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The Impact of Game-based Learning on Sustainability Education for Next Generations: a Case Study Analysis

Abstract

Higher education institutions face increasing pressure to equip students with the competencies needed to address complex sustainability challenges. Game-based learning (GBL) offers a promising approach to engaging students and fostering the development of knowledge, skills, and attitudes required for sustainable development. This study examines the potential of the SEED simulation game, designed using the Octalysis Framework, to improve sustainability education. A mixed-methods study was conducted with 45 university students who participated in the SEED game and completed a post-game evaluation questionnaire. Quantitative analyses included descriptive statistics, correlations, and principal component analysis of motivational factors. Qualitative feedback was also analysed thematically. The results indicate that the SEED game fostered moderate to high levels of student engagement, motivation, and perceived sustainability knowledge gains. Development & Accomplishment and Social Influence & Relatedness emerged as the most effective motivational drivers. A strong positive correlation was found between engagement and motivation. Students particularly valued the game's realism, per-

sonalization, and opportunities for social interaction. The findings underscore the value of integrating well-designed simulation games into sustainability education, especially for new generations who have specific learning preferences. They also highlight key considerations for future game design and educational practice, including the importance of transparent feedback mechanisms and addressing diverse learner expectations. This study contributes to ongoing efforts to leverage gamification to support transformative learning for sustainable development, highlighting benefits for students in terms of engagement and motivation, and for teachers who gain an innovative tool to explain complex sustainability issues. These findings are in line with similar experiences reported at European universities.

K e y w o r d s: Game-based learning, sustainability education, innovative teaching methods, Octalysis Framework, higher education

Nowadays, to educate effectively, it is essential to understand learning preferences of new generations of students and tailor educational strategies accordingly. The UNESCO Education for Sustainable Development (ESD) framework supports this transformation by promoting active learning, critical thinking, and problem-solving (Rieckmann, 2017). Providing ESD is an extremely challenging task for any HEI (Uggla, 2023). Nevertheless, it is essential in the face of increasing demands from employers who need a new set of skills for a workforce who must deal with the challenges of sustainability (Aver et al., 2021). HEI should not be constrained by just trying to achieve Goal 4 ("Quality Education") but also prepare new generations for working with the entire framework of Sustainable Development Goals (SDGs). Graduates need to be prepared not only for personal activities regarding everyday life but also for professional ones within organizations. It is also through the holistic approach in ESD that educators and learners will be able to understand and act on the interrelated environmental, economic, and social dimensions of sustainability. Graduates equipped with SD competencies shall help substantially in attaining all 17 SDGs. When joining the labour market, their understanding of SDGs shall be imperative for companies to easily integrate sustainability into corporate business strategy, processes, and operations. However, there are some barriers that could be encountered by HEI: scepticism of university teachers, students' wrong assumptions about course content, lack of support from university management in integrating ESD content into existing programmes and creating new interdisciplinary subjects that are central to ESG, lack of established ways of curriculum effectiveness (Down, 2006) or training teachers who are able to effectively integrate content to enable students to meet global sustainability challenges (Pavlova, 2013). Another difficulty is defining a set of competencies for sustainable development (Mochizuki and Fadeeva, 2010; Rauch and Steiner, 2013). Nevertheless, all researchers emphasise that effective ESD curricula should

include elements such as interdisciplinary subjects, case studies based on real-world problems, team-based teaching methods and collaboration with the social environment, e.g., projects carried out for different types of organisations. One of the learning strategies is Game-based learning (GBL).

The gaming market has been experiencing dynamic growth, driven by technological innovations, subscription models, and the increasing popularity of mobile games. According to Newzoo, the global games market reached $184 billion in 2023, up 0.6% compared to the previous year. Overall, growth is reflected in both the PC and console segments, which are growing by 5.3% and 1.7%, respectively, while the mobile segment shrinks by 1.4% (Newzoo, 2024). The long-term outlook still appears positive, with estimates that the market will reach $205.4 billion by 2026.

Eurostat data from 2022 (data extracted on 11/09/2024 from [ESTAT]) shows that among EU citizens aged 16 to 24, 58.64% play or download games from the Internet. This percentage is highest in countries such as Finland (78.21%), Greece (76.76%), and Denmark (74.12%). At the other end of the table are Slovakia (36.32%), Croatia (37.48%), and Germany (40.30%). For Polish students, the percentage is also high at 52.81% (42.39%) if the age range is 16 to 29). Still, even the involvement of about 40% of young people in these activities cannot be ignored by schools and universities. Unfortunately, Eurostat data does not show this figure broken down by those studying and those not undertaking higher education.

Given the popularity of digital games among young generations, HEIs have an opportunity to use GBL as a learning strategy to increase students' engagement in sustainability education. This study addresses that gap by examining the educational impact of SEED, a simulation game designed using the Octalysis Framework, which strategically incorporates motivational elements to enhance SD learning outcomes. The aim of the research is to explore how this game influences students' engagement, motivation, and perceived learning related to sustainability. Using a mixed-methods approach, the study evaluates not only the game's motivational effectiveness but also its potential to support the development of key competencies for sustainable development. The findings contribute to the broader discussion on integrating innovative teaching methods into ESD and offer practical insights for educators.

Literature Review

Games for Sustainable Development

The GBL learning strategy, which has proven successful in higher education, is increasingly applied in sustainable development education. Research indicates that students retain knowledge more effectively through game-based approaches,

particularly in interdisciplinary fields that require critical thinking and communication. Educational games give students virtual experiences that can shape their behaviour and reflections. Such games provide an opportunity for the development of problem-solving skills. Ouariachi, Olvera-Lobo and Gutiérrez-Pérez (Ouariachi et al., 2017) highlight that games for sustainability often use narratives and interactivity to engage players in solving problems related to climate, waste management or natural resource management and present local scenarios. By solving unstructured problems in a game-like context, students will be better equipped to solve real-world challenges they meet in their careers. The ability of educational games to support collaborative learning at universities is substantial, many sustainability-focused games involve teamwork. Researchers also highlight that positive discourse and reward systems in games foster engagement and promote proactive attitudes. Whittaker, Russell-Bennett and Mulcahy (Whittaker et al., 2021) conducted a field study that found that reward-based game mechanics significantly influence players' sustainability knowledge and behavioural intentions. Results from other researchers suggest that game designers should combine economic, social and environmental dimensions in games, and often games only focus on one or two of these effects (Stanitsas, Kirytopoulos and Vareilles, 2019). Numerous successful applications of GBL in sustainability education are documented in the literature (Janakiraman et al., 2018; Jääskä et al., 2021; Fernández and Hamari, 2021). A detailed classification of games for SD can be found in the work of Katsaliaki and Mustafee (Katsaliaki and Mustafee 2015) helping users, both teachers and students to identify the games that best suit their teaching and learning needs. Still, the wider diffusion of GBL in higher education faces barriers to broader adoption, including high development costs for advanced game solutions, time required, and significant involvement of academics to integrate games within the curriculum.

The Octalysis Framework in Educational Contexts

The Octalysis Framework was developed by Yu-kai Chou (Chou, 2015) and is widely used to design gamification strategies in various educational and business contexts. The Octalysis Framework was based on the results from Self-Determination Theory (SDT), behavioural economics, Abraham Maslow's hierarchy of needs and shares many features with the Positive Psychology School and The Behaviourist School of Thought (Beerda, 2024). The widespread use of this framework is evidenced by the number of citations: a Google Scholar search for the keyword "Octalysis" returns more than 3000 results (as of 2024). Studies of the application of this framework in various fields such as education, finance and marketing and others have shown that its use changes user behaviour and increases user engagement (Mohanty and Christopher, 2023). The framework can

be applied either to diagnose motivational factors in gamification and games or even at an earlier stage to design game and gamification elements to maximise participant engagement and, in a business context, increase companies' revenues. The Octalysis Group website offers many examples of applications of this framework and empirical evidence of its effectiveness. It is interesting to note that, according to Mohanty and Christopher (Mohanty and Christopher, 2023), 66.6% of the research on this framework is conducted in the social sciences, compared to the sciences and engineering. Interest in this framework can also be seen during the Covid-19 pandemic and its application to increase student engagement in e-learning activities (Marisa et al., 2020). An overview of the eight Octalysis Core Drives and their examples is presented in Table 1.

Table 1
The Octalysis Framework: core drives and examples

Factor no.	Name	Description	Examples
Core Drive 1	Epic Meaning & Calling	Acting for a higher purpose – the need to feel responsible and the need to be noticed and appreciated.	participating in charitable projects or social causes
Core Drive 2	Development & Accomplishment	The need to grow, achieve goals, develop skills, succeed, win and ultimately overcome challenges and difficulties.	points systems, badges, certificates
Core Drive 3	Empowerment of Creativity & Feedback	The need to engage in the creative process, to create new things and ideas and the need to receive feedback	interactive educational platforms with creative tasks
Core Drive 4	Ownership & Possession	The need to own something and improve it.	the ability to set one's own learning paths and goals
Core Drive 5	Social Influence & Relatedness	Includes social aspects such as social life, atmosphere, social acceptance, competition.	team challenges and leaderboards
Core Drive 6	Scarcity & Impatience	The need and compulsion to wait.	time-limited challenges or exclusive content
Core Drive 7	Unpredictability & Curiosity	The need to satisfy curiosity about what will happen next.	unexpected quiz questions or rewards
Core Drive 8	Loss & Avoidance	avoidance of something negative such as failure	deadlines and consequences for incomplete modules

S o u r c e: Own work based on (Chou, 2019).

In the above eight areas, respondents completed an evaluation by selecting the response that best reflected how they felt about each motivator on a scale of 1 to 5 (strongly disagree to strongly agree). The mapping of questionnaire items to Octalysis Core Drives is shown in Table 2.

Table 2
Mapping of questionnaire items to Octalysis Core Drives

Questionnaire item	Corresponding Octalysis Core Drive	Core Drive number
I was motivated by managing the virtual café in a sustainable way – a sense of doing something for the greater good	Epic Meaning & Calling	Core Drive 1
I was motivated by gaining points and ranking positions, completing rounds of gameplay and developing skills	Development & Accomplishment	Core Drive 2
I was motivated by discovering new things, new strategies in the game and feedback	Empowerment of Creativity & Feedback	Core Drive 3
I was motivated by having my own café, which I had to develop in successive rounds of the game	Ownership & Possession	Core Drive 4
I was motivated by the cooperation with other teams during the activities, the friendly competition, the atmosphere in the activities	Social Influence & Relatedness	Core Drive 5
I was motivated by the need to wait for the next round to start so that I could test my strategy as soon as possible	Scarcity & Impatience	Core Drive 6
I was motivated by curiosity about what would be triggered in the next rounds and what lay ahead.	Unpredictability & Curiosity	Core Drive 7
I was motivated by the desire to avoid failure, i.e. to score low (get a low grade)	Loss & Avoidance	Core Drive 8

S o u r c e: Own work.

Research Questions

The aim of this study was to examine the potential of game-based learning for advancing sustainability education through the SEED simulation game. In particular, the study sought to explore how different motivational factors affect engagement and learning outcomes, and whether these effects vary across student subgroups.

Based on prior research on GBL (Ouariachi et al., 2017; Whittaker et al., 2021; Fernández and Hamari, 2021) and the Octalysis Framework (Chou, 2019), the following research questions were formulated:

- RQ1: Does participation in the SEED simulation game increase students' sustainability knowledge and skills?
- RQ2: Which Octalysis core drives are most effective in motivating students in the SEED simulation game?

- RQ3: Are there gender-based and field-of-study-based differences in engagement and motivation?
- RQ4: What is the relationship between engagement and motivation, and how does gaming experience affect these outcomes?

Research Methodology

Participants

A total of 45 students from the University of Information Technology and Management in Rzeszów participated voluntarily in the study. The mean age of participants was 20.89 years (SD = 2.53), ranging from 19 to 35 years. Of the 45 participants, 48.9% (n = 22) were male and 51.1% (n = 23) female. Most participants (62.2%, n = 28) were enrolled in Business and Economics programs, and 37.8% (n = 17) were from Engineering and Technology fields. Participation in the game was voluntary, and the results of the game did not affect any academic grading.

Game Description

The Sustainable Entrepreneurship in EDucation (SEED) project, funded by the European Union (2022-1-PL01-KA220-HED-000088765), aimed to develop a set of innovative didactic tools that would enable young people to make decisions and act in a way that would contribute positively to sustainable development (SD). One of the outcomes of the project is the SEED simulation game where students become managers and make decisions in an activity encompassing the whole business called The Café. Students engage themselves in a simulation game that teaches them how to run their own businesses, with an emphasis on sustainability. Game design was guided by the Octalysis Framework to enhance engagement and motivation. The students are afforded the opportunity to make decisions regarding a number of variables, including the location of the business in consideration of the target customer base, the composition of the menu, the furnishing of the premises, and the recruitment of staff. Additionally, they bear responsibility for advertising and marketing, assessing the response to the product, monitoring competitor activities, and implementing changes to the business strategy as necessary. Their business is placed in a crowded market alongside other businesses built by other teams within the same group. A detailed description of the sustainability competencies it aims to develop is provided in Jakieła, Świętoniowska, and Wójcik (2024).

The choice of coffee shops as an exemplary business was due to two factors. Firstly, coffee shops are an integral part of student life, and secondly, many students are considering running a small catering business as their first business. Through the game, students can develop strategic thinking and decision-making skills. The game promotes environmental awareness and sustainable business practices. As the game operates in the context of a university, an obvious aim of its creation was also to facilitate the work of teachers and to increase student involvement in the learning process through an innovative teaching tool.

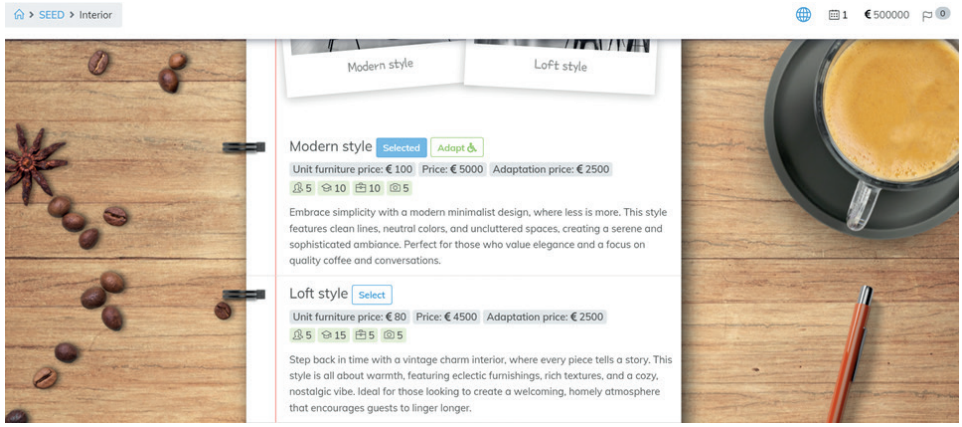

Figure 1. Example of SEED Game Interface: Customizing Café Location and Design (illustrating Ownership & Possession drive)

S o u r c e: SEED Simulation Game (Jakieła, Świętoniowska and Wójcik, 2024).

The game design process used the iterative Agile Software Development methodology. As all Agile methodologies emphasise regular feedback from stakeholders, the game design process involved academics, students and other experts (sustainability researchers, IT specialists, business practitioners working with the university, remote learning methodologists) to ensure that the game met the learning objectives and user needs. The SEED simulation game was developed as part of the Erasmus Plus programme with partners from Poland (*University of Information Technology and Management in Rzeszów*) and the company *Wirtualis*, responsible for the technical implementation of the game, Iceland (*Reykjavik University*), Portugal (*Politécnico da Guarda*) and Lithuania (*Kazimiero Simonavičiaus Universitetas*). The international perspective made it possible to prepare a game that could be used across Europe. This sprint-based design process helped address/avoid problems such as: 1) the lack of ongoing feedback from students and teachers in the early stages of development, 2) the disruption of communication between the development team and academic partners, 3) the lack of end-user oriented design in this case the student which

often leads to a product that meets the provisions of the design proposal but is not engaging for the students.

The SEED simulation game was programmed in Phalcon framework for PHP language with a responsive user interface created in JavaScript. The SEED Game interface is illustrated in Figure 1. The game is divided into 15 rounds, of which 1–7 are warm-up rounds and 8–15 are the actual game:

- (Round 1) Choosing the name and logo of the café, defining the café's mission; selecting the location on the map, choosing a specific establishment from those available in the selected district; selecting the interior design; setting the café's opening hours.
- (Round 2) Composing the menu: deciding on the products offered in the café (coffee, drinks, pastries, sandwiches, ice cream, seasonal products); determining the level of variety in the assortment of each product; choosing between one's own production or purchase from suppliers.
- (Round 3) Completion of equipment: purchase of the necessary equipment for the production of the selected products, taking into account capacity, price, cost of use, eco-friendliness of materials and disposal costs.
- (Round 4) HR: hiring of staff in different categories (waiters, baristas, cooks, etc.), decisions on the number of staff, their diversity, salaries, bonuses and training.
- (Round 5) Supply planning: estimating order quantities for the first period of operation of the café, selecting suppliers and planning orders for ingredients, taking into account cost and quality.
- (Round 6) Pricing products for the coming period, planning promotions such as price reductions or 'buy X, get Y' combined offers.
- (Round 7) Choice of marketing tools, both digital and traditional; planning a marketing strategy targeting different customer groups.
- (Round 8-15) Gameplay: changes to the menu, ingredient purchasing and delivery strategy; continuation of marketing activities and promotions; further HR decisions (recruitment, training); equipment purchases or upgrades.

Figure 2 presents the SEED Game feedback screen with rankings and performance indicators.

The game uses the following five-step algorithm to calculate demand and sales value:

- STEP 1 Estimate the number of potential customers based on opening hours, location and population of customer groups
- STEP 2 Determining the number of interested buyers, taking into account décor, variety of offer, prices, production and marketing
- STEP 3 Analyse the impact of product quality and staff on purchasing decisions.
- STEP 4 Analyse the impact of promotions and technical restrictions on sales.
- STEP 5 Summary of sales revenue.

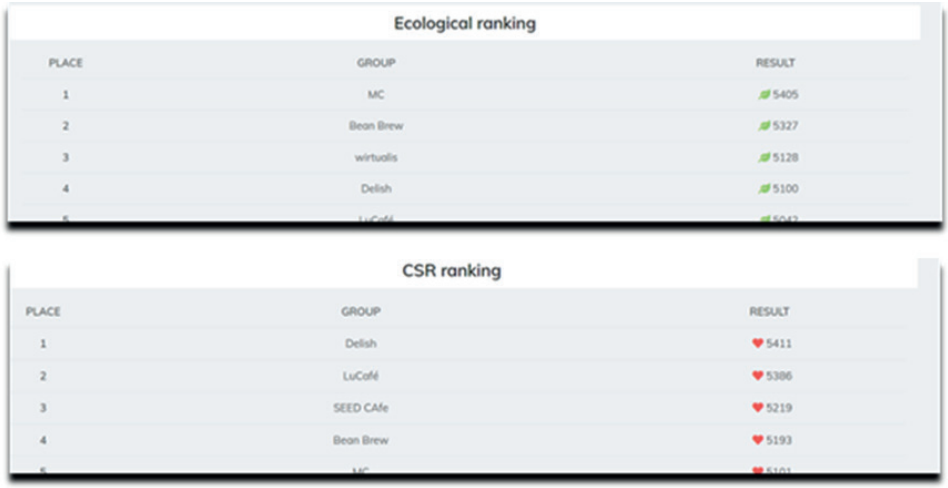

Figure 2. Example of SEED Game Feedback Screen: Rankings and Performance Indicators (illustrating Development & Accomplishment and Transparency)

S o u r c e: SEED Simulation Game (Jakieła, Świętoniowska and Wójcik, 2024).

The game offers three rankings that measure the success of participants. The scoring criteria and performance ranking components of the SEED Game are detailed in Table 3.

Table 3
SEED Game: scoring criteria and components of performance rankings

Ranking 1) Financial performance	Ranking 2) Eco	Ranking 3) CSR
Assesses the profitability of coffee shops	Based on: Average eco-index of equipment owned. Weighted average eco-index of suppliers of procured components. Eco index of marketing shares (based on choices made in previous rounds). Number of leftovers disposed of (leftovers) after each round.	Based on: Eco ranking Adapting cafés for people with disabilities. Employment of people with disabilities. CSR index of marketing actions (based on the message conveyed and the form of marketing actions).

S o u r c e: Own work.

Questionnaire

The process of data collection has been done with the use of the *Sustainability Game Evaluation Questionnaire*, tailored for this research. The questionnaire contains parts related to students' demographics – age, gender and field of study. Participant gaming habits (frequency and duration of gaming sessions, types of games played) have also been taken into consideration.

Five-point Likert scales for rating single-item measures of engagement (*"How engaging did you find the game?"*) and motivation (*"How motivated were you to complete the game objectives?*") have been used to assess participants' experience with the SEED simulation game. Using the Octalysis Framework as a foundation for the research required to include eight items to assess different motivational drives participants experienced during gameplay. They used a five-point Likert scale to express their motivation levels (from 1 = strongly disagree to 5 = strongly agree) with regard to such drivers as: managing the virtual café sustainably, gaining points and ranking positions, discovering new strategies and feedback, developing one's own café, cooperating with other teams, anticipation of future rounds, curiosity about game developments, and the desire to avoid failure. The engagement was measured using single item question, which represents a limitation of the study as it does not fully capture an engagement which is multi-dimensional in its nature (Fredricks et al., 2004). We consider this as area of further improvement. As Octalysis-based motivational items represent conceptually different aspects of motivation (e.g., social influence, accomplishment, curiosity) no calculations or interpretation have been performed for overall scale reliability.

The next important aspect that the questionnaire takes into account is the assessment of how relevant are the challenges provided by game to real world sustainability issues. These are perceived knowledge gain, confidence in applying sustainability knowledge in real life and whether the game helped participants to develop any new skills related to sustainability. The likelihood of recommending the game to others has also been rated. Finally, the questionnaire included two open-ended questions, inviting participants to describe which elements of the game they liked most and which they found less favourable. The two open-ended questions were used to determine which elements of the game were most and least favoured.

Procedure and Data Analysis Methods and Tools

Throughout class meetings, the students participated in the SEED simulation game. Upon completing the game, they were invited to fill out an online form which could be submitted anonymously. The data gathering took place in the spring semester of 2024.

The quantitative data were processed with IBM SPSS Statistics Base 29.0. Normality was checked with Shapiro-Wilk tests. Based on the distribution characteristics, non-parametric (Mann-Whitney U, Chi-square) or parametric tests (t-tests, ANOVA) were conducted. Motivational items structures were explored with Principal component analysis (PCA), the relationships between the variables were examined using Pearson and Kendall's tau-b correlations and qualitative answers were analysed thematically.

Research Results

Game Experience – Engagement, Motivation, Knowledge Gain and Skills

The game was assessed by participants as moderately engaging (M = 3.51, SD = 1.04) and motivating (M = 3.38, SD = 1.11). Knowledge gain was also evaluated as moderate (M = 3.27, SD = 1.27), with confidence in applying sustainability knowledge rated at M = 3.07 (SD = 1.20). 40% of students reported acquiring new sustainability-related skills. A summary of descriptive statistics for these outcomes is presented in Table 4.

Table 4
Descriptive statistics for engagement, motivation, and knowledge/skills outcomes

Questionnaire questions	Mean	Std. Deviation
How engaging did you find the game?	3.51	1.036
How motivated were you to complete the game objectives?	3.38	1.114
How much did the game increase your knowledge about sustainability?	3.27	1.268
How confident do you feel in applying the sustainability knowledge gained from the game in real life?	3.07	1.195

S o u r c e: Own work.

Octalysis core drives related to motivation participants rated as is shown in Table 5.

Figure 3 shows the mean ratings of motivational drivers mapped to the Octalysis Core Drives. From the study, earning points and having a collaborative environment were marked as the most motivating factors, whereas not wanting to fail ranked at the bottom most position.

Table 5
Mean ratings of motivational drivers (Octalysis Core Drives)

Motivation drivers	Core drive (Octalysis Framework)	No of core drive	Mean
Cooperation and competition	Social Influence & Relatedness	Core Drive 5	4.33
Gaining points and ranking positions	Development & Accomplishment	Core Drive 2	4.20
Managing the virtual café sustainably	Epic Meaning & Calling	Core Drive 1	3.96
Developing one's café	Ownership & Possession	Core Drive 4	3.80
Discovering new strategies	Empowerment of Creativity & Feedback	Core Drive 3	3.76
Waiting for the next round	Scarcity & Impatience	Core Drive 6	3.62
Curiosity about future rounds	Unpredictability & Curiosity	Core Drive 7	3.62
Avoiding failure	Loss & Avoidance	Core Drive 8	1.84

S o u r c e: Own work.

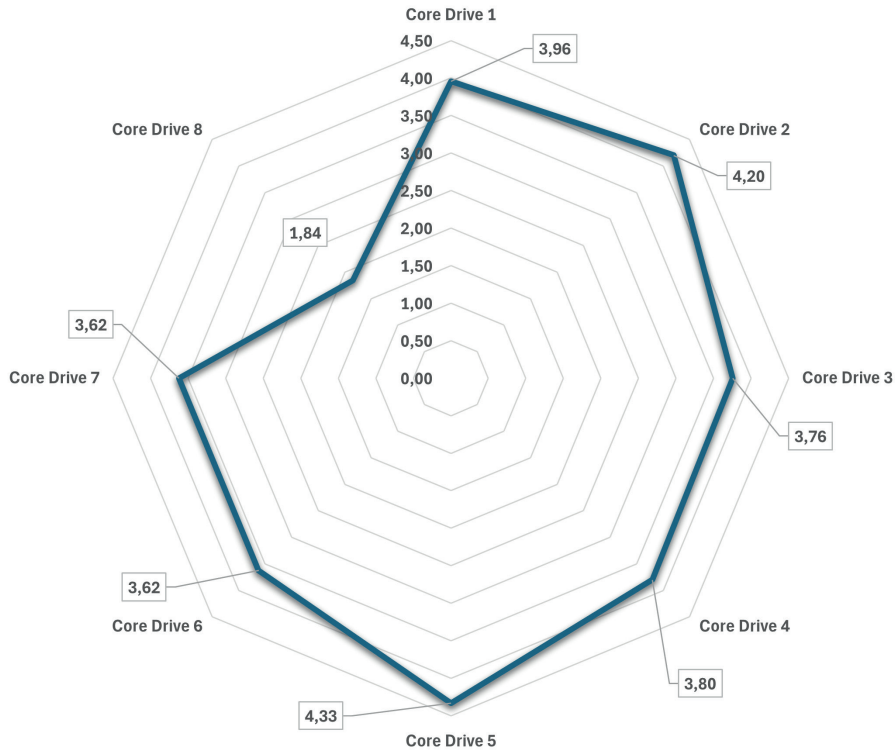

Figure 3. Mean ratings of SEED game motivational drivers mapped to Octalysis Core Drives

S o u r c e: Own work.

Do the Gender and Field of Study Affect Motivation and Engagement?

According to the research, gender has not affected engagement and motivation of participants. In a similar way, *Business and Economics* and Engineering and Technology students engagement and motivation have not shown important differences in these areas. However, the "*desire to avoid failure*" significantly differs across fields of study ($F(1,43) = 7.433$, $p = .009$), pointing at Engineering and Technology students who wanted to avoid failure more.

Are Engagement, Motivation, and Gaming Experience Correlated?

The relationships between game-based learning variables are illustrated in Figure 4. According to the research results engagement and motivation are strongly correlated ($r = .85$, $p < .001$). Experienced gamers, who spend more time playing games were less engaged in playing SEED game as the time spent playing games is negatively correlated with perceived engagement ($r = -0.296$, $p = .049$). Between time spent gaming and motivation, no significant correlation was found ($r = -0.036$, $p = .817$). What research results also suggest is the fact that perceived knowledge gain and confidence in applying acquired knowledge are positively correlated ($r = .42$, $p = .004$). This indicates that participants who feel they have learned more also tend to feel more confident in using that knowledge in practice.

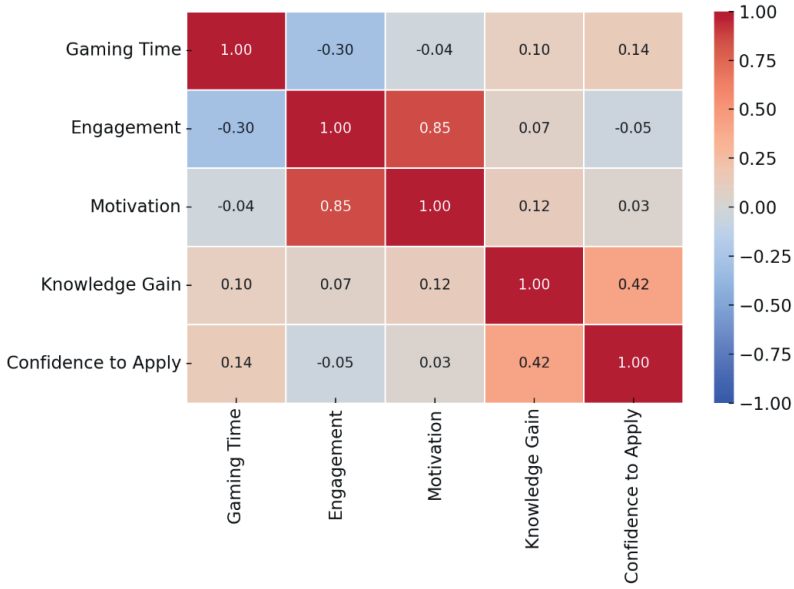

Figure 4. Correlation Matrix of Game-Based Learning Variables

S o u r c e: Own work.

What provides game design hints is the correlation between engagement and motivation. Increasing an engagement level of players may boost their motivation. When focus on correlation between perceived knowledge gain and confidence in applying knowledge, the educational value of SEED game is well visible.

Factor Structure of Octalysis Framework Motivational Drivers

Before the presentation of the results it is worth noting that suitability of data set for *Principal Component Analysis* has been assessed. It was done by calculating Kaiser-Meyer-Olkin (KMO) measure which determines sampling adequacy and Bartlett's Test of Sphericity. KMO was 0.425 while recommended threshold is 0,5. This value shows that data set is minimally suitable for factor analysis. The Bartlett's Test of Sphericity was non-significant ($\chi^2(28) = 18.44$, $p = .915$). This suggests that the study's findings should be interpreted in light of its methodological constraints as the correlation matrix may not significantly differ from an identity matrix. Despite the limitations, as the study conducted is exploratory in nature, PCA has been done to investigate the patterns among motivational factors. Five main components (eigenvalues > 1) have been identified in rotated components matrix. There are the following:

- Component l: Epic Meaning & Calling, Ownership & Possession (personalization and meaningful management)
- Component 2: Scarcity & Impatience (anticipation-driven motivation)
- Component 3: Loss & Avoidance (performance anxiety and risk aversion)
- Component 4: Empowerment of Creativity & Feedback (curiosity and learning)
- Component 5: Development & Accomplishment (achievement orientation through points and rankings)

All these components together explain 75.91% of the variance. The component loadings of motivational items are provided in Table 6.

The results summarized in table 6 allow for drawing few insights. There is an interplay between social and accomplishment-related motivations. Moreover, the factor structure is aligned meaningfully with key Octalysis Core Drives. As such, it proves the relevance of the framework in the attempt to understand the players' motivation when using the game in learning context related to sustainability.

To synthesize the main findings, the results are summarized in Table 7, covering each research question together with the corresponding statistical values and additional comments.

Table 6
Principal Component Analysis: Component Loadings of Motivational Items

Component Matrix[a]					
	Component				
	1	2	3	4	5
3.1. I was motivated by managing the virtual café in a sustainable way – a sense of doing something for the greater good	,610	,038	,035	,203	,462
3.2. I was motivated by gaining points and ranking positions, completing rounds of gameplay and developing skills	–,057	,182	,571	,627	–,335
3.3. I was motivated by discovering new things, new strategies in the game and feedback	–,172	,505	,435	–,156	,603
3.4. I was motivated by having my own café, which I had to develop in successive rounds of the game	,706	,195	–,293	–,137	,082
3.5. I was motivated by the cooperation with other teams during the activities, the friendly competition, the atmosphere in the activities	,206	,703	–,231	,423	–,107
3.6. I was motivated by the need to wait for the next round to start so that I could test my strategy as soon as possible	,413	–,401	,631	–,067	,101
3.7. I was motivated by the desire to find out what the next rounds of the game would be triggered, what would be in front of me	,637	,036	,173	–,236	–,480
3.8. I was motivated by the desire to avoid failure, i.e. to score low (get a low grade)	,119	–,547	–,258	,607	,264
Extraction Method: Principal Component Analysis.[a]					
a. 5 components extracted.					

S o u r c e: Own work.

Table 7
Research questions quantitative analysis summary

Research question	Statistics values	Additional comments
RQ1: Does participation in the SEED simulation game increase students' sustainability knowledge and skills?	• Perceived knowledge increase M = 3.27; SD = 1.27 • Confidence in applying knowledge. M = 3.07; SD = 1.20 • 40% of students self-reported acquiring new sustainability-related skills	A moderate positive correlation was found between knowledge gain and confidence in application (r = 0.42, p = .004).

RQ2: Which Octalysis core drives are most effective in motivating students in the SEED simulation game?	The most motivating factors in the SEED game • Social Influence & Relatedness (Core Drive 5): M = 4.33 • Development & Accomplishment (Core Drive 2): M = 4.20 • The least motivating factor • Loss & Avoidance (Core Drive 8): M = 1.84	PCA identified five motivational dimensions explaining 75.91% of total variance. The dataset showed low suitability for factor analysis (KMO = 0.425; Bartlett's test p = .915).
RQ3: Are there gender-based and field-of-study-based differences in engagement and motivation?	Significant difference emerged for the Loss & Avoidance driver: Engineering and Technology students scored higher on this factor ($F(1,43) = 7.433$, $p = .009$)	No statistically significant differences in engagement or motivation were found based on gender or academic background.
RQ4: What is the relationship between engagement and motivation, and how does gaming experience affect these outcomes?	• Engagement and motivation were strongly positively correlated ($r = .85$, $p < .001$) • Time spent on gaming was negatively correlated with engagement ($r = −.296$, $p = .049$) • No significant correlation was observed between gaming time and motivation ($r = −.036$, $p = .817$)	These findings confirm that engagement and motivation are closely linked and provide insight into the role of motivational structure and user background in shaping learning outcomes through GBL.

S o u r c e: Own work.

Qualitative Findings From Open-ended Questions

The answers to open-ended questions have also been source of interesting insights. They may be summarized as follows:

- Realistic business scenario enabled students to better understand nuances related to running business which operations support SDG.
- Students' engagement, to some extent, was driven by game's personalization feature (business configuration in the areas of location, menu, interior design). It has also deepened the feeling of ownership, what stimulated engagement.
- Learning experience was significantly improved by game environment that promotes social interactions and cooperation.
- The catalyst for understanding the sustainability principles was "learning by doing" and making decisions in simulated business environment.

What is also beneficial includes answers to open-ended questions which have provided the feedback for possible improvements in the next releases of the game. The most important are the following:

- Game complexity and not clear enough relationships between decisions made and final results displayed in rankings. This constrained an improvement of decisions made and deeper understanding of decisions' payoff in terms of SDG achievement.
- Technical problems with using game on smartphones.
- Time needed for a gameplay (some students perceived it as too long) and frequency of feedback with clear connection to decisions made. This kind of feedback may improve learning of sustainability issues.
- Focus only on one business domain (café). Extending the game environment to more business domains may provide better applicability and more realistic scenarios of running business that aligns with SDG.

Discussion

As students have reported, knowledge gains and higher confidence level in applying sustainability concepts, and a real potential of using game-based learning to sustainability education is visible. The study also confirmed the important role of educational games in developing sustainability awareness in students. Apart from knowledge and awareness gains, skills development aspect also seems to be promising – 40% of students reported development of new sustainability related skills, which increases level of competences in this area.

Interesting insights on students' motivation were collected with the use of analysis based on Octalysis Framework. Some findings are similar to patterns identified by Gellner and Buchem (Gellner and Buchem, 2022) and Marisa et al., (2020), who emphasized the importance of mastery and social factors in driving motivation in educational games environments. This study has also shown that Development & Accomplishment (through points and rankings) and Social Influence & Relatedness (through cooperation and team atmosphere) are the most powerful motivation drivers in e-learning and gamified educational settings.

Some factors like Unpredictability & Curiosity and Loss & Avoidance turned out to have smaller impact. It has also been observed and discussed by Marisa et al., (Marisa et al., 2020) who stated that the power of these drives strongly depends on context and can have even negative effects. In sustainability education, too much unpredictability can undermine learners' sense of control and confidence in using what they have learned.

The analysis focused on differences in motivation and engagement that is connected to gender has shown that SEED game offers inclusive environment as

no gender-related differences were investigated. The issue that should be addressed in further research is different levels of desire to avoid failure that depend on major students came form - Engineering and Technology students exhibit stronger desire towards avoiding failure. It may be related to learning styles or cultures (including perception of risk) that are common for specific discipline.

A valuable hint for educational games designers comes from negative correlation between gaming time/ players' experience and their engagement. The longer the time spent gaming, the higher the expectations with regard to game attractiveness (more sophisticated plots, visually appealing game design, etc.). Therefore, in case of educational games, in which main priority is efficient and effective learning, players may feel less engaged. These findings mirror the concerns regarding relationship between time spent on playing games and engagement that have been raised in the literature.

Another insight can be drawn from a strong correlation between engagement and motivation. Hence, in the design, educational game features that positively affect these two elements should be developed. However, as in this study, we have noticed some limitations connected to the way an engagement was measured (single-item global question), further research should use properly selected scales to have better understanding of different engagement dimensions (Fredricks et al., 2004; Sinatra et al., 2015) – behavioural, emotional, and cognitive.

Even though the initial analysis of the dataset showed some limitations, a factor analysis was carried out and its results put stronger emphasis on complex nature of students motivation in game-based learning of sustainability-related issues. The factor analysis has also shown that components extracted can me mapped into key Octalysis Framework drives, which confirmed the framework applicability for this study.

Finally, the qualitative findings provided some educational game development hints based on students preferences. The game environment should include features that support personalisation, cooperation, clear and timely feedback, flexibility and realism. These hints are consistent with sustainability games development methodologies best practices that take into account mechanisms assisting experiential learning team-based interaction, and opportunities for reflection on real-world issues (Pineda-Martínez et al., 2023).

Nevertheless, there are some limitations of the study. The following are the most important:

- small sample size and single-university context,
- the engagement was measured with only one dimension, but as researchers suggest it is a multi-dimensional component (Fredricks et al., 2004; Sinatra et al., 2015),
- unbalanced analysis of engagement and motivation that are distinct psychological constructs (Fredricks et al., 2004; Ryan & Deci, 2000); motivation was assessed with the combination of a single-item question and eight Octalysis-

based drives while engagement was measured with a single-item self-report question ("How engaging did you find the game?"),
- the impact on long-term behaviour regarding sustainability-related skills and awareness developed as well as knowledge gained have not been assessed,
- Octalysis Framework used does not fully captures the experiential or affective dimensions of engagement in learning contexts,
- the data set analysed does not fully meet the requirements for PCA (KMO value (.425) and non-significant Bartlett's test indicate that results should be interpreted with caution)
- the study is focused on students' subjective experiences and self-reported learning outcomes; the actual performance outcomes achieved by students within the SEED simulation game (e.g., financial, eco, CSR scores) have not been deeply analysed.

Conclusions and Further Research

The main aim of the study was to contribute to better understanding of how learning strategies preferred by new generations of students, game-based learning, may be used to develop skills and awareness related to running business in a sustainable way. Research has shown promising results with regard to using SEED simulation game. The study was backed by Octalysis Framework that enabled to better understand students' engagement and motivation. The experiment has also shown that students improved their skills in the area of sustainability, developed awareness in this area and gained knowledge that made them more confident in applying these new personal resources in practice.

Mastery and collaborative learning in educational games have been identified as learning experience components connected with key motivational drivers – Development & Accomplishment and Social Influence & Relatedness. As engagement and motivation turned out to be strongly correlated, game-based learning solutions should actively stimulate both.

The insights drawn from a qualitative part of the study provided design hints by pointing at the features of GBL environments that students valued the most. They should support realism, personalization, feedback and social interaction. These hints are consistent with best practices in sustainability game development which emphasize experiential learning, team-based interaction, and reflection on real-world issues.

While several limitations of the study have already been noted, they also point to clear directions for further research. Future work should include larger and more diverse student samples across multiple universities, apply multi-dimensional

engagement measures, analyse actual in-game performance outcomes, and adopt longitudinal designs to capture the lasting impact of game-based learning on sustainability competencies. Further studies could also explore cross-cultural differences in motivational responses to the SEED game and examine how advanced game mechanics – such as adaptive feedback and real-time personalization supported by AI tools – may influence student engagement, motivation, and learning outcomes. Despite these limitations, the study results suggest that game-based learning may be a valuable support for sustainability education at universities, helping students to engage more deeply and gain practical competencies, while providing teachers with a structured and attractive method to introduce complex content. Compared with traditional learning situations without game elements, these advantages are significant, and they reflect trends observed in other European higher education contexts.

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Joanna Wójcik, Joanna Świętoniowska, Jacek Jakieła

Edukacja nowych pokoleń na rzecz zrównoważonego rozwoju poprzez gry: analiza studium przypadku

S t r e s z c z e n i e

Instytucje szkolnictwa wyższego coraz częściej poszukują innowacyjnych metod nauczania wspierających rozwój kompetencji na rzecz zrównoważonego rozwoju. Uczenie się oparte na grach (*Game-based Learning*) stanowi jedną z obiecujących strategii dydaktycznych, umożliwiających zwiększenie zaangażowania studentów oraz rozwijanie wiedzy, umiejętności i postaw prospołecznych oraz proekologicznych. Celem niniejszego badania było przeanalizowanie potencjału gry symulacyjnej SEED, zaprojektowanej w oparciu o model Octalysis (*Octalysis Framework*), jako narzędzia wspierającego edukację na rzecz zrównoważonego rozwoju na poziomie uczelni wyższej. W badaniu zastosowano podejście mieszane. W badanie zaangażowano 45 studentów, którzy wzięli udział w rozgrywce i wypełnili kwestionariusz ewaluacyjny po jej zakończeniu. Analiza ilościowa objęła statystyki opisowe, analizę korelacji oraz analizę głównych składowych dla czynników motywacyjnych. Dane jakościowe poddano analizie tematycznej. Wyniki wskazują, że gra symulacyjna SEED sprzyjała umiarkowanemu do wysokiego poziomowi zaangażowania, motywacji oraz przyrostowi wiedzy z zakresu zrównoważonego rozwoju. Zaobserwowano istotną dodatnią korelację pomiędzy zaangażowaniem studentów oraz ich motywacją. Studenci szczególnie docenili realizm gry, możliwość personalizacji doświadczeń oraz interakcje społeczne. Wyniki badania podkreślają potencjał dobrze zaprojektowanych gier symulacyjnych jako narzędzi dydaktycznych w edukacji na rzecz zrównoważonego rozwoju, wskazując jednocześnie na korzyści dla studentów w zakresie większego zaangażowania, motywacji i rozwoju kompetencji oraz dla nauczycieli, którzy zyskują innowacyjne narzędzie do przekazywania złożonych treści. Otrzymane rezultaty są zbieżne z doświadczeniami opisywanymi na uczelniach europejskich.

S ł o w a k l u c z o w e: uczenie się oparte na grach, edukacja na rzecz zrównoważonego rozwoju, innowacyjne metody nauczania, model Octalysis, szkolnictwo wyższe

Joanna Wójcik, Joanna Świętoniowska, Jacek Jakieła

El impacto del aprendizaje basado en juegos en la educación sostenible de las nuevas generaciones: un estudio de caso

R e s u m e n

Indented text of the summary in Spanish. Las instituciones de educación superior enfrentan una presión creciente para dotar a los estudiantes de las competencias necesarias para abordar los complejos desafíos de la sostenibilidad. El aprendizaje basado en juegos (Game-Based Learning, GBL) representa un enfoque prometedor para involucrar a los estudiantes y fomentar el desarrollo de conocimientos, habilidades y actitudes orientadas a la sostenibilidad. Este estudio examina el potencial del juego de simulación SEED, diseñado con base en el modelo Octalysis, para mejorar la educación en sostenibilidad. Se llevó a cabo una investigación con métodos mixtos con 45 estudiantes universitarios que participaron en el juego SEED y completaron un cuestionario de evaluación posterior al juego. Los análisis cuantitativos incluyeron estadísticas descriptivas, correlaciones y análisis

de componentes principales de los factores motivacionales. Los comentarios cualitativos fueron también analizados temáticamente. Los resultados indican que el juego SEED promovió niveles de compromiso, motivación y percepción de aprendizaje en sostenibilidad de moderados a altos. "Desarrollo y Logro" e "Influencia Social y Relación" emergieron como los impulsores motivacionales más eficaces. Se observó una fuerte correlación positiva entre compromiso y motivación. Los estudiantes valoraron especialmente el realismo del juego, la personalización de la experiencia y las oportunidades de interacción social. Los hallazgos destacan el valor de integrar juegos de simulación bien diseñados en la educación para la sostenibilidad, especialmente para las nuevas generaciones con preferencias de aprendizaje específicas. También subrayan consideraciones clave para el diseño de juegos educativos y la práctica docente, incluyendo la importancia de mecanismos transparentes de retroalimentación y la atención a la diversidad de expectativas del alumnado. Este estudio contribuye a los esfuerzos actuales por aprovechar la gamificación como herramienta de apoyo al aprendizaje transformador para el desarrollo sostenible, destacando beneficios para los estudiantes en términos de compromiso, motivación y adquisición de competencias, y para los docentes que cuentan con una herramienta innovadora para explicar contenidos complejos. Estos resultados son coherentes con experiencias similares reportadas en universidades europeas.

P a l a b r a s c l a v e: aprendizaje basado en juegos, educación para la sostenibilidad, métodos de enseñanza innovadores, modelo Octalysis, educación superior

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Влияние игрового обучения на обучение по устойчивому развитию на следующие поколения: анализ примеров

А н н о т а ц и я

В высших учебных заведениях всё сильнее возрастает давление на то, чтобы сформировать у студентов компетенцию справляться со сложными вызовами, связанными с устойчивостью окружающей среды. Игровое обучение (game-based learning, GBL) представляет собой перспективный подход, вовлекающий студентов и способствующий развитию знаний и умений, необходимых для устойчивого развития. В данном исследовании изучается потенциял симуляционной игры SEED, разработанной с использованием Фреймворк Октализа (the Octalysis Framework), для улучшения качества обучения экологической устойчивости. Исследование смешанными методами было проведено 45 высшыми учебными заведениями, принимающими участие в игре SEED, и заполнившими постыгровой эвалюационный опросник. Количественные анализы включали: описательные статистики, корреляции и метод главных компонент. Качественная обратная связь была проанализирована также по тематическому критерию. Результаты показывают, что игра SEED способствует актизивации студентов, побуждает их мотивацию и помогает получить знания по устойчивости окружающей среды на среднем уровне, до высокого. Принципы Развития и достижения, а также Общественного влияния и сопричастности, оказываются самыми эффективными мотивационными факторами. Было найдено сильное соотношение между вовлечённостью и мотивацией. Студенты особенно ценили игровой реализм, персонализацию и возможность входить в социальные взаимодействия. Итоги подчеркнули значение включения умело разработанных игр в процесс обучения устойчивости окружающей среды. Это касается особенно новых поколений, у которых есть специфические образовательные предпочтения. Результаты указывают также на ключевые соображения студентов для будущей разработки игр и образовательной практики, включая большое значение

транспарентных механизмов обратной связи и учёта разновидных ожиданий учащихся. Данное исследование вносит вклад в текущие усилия по использованию геймификации для поддержки преобразующего обучения в области устойчивого развития, подчеркивая преимущества для студентов в плане вовлеченности, мотивации и развития компетенций, а также для преподавателей, которые получают инновационный инструмент для объяснения сложных тем. Эти результаты согласуются с аналогичными наблюдениями в университетах Европы.

К л ю ч е в ы е с л о в а: Игровое обучение, устойчивое развитие, инновационные методы обучения, Фреймворк Октализ, высшее образование