioned how man and nature affect each other. However, the post-test responses were shorter, less specific and less analytical. The rest of the answers were focused solely on the benefit of natural systems.

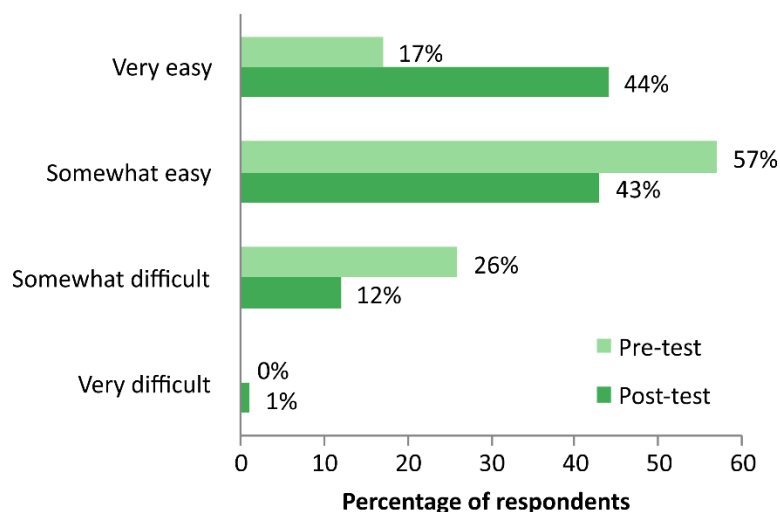


Figure 3. Pre- and post-test results of the question „How easy or difficult is it for humans to affect the natural balance?”

4.2 Knowledge About Ecosystem Services

There were mixed results in the understanding of ecosystem services. According to self-assessment, 94% of players found that after the game it became clearer to them what ES are. When asked „How would you describe what ecosystem services are?” the number of the most accurate definition for ecosystem services (i.e. „„Goods or services” nature provides for humans”), grew as well as human-nature related answers (Table 1). This was also the most popular answer. The category „„Services” related to „ecosystems”” are also mentioned multiple times.

Cultural services presented the least difficulties when identifying ES categories. Provisional services were also well-recognized and students were able to relate them with open-ended questions (i.e. „How would you describe what ecosystem services are?“, „Why do you think biodiversity is important?“).

However, when asked about players' ability to explain ecosystem services to their peers, only 19% of the respondents were confident („agree“), 48% either were hesitant or disagreed. Although many of the 48% had provided correct answers to the question „How would you describe what ecosystem services are?“. Answers to this open-ended question were mostly rather short, and had less variety and depth than in the pre-test. Additionally, more players gave unrelated answers or implied that they did not know (Table 1). Players also struggled with systematising and categorising ES with the most difficulties occurring in supporting and regulating services.

Table 1: Results of the pre-test question „How would you describe what ecosystem services are?“ with example keywords

Category	Examples of keywords	Pre-test	Post-test
"Goods or services" nature provides for humans	Things, goods, services, humans, us	12 (14%)	16 (19%)
Knowledge	Educating, understanding, getting to know	4 (5%)	0
Sustainability	Ecofriendly, recycle, production	9 (11%)	2 (2%)
Human-nature interactions	Impact, providing, benefit, human, nature	0	10 (12%)
Food	Healthy eating	2 (2%)	0
Preserving nature/life	Protect, support, sustain, nature	8 (10%)	3 (4%)
Nature conservation	Nature reserve, conservation, ecosystem, nature	6 (7%)	0
Unspecific things that help nature	Developing, helping, balance	5 (6%)	0
"Services" related to "ecosystems"	Services, providing, ecosystem, relating	11 (13%)	8 (10%)
Naming specific ecosystem services	Improve air quality, foraging, oxygen	9 (11%)	4 (5%)
Do not know	"I have no clue", "?"	9 (11%)	6 (7%)
Other	Area, surroundings, living being	3 (4%)	4 (5%)
Unrelated answers	"Rather not answer", "Same as before"	2 (2%)	7 (8%)

4.3 Interest and Engagement

80% of players found the game to be interesting, 78% of players found the game to be engaging and the results presented correlation ($r=0,744$; $p<0,001$). This means that players who found the game to be interesting, also considered the game to be engaging. Additionally, the respondents who found the game to be interesting also answered „agree“ or „mostly agree“ when asked about their ability to explain the concept of ecosystem services to their peers.

5. Discussion

Players found that the game was engaging and sparked interest in them, which creates a positive attitude towards learning. The players' positive attitude towards their own abilities and the game as well as engagement and interest are important factors in enhancing academic results (Sitzmann et al, 2010; Hsiao et al, 2014; Anastasiadis et al, 2018; Yu et al, 2021). As motivation is often a key component in improving learning and its outcomes we conclude these are promising results and provide us with confidence in the game's suitability in being an effective educational tool.

The results showed that the game helps to illustrate causality between human activities and the natural environment. This is most likely the result of each card having some kind of effect on the game world, due to the Doomsday Clock element and it causing players to draw (+) and (-) Cards as the game progresses. Other researchers point out that games can provide immediate feedback to players (Toda et al, 2019), and games can be suitable for teaching associations and causality (Castronova & Knowles, 2015). In teaching human-related subjects like ecosystem services, causality can be a valuable concept due to ES (including natural balance and biodiversity) being affected by human activities. According to Burkhard & Maes (2017), understanding consequences of humans' actions plays an essential part in understanding ecosystem services and the overall complexity of natural systems. Previous research on game-based learning has similarly found that nature-related board games can help to teach complex nature- and ecosystem services-related systems (Eisenack, 2012; Phoomirat et al, 2018; Gitgeatpong & Ketpichainarong, 2022).

According to players' self-assessment, the majority found the game helped them understand the concept of ecosystem services better and in the post-test more players were able to provide a more accurate description of ES. However, the results were mixed. The post-test replies were shorter, had less depth to them and many players did not know how to answer. The respondents struggled with describing the concept and categorising the services (especially supporting and regulating services). This can prove to be an important knowledge gap and greater emphasis might be needed on these categories when teaching ES. It seems players did not understand ES as well as they had initially thought. Castronova & Knowles (2015) point out that it can be difficult to change people's perceptions about the functioning and interactions of complex systems. We believe that playing the game only once is not sufficient for making the concept of ecosystem services clear. As we consider the students' impatientness while filling in the post-test to move on to other activities, we propose the shallowness of the latter answers could be pinned to that fact.

Despite the mixed results the game makes players feel smarter (related to motivation, interest, and engagement (Anastasiadis et al, 2018)), helps to explain the concept and assists in understanding humans' role in it. Further research should be done to study the effects of repeated gameplay on attaining new knowledge. The board game achieved the learning values highlighted by the authors such as engagement, interest, motivation and therefore improved understanding of the complexity of ES. Another reason to believe the game is a suitable educational tool is its correspondence with the learning goals set out in the Estonian national curricula. Due to the latter and the widespread adoption of GBL in the classroom (Jesmin & Ley, 2020) the game may gain popularity, especially in Estonia.

6. Conclusions

The objective of this paper was to assess the potential of an Estonian ecosystem services board game called "End of the World Begins in Kurtna" to provide players with knowledge about nature and promote understanding of the concept of ecosystem services. The game creates a positive attitude in the players about learning and ecosystem services, demonstrates causality, and makes players notice and perceive human impact on nature. As the understanding of human-nature relationship is closely related to better understanding of the ecosystem services, it supports teaching the concept. The game achieved the learning values highlighted by the authors such as engagement, interest, motivation and therefore improved understanding of the complexity of ecosystem services. Since in game-based learning interest and engagement are closely related to motivation and improved academic results, it concludes the game has also a positive effect on learning motivation.

However, post-game the players rated their ability of explaining ecosystem services to their peers moderately and we could not prove deeper synthesis of knowledge in explaining the concept of ES after the game. Players also faced difficulties in systematising ecosystem services which is still an important knowledge cap. The impact of a game session on gaining new knowledge about ecosystem services was not as good as the players

themselves had initially thought. We suggest that a single game session does not make the ecosystem services concept clear. Although it makes players feel smarter the results are insufficient to confirm the game's ability to provide a deeper understanding of ES and knowledge retention. Further research should be done to study the effects of repeated gameplay on attaining new knowledge. However, playing the game helps to clarify the concept and enhance understanding of human impact. We have proven that the game is suitable as an educational tool, can be used for enriching natural science education and is valid as a good supporting material for teaching.

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