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Learning sustainability by making games. The experience of a challenge as a novel approach for Education for Sustainable Development

Sara Cravero[1], Francesco Strada[2], Isabella Lami[1], Andrea Bottino[2]
[1]InterUniversity Department of Regional and Urban Studies and Planning, Politecnico di Torino, Italy, [2]Department of Computer and Control Engineering, Politecnico di Torino, Italy.

Abstract

Nowadays, the programs of Education for Sustainable Development (ESD) are designed for changing attitudes on environmental, economic, and social dimensions. In this context, and considering the varied ages of the participating students, it is necessary to implement appropriate pedagogical methods that are generally different from the traditional ones. Among the available approaches, Sustainability serious games (SSGs) appear to be an ideal candidate to facilitate ESD providing students with opportunities to experience the complex issues of sustainability. Besides learning by playing SSG, another relevant opportunity, capable of engaging teachers and students into a relevant and meaningful learning context, is learning by making SSGs, capable of engaging teachers and students into a relevant and meaningful learning context. In light of these comments, this paper proposes a major contribution to the research on learning by making games through a detailed discussion of the results obtained during a University Challenge experience, where students were involved in the design and development of SSGs. The Challenge involved 59 higher education (HE) students who were asked to work in groups to create a (per-group) prototype of a SSG aimed at improving the sustainability of our campus. Results of the Challenge assessment show that this learning approach can indeed be considered a valuable alternative for ESD.

Keywords: *Sustainability serious games; learning by making; sustainable development goals (SDG); education for sustainable development (ESD).*

1. Introduction

The concept of Sustainable Development (SD) is currently one of the goals of the world's policy agenda. For this purpose, in 2015, the Agenda 2030 defined 17 Sustainable Development Goals (SDGs) that are the blueprint for achieving a better and more sustainable future for the next generation. The concept of SD has thus been associated with environmental education to promote development models based on the wise use of resources that concerns economic, environmental, and social dimensions. Furthermore, it has become essential to convey behavioral changes to prioritize the Education for Sustainable Development (ESD) (Carteron, et al., 2014). ESD requires suitable pedagogical methods that are different from traditional teaching approaches since it should leverage collaborative problem-solving processes set in scenarios mimicking real-world issues eliciting the integration of diverse perspectives (Buckler and Creech, 2014). Among the available tools exploited in student-led learning experiences, Sustainability serious games (SSGs) appear to be an ideal candidate to facilitate ESD. SSGs can (i) engage players in problem-based transformative activities, (ii) promote exploration and critical analysis of events, things, relationships, and meanings in the game space, and (iii) foster collaborative decision-making and actions (Dieleman and Huisingh, 2006). SSGs help transfer knowledge while offering fun and entertainment among players, who eventually learn by doing (and failing), and offering shared experiences that promote collaboration and interdisciplinarity (Michael, 2006; Sawyer and Smith, 2008). While the educational effectiveness of SGs and SSGs is largely recognized in the literature (Al-Makhzoomy et al., 2020), one viable alternative to approach ESD through SSGs is turning the table, that is, making games for learning instead of playing games for learning. This approach stems from the constructionist theory applied to games (Papert and Harel, 1991) which builds upon Piaget's constructivist theory (Piaget, 2013). The general concept behind the idea of learning by making games is that the process of designing and creating games helps students to (i) improve their understanding of the subject matter, which needs to be broken down and analyzed in every detail to allow for the development of contextually appropriate game mechanics, (ii) construct new relationships with knowledge, (iii) express in more depth their ideas and feelings about the subject matter of the game, and (iv) develop collaborative (and creative) problem solving, which in the specific context of ESD has concrete benefits in terms of learning (Ke, 2014; Earp, 2015; Mercer et al., 2016). Nevertheless, while there is a certain degree of evidence pointing to the effectiveness of learning by making games (Kafai & Burke, 2015), sound empirical evidence is still lacking. This learning approach has primarily been exploited with kindergarten-to-12th grade (K12) students, whereas very few examples can be found for HE students. Moreover, although SSGs are widely adopted, to the best of our knowledge, examples of learning by making games for ESD are still lacking. Finally, the average length of these activities is mainly short in time, whereas complex topics, as ESD, might benefit from long

interventions to solicit more significant knowledge sedimentation. This work contributes to the state-of-the-art by presenting and assessing an educational experience where HE students were challenged to design and develop SSGs over three months. We assessed the Challenge experience through a post-experience questionnaire and structured interviews on nearly all the 59 students involved. Results show that students evaluated the challenge as an effective learning and motivating experience, fostering 21st-century skills like collaboration and communication. Finally, we believe our findings could guide future practitioners who wish to propose an ESD intervention in a learning-by-making fashion.

2. Related works

According to the literature, the primary goal of learning through game creation is programming (Denner et al., 2012, Al-Makhzoomy et al., 2020). The main reason can be found in the strong links that already exist between coding and digital game creation, where the use of language programs in implementing the game behavior and logic is a key element of game development. In this way, creating a captivating and engaging artefact (a digital game) is the main motivation that fosters students to acquire the first rudiments, or more advanced skills, of programming. However, in education for coding, the focus of learning-by-making is not on the game's subject but on the process of creating it. On the contrary, recent research explores the use of SG making to transfer knowledge about the specific topic addressed by (or the specific scenario involved in) the game. As for ESD, to the best of our knowledge, the only work proposing a learning-by-making approach is (Mercer et al., 2016), which demonstrates that the application of this method in the specific domain of ESD is almost unexplored. Concerning the assessment of the effectiveness of learning-by-making game approaches (in terms of learning outcomes), most authors could not find quantitative data demonstrating learning outcomes on the specific topics the interventions focused on, mainly due to the difficulty of evaluating learning effects (Garneli et al., 2013). However, through qualitative evaluation of the studies (conducted through interviews, questionnaires, and video recordings' analysis), researchers observed that learning through making games supported the development of 21st-century skills, such as creativity, innovation, communication, collaboration, critical thinking, and problem-solving. Furthermore, most of the students involved in these educational activities expressed high levels of engagement and, above all, manifested their strong interest in being able to repeat similar activities. As pointed out by several authors (Kafai and Burke, 2015), one of the drawbacks of current approaches to learning by making games, regardless of their scope, is that they primarily target K12 students in extracurricular activities, such as summer camps and after-school clubs. In contrast, far fewer examples can be found in higher education and almost none that target an adult audience (Earp, 2015). This fact is quite surprising, especially when compared to the

field of learning by playing games, where SG and gamified activities are generally directed at all age groups.

3. The challenge

From the academic year 2014/15, the Politecnico di Torino has started an educational program known as "The Path for Emerging Talents" to develop the potentials of promising students selected because of specific merit requirements. The Path for Emerging Talents has also become a field of experimentation for innovative educational initiatives that will complement traditional study plans. In the academic year 2019/2020, one of these educational initiatives has been envisioned as a challenge in which students were asked to develop a SG prototype focused on raising awareness on sustainability-related themes. In this regard, the Challenge's premise is that students' role as developers of SGs, would enable them to become active participants in the overarching learning activity. The final SGs could be either digital or physical (tabletop) and feature either single or multiplayer mechanics. However, all SGs were required to (i) promote sustainability within the Politecnico di Torino (ii) focus on at least 2 SDGs (iii) involve all the sustainability dimensions (i.e., social, environmental, economic) (iv) provide a minimal gameplay length of 30 minutes and (v) investigate the interconnections between different SDGs. In the end, the expected outcome is to make participants more aware of sustainability themes through a constructionist approach.

3.1. Organization

The Challenge took place from March 10th to June 12th, 2020. During this period, students attended teaching activities delivered by university professors and tutoring sessions guided by a team of four tutors, composed of industry professionals and Ph.D. students with a solid background on the Challenge's topics. It is also important to note that the Challenge was planned as a regular face-to-face teaching activity, but with the outbreak of the pandemic and the hard lockdown in Italy, the whole course had to be held online. In total, 59 students, divided into eight teams, attended the Challenge. The teams' composition was based on information gathered from a questionnaire submitted a couple of weeks before the Challenge's launch. Participants were asked to self-evaluate their technical and practical skills related to areas of expertise relevant to developing a SG.

The Challenge was divided into three main phases: (i) Preparatory and Design, (ii) Development, and (iii) Playtesting and Finalization. Each phase ended up with submitting specific assignments, assessed by the professors, whereas tutors monitored the in-phase advancements through a set of weekly day-long sessions. The Preparatory phase's first step was introducing the Challenge and presenting the requirements for the final SGs. To promote team-building, encouraging students to meet and interact with the different team members (students did not know each other before the Challenge), we asked them to play Fate of the

World collaboratively. In this game, players are in charge of a fictional international organization and must manage social, technological, and environmental policies. The playing session also introduced the first game design and game development lectures, which were then deepened throughout the following weeks.

In the following weeks, students attended lectures to acquire all the funding knowledge required to develop a sustainability SG. Moreover, during this first phase, students were supervised by the tutors in brainstorming and design sessions aimed at defining a game concept which students eventually pitched to the professors' board.

In the Development phase, students focused on creating a working game prototype (Minimum Viable Product, MVP) inclusive of the main mechanics and technologies. Students had completed all the lecturing activities, and during this phase, they mainly met with the tutors, which helped adjust and refine their MVPs. Once professors assessed the MVPs, students started the final phase (Playtesting and Finalization). They focused on improving the prototypes based on feedback received during playtesting sessions and from a revision session with the ETH Game Technology Center (GTC). This phase's final step has been the definition of a simplified "Production Plan" to make students reflect on the resources required to finalize their prototype into a commercial product. The final delivery was organized as a two-day activity. On the first day, four professors and four tutors played each SG for at least 45 minutes. They filled an evaluation questionnaire to assess the games' requirements fulfillment and overall playability at the end of each play session. On the second day, each team presented their SG to a board composed of the teaching professors and the Green Team, a university group in charge of promoting sustainable practices for the campus. We eventually prepared a leaderboard of the teams combining the audience votes, on a scale from 1 to 5, with the day one questionnaire. It must be noted that, before the pandemic situation erupted, the final presentation was envisioned as a physical exhibition composed of stands equipped with gaming stations where any visitors (students of the university, members of the other teams, teachers/tutors) could test the different SGs. The visitors would have been equipped with an evaluation card to evaluate at least two games.

Among the eight final SSGs, 7 are table games, and 1 is a smartphone app. The winners of the challenge were 4. “Patent” (1st place) is a cooperative game where players are the main characters of the sustainable transition and have to obtain more sustainable points as fast as possible by the end of the game. “Polinks” (2nd place) is a competitive card game developed to establish links and connections among different actions workable for the campus. “iPolito” (3rd place) aims to transmit knowledge on SD areas through the interactions among the cards in which wins who first reaches his game-objective. “4…3…2…1…Sustainability” (3rd place ex-aequo) is a challenging board game where players have to invest money and limited resources in sustainable projects within the campus.

4. Challenge assessment

Our assessment's objective was to qualitatively assess the students' experience and appreciation with this alternative form of ESD intervention. At the end of the Challenge, we submitted a questionnaire to all the 59 students and conducted structured interviews on a smaller sample (n = 32). In the following sections, we first describe the questionnaire's details and finally present and discuss the results.

4.1. Data Collection

The post-experience questionnaire was composed of 68 items, organized into four main parts, and formed of both open questions and statements to which participants had to express their agreement using a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). The first part aimed to collect information on students' habits and knowledge with playing and making games digital or non-digital. The second part focused on assessing the Challenge experience according to three sub-scales, evaluating three dimensions: (i) Teamwork, i.e., the effects on teamwork abilities fostered by the Challenge, (ii) Learnability, i.e., the self-assessed learning effectiveness, and (iii) Likeability to Repeat, i.e., the likeability of students to repeat a similar experience. In this part, we also asked students to self-evaluate their knowledge of sustainability themes according to Environment, Economic, and Social macro-dimensions using the same questions proposed in the initial questionnaire students had to fill at the start of the Challenge. In the third part, we examined the Challenge's phases (Section 3.1) to identify practices commonly adopted by groups and highlight students' main difficulties. Finally, in the last part, we gathered students' personal information (e.g., gender, age, the field of studies). The proposed questions have been either adapted from questionnaires used in similar activities (Hava et al., 2020, V. Garneli et al., 2017) or newly formulated to account for our particular investigation needs. Descriptive and inferential statistical methods were used to analyze the collected data. For frequency analyses, responses 4 and 5 on the Likert scales were aggregated to indicate agreement or positive viewpoints. Finally, to give a more precise explanation of the questionnaire's results, we conducted structured interviews with 32 students.

4.2. Results and Discussion

Nearly all students completed the questionnaire (56 out of 59), 93% were male, aged 21-22, and were evenly divided between those who frequently play digital games (47%) and those who do less frequently (53%). Only 12% reported playing non-digital games regularly, and 37% stated having had experience playing SGs, primarily in an academic context (e.g., high school or university). Also, students were mainly at their first experience (75%) with making games. The majority of students (61%) positively evaluated the learning effects solicited by the Challenge (i.e., Learnability sub-scale) alongside 65% of all respondents who stated

improved teamwork abilities fostered by this experience (i.e., Teamwork sub-scale). Unfortunately, only 37% expressed their likeability in repeating a similar experience in the future (i.e., Likeability to Repeat sub-scale). However, we detected a high correlation (r=0.76) between the Learnability and the Likeability to Repeat sub-scale, suggesting that this result was not caused by the Challenge's learning experience. This finding is important because it highlights the positive impact on learning of a similar activity (i.e., learning by making SGs) and shifts the focus on what did not work onto something else. What has emerged from the interviews is that students negatively assessed the Likeability to Repeat sub-scale due to the difficulties they faced at the beginning of the Challenge, mainly during the design phase (64% of students). As they reported, these difficulties were primarily caused by the current pandemic situation, which forced students to work remotely without ever having the chance to meet in person (and they had also never met before). According to the students' feedback, this limitation compromised their ability to establish a positive bond, resulting in an initial lack of group work commitment that jeopardized the brainstorming and initial design stages. Based on past group work experiences, most students agreed that carrying out similar activities in person could help surpass these issues. It should also be noted that students were able to overcome most difficulties once the game was designed and the development started. As a result, a significantly lower percentage (39%) of students declared having faced problems during this stage.

Furthermore, positive learning effects were also detected from the questionnaire items requiring students to self-evaluate their knowledge across the three sustainability dimensions (i.e., Environment, Economic, and Social). To compare statistical significance differences with the same questions submitted at the beginning of the Challenge, we performed a Mann-Whitney U test. We obtained significance across all dimensions as follows: Environment (alpha = 0.04), Economic (alpha = 1.1e-08) and Social (alpha=0.000105). Also, we detected an improvement for each dimension with different effect sizes (Cohen d) as follows: Environment small (d=0.358), Economic large (d=1.189), and Social medium (d=0.761). These results show a positive and detectable influence solicited by the Challenge. Through interviews, students highlighted that the economic sustainability dimension was the less mastered one at the beginning of the Challenge. Thus, the greater impact (i.e., larger effect size) detected might be attributed to knowledge acquired solicited by the requirement of producing an accurate and sustainable business plan for the production of the developed game.

Finally, we evaluated statistical differences across different groups for the overall sub-scale items (i.e., Learnability, Teamwork, and Likeability to Repeat) and the Sustainability Dimensions Knowledge (derived from the background information obtained from questionnaire). We analyzed statistical differences either with a standardized T-Test or a Mann-Mann-Whitney U test based on the normality or non-normality of the sample

(measured through a Shapiro Wilk test). All these subscales showed no statistical difference (alpha > 0.05) between users who had a different experience and familiarity with either playing digital-games or SGs (digital and non-digital). This finding is promising because it shows that the positive outcomes of this learning experience yield no difference regarding the student's background experience with playing and making games.

5. Conclusion

This paper describes a novel approach to ESD where we challenged university-level students in developing SSGs as a learning activity. This approach stems from the emerging and, yet entirely unexplored, paradigm of learning by making SG instead of merely learning by playing them. Organized in groups for three months, 59 students designed and developed digital and non-digital SSGs to raise awareness on sustainability-related themes within their university campus. Through a post-experience questionnaire and structured interviews, we qualitatively assessed the students' experience. Results show that students positively assessed the learning effect and their improved teamwork abilities solicited by the activity. Moreover, students' self-evaluation across the three sustainability macro dimensions (i.e., economic, social, and environmental) increased between the start and the end of the Challenge. Interestingly, all the positive effects measured in the questionnaire yielded no difference between students who had previous knowledge of playing or making games. Finally, although their likeability to repeat a similar experience was low, this was mainly due to the unique Covid-19 lockdown we faced in Italy throughout the entire length of the challenge, forcing students to work and collaborate entirely remotely. Future works will address the collection and analysis of qualitative and quantitative data to assess the developed SSGs' effectiveness through play sessions with other HE students.

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