# Design and Evaluation of a Serious Game on Household Sustainability

Jan Sau[1(✉)], Imma Boada[2], Aleix Dorca Josa[1], and Laura Sánchez-Pascuala Gómez[2]

[1] Universitat d'Andorra, AD600 Sant Julià de Lòria, Andorra
JSAU@UDA.AD

[2] Graphics and Imaging Laboratory, Universitat de Girona, 17003 Girona, Catalonia

**Abstract.** Sustainability education has evolved from a necessity to a responsibility, or even an obligation. Numerous awareness initiatives have been implemented to meet this, including advertising campaigns and educational materials. Serious games combine entertainment with education and offer a powerful communication strategy to engage society and promote sustainability awareness. This paper presents Pick Energy Cards, a prototype of a serious game designed to educate players on energy consumption, water waste, and environmental pollution. The study's primary focus is the evaluation process, which aims to validate the game concept and assess both its usability and playability before testing its educational impact. To achieve this, the EGameFlow usability survey has been employed. A diverse group of 24 participants, aged 18 to 60, with varying levels of video game experience, participated in the study. After playing the game, participants completed the survey. The results demonstrate that Pick Energy Cards has the potential to serve as an effective learning tool for players across all age groups.

**Keywords:** Serious games · Evaluation · Gamification · Sustainability · Energy · Household ecology

## 1 Introduction

Sustainability is defined by United Nations Brundtland Commission as *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"* [19]. This definition offers a broad perspective on sustainability, revealing the complexity of conveying its pedagogical content to educate the population. This complexity arises from interconnected systems, long-term considerations, the balance between human needs and environmental limits, and the call for active engagement. In this context, serious games can be a good strategy to engage the population, as they both entertain and educate, making complex sustainability concepts more accessible and compelling to the audience.

Serious games are an effective strategy for transmitting important concepts across various domains. They are used in fields such as climate change adaptation, corporate settings, research, rehabilitation, and team building to engage


A. SchÃűnbohm et al. (Eds.): GALA 2024, LNCS 15348, pp. 145–155, 2025.
https://doi.org/10.1007/978-3-031-78269-5_14

audiences, improve efficiency, gather data, aid recovery, and build trust. These games offer an accessible and cost-effective approach that traditional methods cannot match [4,6].

Focusing on sustainability, a variety of serious games can be found in the literature. Among these, there are: *Cansuyu Elektrik*, a game proposed by Abdusselam to educate on energy consumption that requires players to manage energy sources to keep lights on and enemies away [2]. Tests with the game demonstrated a significant increase in students' awareness of energy sources after playing, indicating a positive effect on behavior change; Gustafsson et al. proposed *Power Agent*, a serious game designed to engage teenagers and families in reducing home energy consumption by tracking the energy consumption in the participants' homes and competing with rival households [14]; Liu et al. proposed *Smarter households*, a serious game aimed to influence energy use in social housing. Households received dashboards displaying real-time data, collected via utility meters and indoor sensors, on energy consumption, costs, and indoor environmental conditions, comparing weekly consumption [17]. There are also *Climate Challenge* and, *EnerCities*, designed for societal and environmental studies at various educational levels, and *Shortfall*, for industrial management and targeted to engineering students. These three games, evaluated by Katsaliaki and Mustafee [16], effectively incorporate environmental, economic, and societal sustainability, providing players with a comprehensive understanding of sustainable decision-making. Casals et al. proposed *EnerGAware* where players complete missions to learn energy efficiency, using real energy data for the decisions [7]. Initial findings showed promising short-term energy savings, with tenants voluntarily participating in the engaging and visually appealing game. More recently, Gawel et al. presented *BizArena* that seeks to integrate sustainability into virtual business simulators for higher education to boost students' environmental awareness [13]. Their findings emphasize the complexity of incorporating all aspects of sustainability into a single game, as it complicates the interactions between various business elements, making the objective of business diversification more challenging. For a review of how serious games can enhance understanding of sustainability issues, see Stanitsas et al. [22].


(a) (b)

**Fig. 1.** The two types of situations that may appear in the game: (a) *Pick Situation*, (b) *Event Situation*.

This paper presents Pick Energy Cards, the prototype and validation of a serious game to educate on sustainability and focused on energy consumption, water usage, and environmental impact to all ages. The game design allows for content customization, making it adaptable to evolving sustainability topics and various learning situations. Following this introduction, the paper is structured as follows: Sect. 2, Materials and Methods, presents the serious game, the testing scenario, and the evaluation methodology. Section 3 presents Results and Discussion. Finally, Conclusions and Future Work are given in Sect. 4.

## 2 Material and Methods

### 2.1 Pick Energy Cards Serious Game

Pick Energy Cards aims to promote sustainable lifestyles by integrating insights from various disciplines. The goal is to reduce the ecological footprint of domestic activities through engaging gameplay focused on waste management, energy consumption, and water usage. To design the game the Learning Mechanics-Game Mechanics design model [5] has been applied. This ensures coherence between learning objectives, game mechanics, learning mechanics, and assessment strategies [3,15]. The key concepts of the game are presented below.

**Learning Objectives.** In the game, Andorra's government official guides on household ecology were analyzed and used as a reference [1]. The referenced guide introduces daily household actions, such as managing different types of waste, using electricity-consuming appliances, regulating energy for heating or cooling rooms, and using water resources for various purposes. It also informs about the implications of each situation in terms of consumption, pollution, and cost, and it offers useful advice to be more sustainable in the short and long run.

**Game Mechanics and Learning Mechanics.** The game integrates Andorra's guide actions using the *dilemma choice mechanic*, presenting binary choices that impact sustainability, based on source material [1]. The gameplay of Pick Energy Cards revolves around players engaging in decision-making processes concerning energy consumption, water waste, and environmental pollution using a card-based mechanism, while keeping track to stay on budget. Players are tasked with selecting pairs of actions, named situations, that are presented as cards to manage resources at both the household and neighborhood levels effectively. These cards (as shown in Fig. 1) feature a relevant image, a pick cost that affects the budget on the corresponding level, the resources they affect (represented as colored circles), and an icon if the card may impact future situations. There are two types of possible situations (see Fig. 1), i.e., Pick Situations, where the player must select between two different options (such as taking a shower or having a bath), and Event Situations, which are unpredictable misfortunes that may affect your scores if you have not provisioned it (such as a heat wave, where having an isolated home can palliate the energy consumption effects of it). Strategic

decision-making is crucial as players navigate sustainability challenges, strive to optimize their resource usage, and not spend all the level coins before obtaining all three stars.

**Assessment.** The game pathway initiates with an interactive tutorial designed to familiarize players with the core mechanics of the game. Subsequently, players progress to the main gameplay, where they are presented with a level selection interface featuring nine levels and three difficulty settings. Following each level attempt, players receive a color grading score reflective of their performance, mirroring the European Energy Label system [8], achieved through their progression and solving of situations presented and their budget management. Score follows the three-star system, that many games have and that has shown a potential to encourage players to follow the desired behaviour [12]. High scores unlock bonus playtime, serving as an incentive for players to excel and engage further.

The game employs a feedback mechanism to motivate players and maintain engagement. Upon completing a level or when the allotted time runs out, players receive a final score reflecting their performance across levels. The final score is obtained by aggregating the three-star scores achieved in each level, resulting in a score ranging from 0 to 27. The score is then graded using the color coding and the lettering system of the European Energy Label.

**Global Game Overview.** In Fig. 2 the structure followed by the main game and each level to complete them is illustrated. This structured game progression reinforces learning outcomes and enhances decision-making skills. Based on learning and game mechanics principles, Pick Energy Cards guides players through distinct stages: *Situation events*: These present players with realistic scenarios to solve; *Resource management challenges*: Players must make strategic decisions about allocating limited resources; *Level recaps*: These provide a recap of key learning points from each level; and *Feedback loops*: Players receive immediate feedback on their actions, allowing them to learn and improve.

### 2.2 Evaluation Based on EGameFlow

To validate the game concept, test the prototype's usability and playability, and green-light the game for evaluation in a future learning effectiveness study, the EGameFlow questionnaire was selected. This questionnaire [11] follows a seven-point Likert scale and gauges how much a player enjoys themselves while playing a serious game. Therefore, it serves as a reliable predictor of the game's capacity for learning, according to previous research [9], as well as the validity of its results [11,21]. To assess Pick Energy Cards eight EGameFlow criteria have been considered. These are *focus*, *challenge*, *objective clarity*, *feedback*, *autonomy*, *immersion*, *social interaction*, and *knowledge enhancement*. The *social interaction* element of the survey was excluded since the game does not partake in social engagement in-game. The seven selected EGameFlow scales have a list of sub-scales, that measure in detail each of the seven main items. For each scale,

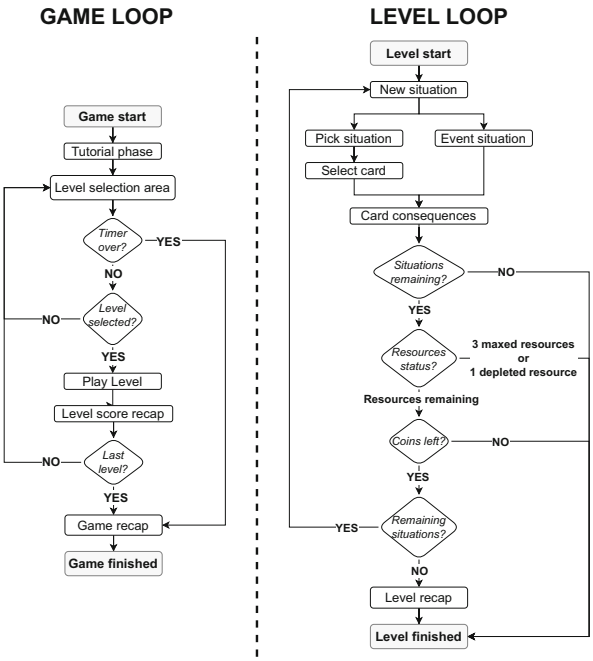


**Fig. 2.** A game flux diagram for both the full game and for each level.

four questions were selected forming the 7 sub-scales and 28 items included in the overall assessment as shown in Table 1.

Additionally, questions regarding demographics were incorporated (see Table 2), which can also be found in previous related research [18]. These questions provide further insight into the study participants, allowing the possibility to determine whether the designed prototype can be utilized by all user types or if it only caters to specific target audiences. Questions in this demographic poll focused on participants' age and occupation status, as well as topics related to the participants' familiarity with games.

### 2.3 Participants

To obtain information from a diverse sample, the prototype concept was tested on a demographically varied group of 24 people, spanning ages 18 to 60, who were contacted via email to participate. This range of participants was considered appropriate for the assessment because the base document, used to design the game, is targeted at all types of audiences, and adults and young adults are familiar with the everyday decisions the game portrays.

Participants received a fixed set of instructions to conduct the experiment. In these, the participants needed to download the game, play it to completion, without any more guides or clues than the ones already included in the serious game,

**Table 1.** EGameFlow survey questions

| EGameFlow survey | | |
|---|---|---|
| Scale | Code | Sub-scale |
| Concentration | C1 | The game grabs my attention. |
| | C2 | The game provides content that stimulates my attention. |
| | C3 | I can remain concentrated throughout the game. |
| | C4 | Most of the gaming activities are related to the learning task. |
| Goal Clarity | GC1 | Overall game goals were presented in the beginning of the game. |
| | GC2 | Overall game goals were presented clearly. |
| | GC3 | Intermediate goals were presented in the beginning of each scene. |
| | GC4 | Intermediate goals were presented clearly. |
| Feedback | F1 | I receive feedback on my progress in the game. |
| | F2 | I receive immediate feedback on my actions. |
| | F3 | I am notified of new tasks immediately. |
| | F4 | I receive information on my success (or failure) of intermediate goals immediately. |
| Challenge | CH1 | The game provides "hints" in text that help me overcome the challenges. |
| | CH2 | The game provides video or audio auxiliaries that help me overcome the challenges. |
| | CH3 | I enjoy the game without feeling bored or anxious. |
| | CH4 | The game provides new challenges with an appropriate pacing. |
| Autonomy | A1 | The game does not allow players to make errors to a degree that they cannot progress in the game. |
| | A2 | I feel a sense of control and impact over the game. |
| | A3 | I know next step in the game. |
| | A4 | I feel a sense of control over the game. |
| Immersion | I1 | I forget about time passing while playing the game. |
| | I2 | I become unaware of my surroundings while playing the game. |
| | I3 | I can be involved in the game. |
| | I4 | I feel emotionally involved in the game. |
| Knowledge | K1 | The game increases my knowledge. |
| Improvement | K2 | I catch the basic ideas of the knowledge taught. |
| | K3 | The game motivates the player to integrate the knowledge taught. |
| | K4 | I want to know more about the knowledge taught |

and once completed respond to the designed questionnaire. After responding the questionnaire participants' game data was retrieved, to verify the game was played to completion, as well as the overall game time. This procedure aimed to avoid any variance in experience for the participants and ensure their experience was homogeneous. Participants were also encouraged to send written feedback on their experience, which will be taken into account in further iterations.

### 2.4 Evaluation Metrics

The answers from the demographic survey and the EGameFlow survey have been analyzed to evaluate the outcome of the testing. Demographic questions served two purposes. First, they were used as sub-setting items to identify relevant discrepancies between groups. Second, they provided a profile of the participants, helping to validate that a diverse sample had been selected. For the EGameFlow survey seven-point Likert answers, have been analyzed numerically to get a mean score for each scale and subs-scale, as well as an overall score.

The Mann-Whitney U test was selected to evaluate differences between groups. This non-parametric test was deemed most appropriate because the data

comprised ordinal satisfaction ratings on a 1 to 7 scale, which do not meet the normality assumptions required for parametric tests like the t-test. By comparing the distributions of these ranked satisfaction scores between groups, the Mann-Whitney U test allows for the identification of statistically significant differences in perceived satisfaction levels without assuming normality in the data.

## 3 Results and Discussion

Table 2 displays demographic questions and results gathered through the survey. Results show that the survey received responses from a varied group, ranging between 18 and 60 years old, with almost half of them ranging between 27 and 35 years old (50%), followed by 18 to 26 years old (25%). In terms of occupation, the survey received no answers from unemployed people, and the majority of the responses came from employed people (75%).

In terms of their relationship with video games, around 29,17% of participants do not play video games regularly, which correlates with the novice (8.33%) and less experienced gamer (20.83%) in the experience with video game questions. In terms of participants who regularly play video games, most view themselves as experienced players (45.83%) and all of them play games for their entertainment, but only a set of them play to learn something (29.41%). These varied results will allow the possibility of having a more global view of the perception of the game by many player profiles, through the EGameFlow survey.

Results for the overall EGameFlow test are positive, as seen in Table 3. For each of the seven scales, and each question the mean was calculated to show the overall perception for each dimension of the test, also a mean for all categories was calculated to give an overall perception of the game. Having a seven-point Likert test sets 4 as the average score, so all scores surpassing 4 show a positive perception. In terms of scoring the overall score for the game, for all categories, is 5,32, with *Feedback*, *Goal Clarity*, and *Knowledge Improvement* graded as the highest ones, and *Immersion* graded as the worst one, being the only scale under 5. Concentration is also close to third best score. These results show that the game gives clear instructions, guides the players and communicates their performance through feedback, and makes the players perceive a gain of knowledge, as well as incites their curiosity to expand it.

Figure 3 shows the results for each question and each of the 7 Likert score answers (from Strongly Disagree to Strongly Agree) by percentage. This visual representation further displays that the majority of results are positive. Also, data was analyzed by grouping answers to analyze if there were any significant differences. Separations aimed to ensure that the lack of games literacy of the participants and the particular ways a game uses to communicate were not affecting the overall game experience, since they can hinder the transmission of knowledge [20]. Grouping participants between people who do not play often (n=7) and people who play weekly (n=17) showed no statistical difference in any of the survey questions. Conversely, when separating the age groups into two (35 and younger and 36 and older), out of the 28 questions analyzed using

**Table 2.** Demographic survey answers

| Characteristics | Item | Amount | Percentage |
|---|---|---|---|
| Age | 18–26 | 6 | 25,00% |
| | 27–35 | 12 | 50,00% |
| | 36–44 | 3 | 12,50% |
| | 45 and older | 3 | 12,50% |
| Current occupation | Student | 6 | 25,00% |
| | Employed | 18 | 75,00% |
| | Unemployed | 0 | 0,00% |
| How many hours do you spend playing video games per week? | I don't play video games | 7 | 29,17% |
| | 0–2 hours per week | 5 | 20,83% |
| | 3 h per week | 2 | 8,33% |
| | 4 - 6 h per week | 3 | 12,50% |
| | 7 - 9 h per week | 1 | 4,17% |
| | 10 h or more | 6 | 25,00% |
| I play computer games: (Multiple choice) *(Only answers from people who play weekly)* | To learn something | 5 | 29,41% |
| | For a challenge | 8 | 47,06% |
| | For fun | 17 | 100,00% |
| | To fulfill my leisure time | 12 | 70,59% |
| I feel that I am a/an | Experienced gamer | 11 | 45,83% |
| | Moderate experience gamer | 6 | 25,00% |
| | Less experienced gamer | 5 | 20,83% |
| | Novice gamer | 2 | 8,33% |

the Mann-Whitney U test, four questions-GC1, GC4, F3, and A1-showed statistically significant differences between the groups (p-values below 0.05). Specifically, for GC1, the test statistic was $W = 81$ ($p = 0.041$), for GC4, $W = 85$ ($p = 0.034$), for F3, $W = 81$ ($p = 0.041$), and for A1, $W = 82.5$ ($p = 0.045$). These results indicate that, while the majority of the questions did not show significant differences, responses to these four questions revealed a meaningful distinction between the groups. Even though the overall responses are positive in both groups, results may imply that the detailing of goals can be improved and rewritten to be clearer. These results highlight the potential of the developed prototype to educate users of all profiles on the importance of household ecology. Data from the written commentaries for the participants, as well as the survey results, provides crucial information to iterate on the developed prototype and release the game.

**Table 3.** EGameFlow survey average answers

| Scale | Code | Mean | Scale | Code | Mean | Scale | Code | Mean | Scale | Code | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Concentration** | C1 | 5,63 | **Feedback** | F1 | 6,00 | **Autonomy** | A1 | 5,38 | **K. Improvement** | K1 | 5,75 |
| | C2 | 5,29 | | F2 | 6,46 | | A2 | 5,58 | | K2 | 6,33 |
| | C3 | 6,08 | | F3 | 6,54 | | A3 | 6,00 | | K3 | 5,71 |
| | C4 | 6,21 | | F4 | 6,33 | | A4 | 5,54 | | K4 | 5,71 |
| | **All** | **5,80** | | **All** | **6,33** | | **All** | **5,63** | | **All** | **5,88** |
| **Goal Clarity** | GC1 | 6,33 | **Challenge** | CH1 | 5,42 | **Immersion** | I1 | 4,63 | **EGameFlow** | **Global** | **5,66** |
| | GC2 | 5,92 | | CH2 | 4,88 | | I2 | 4,46 | | | |
| | GC3 | 5,83 | | CH3 | 5,29 | | I3 | 5,58 | | | |
| | GC4 | 5,58 | | CH4 | 5,50 | | I4 | 4,54 | | | |
| | **All** | **5,92** | | **All** | **5,27** | | **All** | **4,80** | | | |

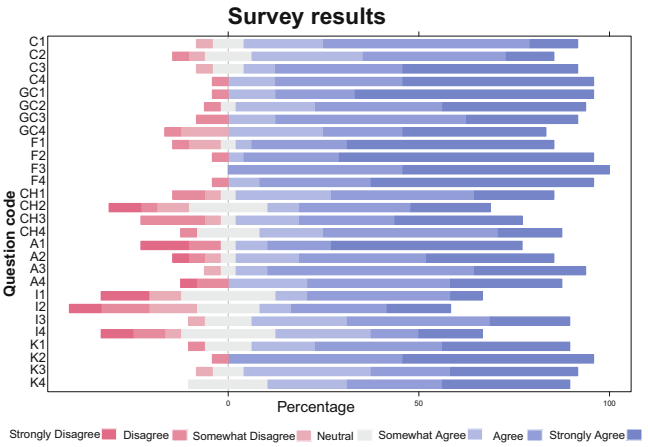


**Fig. 3.** EGameFlow survey results in percentage

## 4 Conclusions and Future Work

This paper introduced Pick Energy Cards, a game designed to educate players about sustainability. The game employs a card-based system where players must select the best options to efficiently preserve their resources, addressing a broad range of sustainability issues. This design allows for easy expansion and scalability. The study reports the results of the EGameFlow survey, which was conducted with a diverse group of participants varying in age and video game experience. Survey results suggest that the game has strong potential as an effective educational tool. From the results obtained and discussed, the game provides an enjoyable way to learn about sustainable practices in households, benefiting people of all ages by increasing their interest and desire for knowledge on home sustainability.

Future work will focus on testing the game in real-world environments (e.g. Fijnheer et al. [10], a game that engages players in real-world energy-saving missions, where they complete tasks while receiving feedback on their energy

consumption). A key area of interest is evaluating the amount of knowledge players acquire about sustainability. To achieve this, in-game statistics will be collected and analyzed quantitatively. Additionally, the game will be expanded to include more cards and scenarios, covering a broader range of sustainability themes. Improvements will be made to enhance game immersion and challenge scaling based on survey results. The goal is to ensure the final game is accessible and beneficial for all types of players, regardless of their video game experience.

***Conflict of interest.*** The authors declare that they have no conflict of interest.

## References

1. Ecologia domèstica, https://www.sostenibilitat.ad/docs/ecologia_domestica.pdf
2. Abdüsselam, M.: The effect of serious games on the awareness of energy sources consumption. Int. Technol. Educ. J. **4**, 7 (2020)
3. Adam, S.F.: An introduction to learning outcomes a consideration of the nature , function and position of learning outcomes in the creation of the European higher education area (2006). https://api.semanticscholar.org/CorpusID:8549631
4. Aragonez, T., Saur-Amaral, I., Gouveia, M.: Game-based learning in higher education: a systematic literature review. In: EDULEARN Proceedings, pp. 1849–1856. IATED (2021)
5. Arnab, S., et al.: Mapping learning and game mechanics for serious games analysis. Br. J. Edu. Technol. **46**(2), 391–411 (2014). https://doi.org/10.1111/bjet.12113
6. Brandl, L.C., Schrader, A.: Serious games in higher education in the transforming process to education 4.0—systematized review. Educ. Sci. (Basel) **14**(3), 281 (2024)
7. Casals, M., Gangolells, M., Macarulla, M., Fuertes, A., Vimont, V., Pinho, L.M.: A serious game enhancing social tenants' behavioral change towards energy efficiency. In: 2017 Global Internet of Things Summit (GIoTS), pp. 1–6 (2017)
8. Comission, E.: Understanding the energy label. https://energy-efficient-products.ec.europa.eu/ecodesign-and-energy-label/understanding-energy-label_en
9. Espinosa-Curiel, I.E., Pozas-Bogarin, E.E., Martínez-Miranda, J., Pérez-Espinosa, H.: Relationship between children's enjoyment, user experience satisfaction, and learning in a serious video game for nutrition education: empirical pilot study. JMIR Serious Game. **8**(3), e21813 (2020)
10. Fijnheer, J.D., van Oostendorp, H., Giezeman, G.J., Veltkamp, R.C.: Competition in a household energy conservation game. Sustainability **13**(21) (2021). https://doi.org/10.3390/su132111991, https://www.mdpi.com/2071-1050/13/21/11991
11. Fu, F.L., Su, R.C., Yu, S.C.: EGameFlow: a scale to measure learners' enjoyment of e-learning games. Comput. Educ. **52**, 101–112 (2009)
12. Gaston, J., Cooper, S.: To three or not to three (2017)
13. Gawel, A., Strykowski, S., Madias, K.: Implementing sustainability into virtual simulation games in business higher education. Educ. Sci. (Basel) (2022)
14. Gustafsson, A., Katzeff, C., Bang, M.: Evaluation of a pervasive game for domestic energy engagement among teenagers. Comput. Entertain. **7**(4), 1–19 (2009)
15. Kalmpourtzis, G., Romero, M.: Constructive alignment of learning mechanics and game mechanics in serious game design in higher education. Int. J. Serious Game. **7**(4), 75–88 (2020)
16. Katsaliaki, K., Mustafee, N.: Serious games for sustainable development. J. Manag. Educ. **37**(6), 889–894 (2013)

17. Liu, S., et al.: Impact of emerging interaction techniques on energy use in the UK social housing. Futur. Cities Environ. **4**(1) (2018)
18. Johari, N.F.M., L, Ishak, N., Zaini, H.: Adopting the eGameFlow model in an educational game to increase knowledge about vaccination. JOIV : Int. J. Inf. Vis. **7**, 338–344 (2023) https://doi.org/10.30630/joiv.7.2.1809
19. Nations, U.: Sustainability defintion. https://www.un.org/en/academic-impact/sustainability (2024), [Online; Accessed 3 June 2024]
20. Sherrick, B.: Video games and communication (Mar 2018), title of the publication associated with this dataset: Oxford Bibliographies Online Datasets
21. Shu-Hui, C., Wann-Yih, W., Dennison, J.: Validation of eGameFlow: a self-report scale for measuring user experience in video game play. Comput. Entertain. **16**(3) (2018). https://doi.org/10.1145/3238249,https://doi.org/10.1145/3238249
22. Stanitsas, M., Kirytopoulos, K., Vareilles, E.: Facilitating sustainability transition through serious games: a systematic literature review. J. Clean. Prod. **208**, 924–936 (2019)