Received 14 November 2023
Revised 14 February 2024
24 May 2024
7 August 2024
Accepted 8 August 2024

Game-based learning about the circular economy in building sustainable communities: a case of international and interdisciplinary university collaboration

Imge Akcakaya Waite
Department of Urban and Regional Planning, Istanbul Technical University, Istanbul, Turkey

Aysegul Akcay Kavakoglu
Department of Landscape Architecture, Istanbul Technical University, Istanbul, Turkey

Lacramioara Diana Robescu
Department of Hydraulics, Hydraulic Machinery and Environmental Engineering, National University of Science and Technology Politehnica Bucharest, Bucharest, Romania

Diana Mariana Cocarta
Department of Energy Production and Use, National University of Science and Technology Politehnica Bucharest, Bucharest, Romania and Academy of Romanian Scientists, Bucharest, Romania, and

Liana Ioana Vuta
Department of Hydraulics, Hydraulic Machinery and Environmental Engineering, National University of Science and Technology Politehnica Bucharest, Bucharest, Romania

Abstract

Purpose – This study aims to enhance integration of game-based learning (GBL) as a tool for conveying intricate circular economy (CE) concepts effectively into international and interdisciplinary higher education collaborations for the development of sustainable communities.

Design/methodology/approach – A series of game-based workshops by the Circular EELISA Community of the EELISA European University program were examined in terms of their compliance with literature-

International Journal of Sustainability in Higher Education
Vol. 25 No. 9, 2024
pp. 378-396
Emerald Publishing Limited
1467-6370
DOI 10.1108/IJSHE-11-2023-0547

based GBL characteristics and their international, interdisciplinary and online conduct. An online survey conducted with 17 workshop and/or challenge organizers from four participating universities in different countries revealed expert experiences and perceptions on these points.

Findings – It was found that sensory elements, rewards and game choice enhanced engagement and motivation in all gamification, serious game and storytelling experiences, and that a combination of multiple GBL approaches was more effective than a single-method challenge design. Diversity-friendly collaboration, cooperation and immersion were particularly important when involving culturally and disciplinarily diverse participants.

Practical implications – This study offers practical recommendations to improve both the performance of GBL-based learning environments in current and future education alliances and collaborations and the potential of GBL approaches to motivate youth to contribute to more sustainable communities across and beyond Europe.

Originality/value – The findings underscore the value of innovative pedagogical methods in shaping environmentally conscious mindsets and practices across institutions of higher education. To that end, this is the first study that investigates GBL in CE education with implications for international university cooperation.

Keywords Game-based learning, Circular economy, Higher education alliances, CIRCULAR IN PLAY project, EELISA European University

Paper type Research paper

1. Introduction: collaborative learning environments promoting the circular economy

Circular economy (CE) represents the transition from a linear model of consumption, in which materials are eliminated, to a circular model that promotes their preservation, with the overall goal of zero waste. On the one hand, it has increasingly become possible in this way to emphasize the design of manufactured goods with added value and maximum use over longer life cycles, develop products with multiple functions throughout their useful lives, return orderly solid waste to the industrial sector and analyze the connections between the environment and the energy generated and materials extracted (Arruda *et al.*, 2021; Budiul Berghian *et al.*, 2021). On the other hand, implementation of the strategies of the CE, and sustainability in general, have increasingly become project-based, and educational games are a way to facilitate this process (Andreoni and Richard, 2023; Jaaska *et al.*, 2021). Unlike other traditional educational methods, where students only improve their knowledge, educational games emphasize their involvement in different activities. The purpose of game-based learning (GBL) in higher education is to educate students in a targeted field – CE, in this study – by incorporating learning outcomes into game content and to form close ties between diverse participants (i.e. those from different education levels, disciplines, institutions, countries and cultural contexts). GBL, based upon cognitive, affective, motivational and sociocultural theoretical foundations (Plass *et al.*, 2015), fosters a creative and engaging learning environment for CE's complex context (Manshoven and Gillabel, 2021). It raises awareness of CE's principles, impacts, opportunities and challenges more effectively than conventional instruction methods by engaging learners, encouraging experimentation and developing critical thinking and problem-solving skills (Manshoven and Gillabel, 2021; Whalen *et al.*, 2018). It also addresses the practical challenges of diversity in international and interdisciplinary settings when bringing people together.

GBL-driven CE and sustainability tools that aim to encourage individuals and organizations to implement sustainable practices and choices in their daily lives have lately started to be developed and used. Even if the multidisciplinary grasp of the required knowledge can make these topics more complex, the literature contains several studies focused not only on students and entrepreneurs but also on any other interested parties. For

instance, Stanitsas and colleagues (2019) identified 77 serious games developed to integrate sustainability into scholarly curricula between 1990 and 2018, spanning multiple specific areas of sustainability such as resource management, global warming and energy conservation. There have been various games developed to promote CE in education settings (Khoury *et al.*, 2023; Lange *et al.*, 2022; Manshoven and Gillabel, 2021; Whalen *et al.*, 2018). The related literature concentrates on the relationship between GBL and CE in the context of game approaches; however, further studies are needed to determine the embedded connections between GBL and CE in international and interdisciplinary environments. Doing so also serves to contribute to the literature of international and cross-cultural higher education environments promoting experiential and collaborative student learning, such as Collaborative Online International Learning (COIL) projects that pose a collaboration coverage as wide as Europe, North America, South America and Africa (Hackett *et al.*, 2023; Naicker *et al.*, 2022; Appiah-Kubi and Annan, 2020). Consequently, this study examines the European Engineering Learning Innovation and Science Alliance (EELISA), an initiative of various European universities. Founded in 2020, EELISA is the first alliance of higher education institutions created to focus on the creation of multidisciplinary communities to identify and solve different types of social, economic and environmental challenges by defining and implementing a new model of the European engineer rooted in society (Valdés and Comendador, 2022). Currently, EELISA consists of 10 member universities from eight countries, 45 active communities, 12,000 staff members, 18,500 faculty, 194,000 students and 34 associate partners (EELISA, 2023).

This study investigates online GBL processes designed through an international and interdisciplinary collaboration of institutions of higher education to foster sustainability- and CE-driven attitudes and behavior among engineering students from around the world. To this end, the case study examines game-based methodological approaches and their effectiveness in creating original GBL content during CIRCULAR IN PLAY, a project designed to promote CE among higher education students and the general public and supported by the first EELISA Call for Joint Inter-institutional Activities in Communities between September 2022 and March 2023. CIRCULAR IN PLAY was a venture of the Circular EELISA Community and the Circular and Socio-Civic Learning Hub (CIRC.LE) project supported by the Erasmus+ program, and a product of collaboration between Istanbul Technical University (ITU, Türkiye), Universidad Politécnica de Madrid (UPM, Spain), the National University of Science and Technology Politehnica Bucharest (Romania) and Scuola Superiore Sant'Anna (Italy), which have worked together to enhance the sociocivic and green competences of the European engineer since the community's founding in April 2021. The project consisted of six workshops spanning three GBL approaches (i.e. gamification, serious games and storytelling) in four workshop types, all of which provided a rich context for assessment and discussion of the adaptability and usefulness of GBL methods in an international, interdisciplinary and online collaboration. The study argues that GBL may prove an effective tool in promoting CE awareness and improving the related competences of higher education students in an alternative motivational and fun environment; however, there are some caveats concerning its effectiveness, as learned from the GBL literature. The paper is organized as follows: Section 2 discusses the concept, evolution and current methods of GBL and adapts a literature-driven compilation of GBL characteristics to CE learning; Section 3 outlines research design and methodology; Section 4 relays the results of the case study and a discussion in three parts: the description of workshops and their GBL approaches, expert perspectives on the relevance of the GBL characteristics to workshop processes and methods and the perceptions of the workshops' collaboration setting in terms of their multinational, multidisciplinary and online conduct. Section 5 provides a critical

discussion and conclusions regarding how and with what strategies gamification and serious games were used as a learning method by the Circular EELISA Community and what kind of feedback emerged throughout the case evaluation. The results also shed light on how European university alliances, as well as similar collaborations outside of Europe, can move toward CE in higher education in collaborative international and interdisciplinary settings.

2. Literature review: game-based learning and the circular economy

2.1 Game-based learning as an alternative learning environment

GBL has attracted attention for its ability to increase motivation and engagement in learning environments both individually and socially, particularly since the 20th century, due to technological developments in the video game industry and digital media (Bado, 2022; Plass *et al.*, 2019; Kapp, 2012; Prensky, 2001). However, GBL as a concept long predates popular modern forms of gaming; dating as far back as Plato and Aristotle, it is constructed upon the *idea of a game* either as a constructive tool for learning or a way to relax (Hellerstedt and Mozelius, 2019). From a Platonist perspective, the idea refers to when novel forms of learning and relaxing emerge during an activity. Thus, it becomes crucial to define the *form of this emergence*, which is called a *game*, in this study.

Gaming can be said to take place when concepts such as fun, amusement, relaxation and social activity are structured through a system defined by rules with clear tasks in which people engage and interact with and through a process and its outcomes. The game can be a board game such as chess or a sport such as basketball, structured around strict rules, or a game of a child built on unstable ones. However, although all these activities are constructed upon the idea of a game, they cannot all be called GBL. How learning occurs in these processes depends on the components of the game design and its context. Therefore, defining the components and context of game-concerning learning activities is crucial.

In the research fields of both GBL and gamification, the tasks involved in the abovementioned definition of a game may include features such as challenge, choice, feedback, cooperation, interaction, immersion and conflict (Bado, 2022; Nadolny *et al.*, 2020; Hellerstedt and Mozelius, 2019; Nie *et al.*, 2014; Kapp, 2012). Although these research domains have common characteristics, their context, goals, activities and outcomes differ. While GBL creates and facilitates a learning experience through a game, gamification uses game elements in nongame contexts (Plass *et al.*, 2019; Kapp, 2012; Deterding *et al.*, 2011). Games used for GBL can be preexisting or designed for it, depending on the cognitive objectives linked to skill, knowledge generation and development. On the contrary, gamification aims to motivate and engage participants, students and contributors through the use of game elements and characteristics in various environments. These elements and characteristics are broadly identified in the literature as points, badges, leaderboards, levels, feedback, challenges, storytelling (narrative), role-play, avatar/virtual identity, choice, low-risk failure, time-based tasks, task progress, time countdown, scoreboard, progress bar, rewards, virtual goods, teammates, medals and trophies (Khaldi *et al.*, 2023; Kalogiannakis *et al.*, 2021; Nadolny *et al.*, 2020; Deterding *et al.*, 2011). Among many attempts at definition, Nadoly and colleagues (2020) proposed a GBL framework based on game design by classifying game characteristics to clarify terminological confusion. Instead of directly identifying the game elements, they constructed a framework for the design of the learning environment, i.e. the game, which directly influenced the learning outcomes positively and creatively (Nadolny *et al.*, 2020; Plass *et al.*, 2015). Therefore, it is crucial for achieving the educational objectives to know how these learning environments are designed and in which contexts they facilitate learning.

2.2 Characteristics of game-based learning in a circular economy-driven context

In the past few years, numerous studies have investigated the effect of gameplay on knowledge gain and the most important characteristics to be considered its design (Sun *et al.*, 2023; Nadolny *et al.*, 2020; Plass *et al.*, 2015), with researchers from varying perspectives focusing on GBL elements, principles, characteristics, applications and environments. As mentioned in the previous section, these elements, principles and characteristics require more terminological clarity. In their influential study, Nadolny and colleagues (2020) describe GBL as a learning environment that needs to be designed and offer a system for defining the medium of GBL through its characteristics; the description is aligned with this study's undertaking of GBL, while the system offered provides an effective measure for assessing GBL-based learning environments. This study has thus adopted Nadoly and colleagues' classification for GBL characteristics, compiled from 194 publications, offering an adapted version to structure and explain the CE-driven GBL framework. This system is structured in two tiers, divided into six primary characteristics, which are named categories in this study for ease of reference and several secondary characteristics (Table 1).

Learning support sees to it that players, regardless of their skills or knowledge, succeed in completing a game. Considering the diverse possibilities of the use of its characteristics, it is no wonder that, when focusing strictly on GBL in CE and sustainability, there are many different approaches. When the game targets professionals, the learning support can be limited to only presenting the game mechanism and the CE and sustainability goals. In case

Table 1. Characteristics of GBL

GBL category	GBL characteristic	Short description
Learning support	Tutorial	Guided learning of game mechanics, sandbox play, explicit and implicit direction
	Support	Help guidelines, forums, help buttons, in-game guided corrections, players supporting players, teacher guidance
	Challenge/variability	Different levels of difficulty, extended gameplay, levels of gameplay
Assessment	Reward/positive reinforcement	Increase in score, badges, avatar modifications, unlock of new levels, digital coins, candy or treats, location on leaderboard, player lives
	Penalty/negative reinforcement	Decrease in health or strength or score, end of game, time restrictions, loss of rewards
	Feedback	Notifications, music cues (e.g. ticking clock), haptics, game health
Learner control	Control over gameplay	Following different paths, completing side quests
	Game choice	Customize an avatar, changing language preferences, selecting weapons
Immersion	Sensory elements	Music, 3D visuals, computer interface, boxes to physically unlock, rumble pack
	Digital immersion	Augmented reality, virtual reality, GPS, virtual world
Interaction	Collaboration	Real or virtual teams working together for a common goal
	Competition	Real or virtual individuals or teams working against each other
	Other communication	Interaction with computer characters, two-way chat feature
Narrative	Storytelling/narration	Storyline or game cohesion that provides contextual information for learning

Source: Adapted from Nadolny *et al.*, 2020

the game targets an audience with limited experience and knowledge in CE or sustainability, some preparations before the actual game can be performed (e.g., see Lange *et al.*, 2022; Manshoven and Gillabel, 2021; Whalen *et al.*, 2018). *Assessment* corresponds to evaluation of a player's skills and knowledge through positive or negative reinforcement and feedback. Despite the fact that all games, including those focusing on CE and sustainability, provide in the end a winner (an individual or a team) based on the final victory points gained, assessment in GBL is not that simple, since it is based on dynamic experimentation coupled with various possible strategies. Thus, most CE and sustainability games are used to deliver specific knowledge, including the importance of CE concepts such as scarcity of resources, resources efficiency, recycling possibilities and circular business models. As a result, assessment can be performed not only based on the winner of the game session, but also through pre- and post-game surveys, debriefing sessions at the end of the game, or by individual reports or essays prepared by the players (Lange *et al.*, 2022). *Learner control* allows players to make choices and to explore the game at their pace, so that the players have some control over the gameplay. Different strategies to nourish players' motivation have been reported in CE and sustainability games (Khoury *et al.*, 2023; Lange *et al.*, 2022). The players must adopt the best strategy (according to their knowledge) to close their loops and the game unfolds more or less depending on the performance of this strategy. In other cases, the players must develop a prospering business, starting with linear economy principles and, as the game progresses, shift to CE strategies, such as recycling, remanufacturing, lifetime extension and repairing (Manshoven and Gillabel, 2021). This shift to CE principles depends on the investment and management strategy adopted by the player.

Immersion in games stimulates the senses and transports the user into a state of deep engagement with or absorption in an activity or environment. Many CE and sustainability games use real-case scenarios and players must solve real-life problems. To make a game experience tangible and immersive, resource exhaustion can be illustrated through a depleting card deck can while employees, materials and products can be represented by small, tangible pieces (Manshoven and Gillabel, 2021). These features convey material flows on the game board, making the games highly visual. *Interaction* refers to the possibilities for players to cooperate, form teams or compete with other players/teams. No matter what kind of interaction is used, it brings only advantages in the case of CE or sustainability games. When players cooperate, they can discuss the different CE or sustainability strategies to be used and pathways to be followed to ensure the success of the team. When players compete with others, not only they are focused on increasing their performance but they can learn from the different strategies used by their opponents. Finally, *narrative* provides contextual anchoring, helping players to better understand the situation from the game and inspire them to continue to play. Sustainability games rely on real-case scenarios, so it is relatively easy for the players to relate. The use of an engaging storyline, including unexpected events and various challenges, triggers curiosity and fantasy, whereas studies on sustainability games report that students sometimes even appeared emotionally concerned about running out of materials (Whalen *et al.*, 2018).

3. Research methodology

This study uses exploratory research with mixed methods to examine the EELISA European University program's Circular EELISA Community's CIRCULAR IN PLAY project activities in terms of their GBL methodology and their adherence to literature-driven GBL characteristics in an online, interdisciplinary and international setting. The aim is to assess and derive lessons for the design process of CE- and sustainability-based educational workshops targeting engineering students in Europe. Based on the characteristics of GBL compiled above,

the methods and outcomes of the workshops were analyzed, followed by a comparative assessment to determine the engagement and efficiency of the outcomes of GBL.

Primary data was collected through purposive sampling and an online survey conducted to collect the impressions of the informed organizers and moderators who actively partook in the designing, optimizing and moderation of the workshop challenges. A total of 34 professors and researchers from the four participating universities were involved in the six workshops of CIRCULAR IN PLAY, which were categorized into four types. To conform to the comparative assessment nature of the research design, the organizers who participated in two or more workshops were included in the study, resulting in a population size of 23, of which 17 volunteered to take part in the survey, achieving a 90% confidence level with a 10% confidence interval. The distribution of the participants' institutions is representative of the institutional team sizes and their specializations encompassed various technical education and research fields related to the CE (i.e. engineering of energy and environment, agroforestry and aeronautical systems, as well as business management, urban planning, architecture and building technology and landscape architecture). The survey was conducted in English, which was also the language used in the international workshops of the case project.

The interview questions contained three parts. The first part collected descriptive information. The second investigated the relevance of the four types of workshops to the 14 GBL characteristics in the form of a checkbox grid and detailed comparison of these types in terms of the six GBL categories. The survey participants were provided with brief descriptions of the workshop methodologies and the GBL characteristics to ensure a common contextual knowledge basis in seeking viable responses and improving the validity of research (Fowler, 1995). The last part elicited the participants' opinions on the setup of CIRCULAR IN PLAY workshops in the form of contrast-based comparisons. The data were analyzed two-fold: The quantitative data derived from the checkbox grid were supported by the analysis of qualitative questions coded by GBL characteristics, whereas qualitative in-depth perceptions were assessed through content analysis under three themes of comparison:

(1) unrestricted vs restricted international scope in admitted participants;

(2) unrestricted vs restricted interdisciplinarity and multidisciplinarity in admitted participants; and

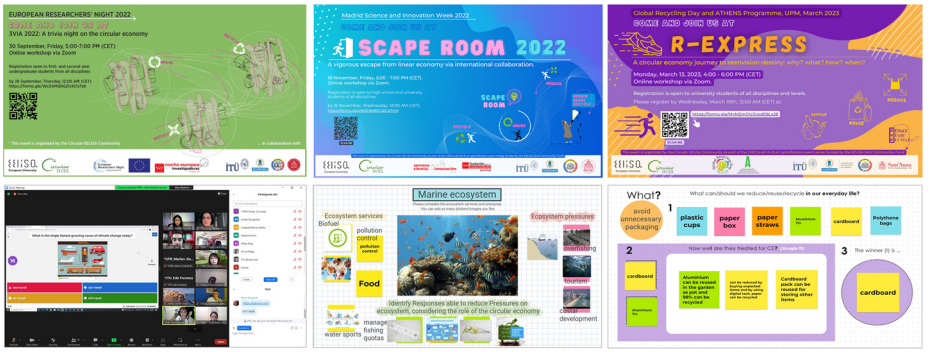
(3) online vs in-person conduct.

In the conduct of content analysis, raw data or open-ended responses were coded into these themes and further categorized to reveal different perceptions, including similarities and contrasts. To allow for effective and communicable results, findings were derived in a comparative manner in line with the comparative nature of the coding themes. Final assessments involved the implications of the study findings for future workshops of similar international alliances.

4. Results

4.1 Game-based methods of CIRCULAR IN PLAY

CIRCULAR IN PLAY comprised a series of six workshops – three online GBL nights in the form of open workshops and three subsequent design activities – all of which were associated with international events celebrating innovation and environmental science. The primary aim of the project was to enhance participants' awareness and knowledge of the CE and the accompanying sociocivic competencies in a GBL setting, whereas its secondary aims included enhancing knowledge about the EELISA Alliance and thus contributing to the participants' educational mobility. Each open workshop was a 2-h activity consisting of short



Source: Project archive; figure created by authors

Figure 1. Posters and challenges of the three open workshops of CIRCULAR IN PLAY

Table 2. CIRCULAR IN PLAY workshops and their game-based characteristics

Activity name/type	Challenge name/type	Challenge medium	Learning approach
3VIA 2022	Trivia	• Zoom (main room) • Kahoot!	Gamification
ScapeRoom	"Pictionary"	• Zoom (breakout rooms) • Manual drawing materials • Google Jamboard	Serious game
	"Earth's defenders"	• Zoom (breakout rooms) • Google Jamboard	Serious game
R-Express	"Why? What? How? When?"	• Zoom (breakout rooms) • Kahoot! • Google search • Google Jamboard	Gamification and serious game
Circular infographics design #1, #2, #3	Content research and graphic design	• Zoom (main room) • Google search • Adobe illustrator/ Photoshop	Storytelling/narration

informative presentations on sustainability and SDGs, EELISA and the Circular EELISA Community, followed by game-based challenges and discussion sessions on the basics of the CE (Figure 1, Table 2).

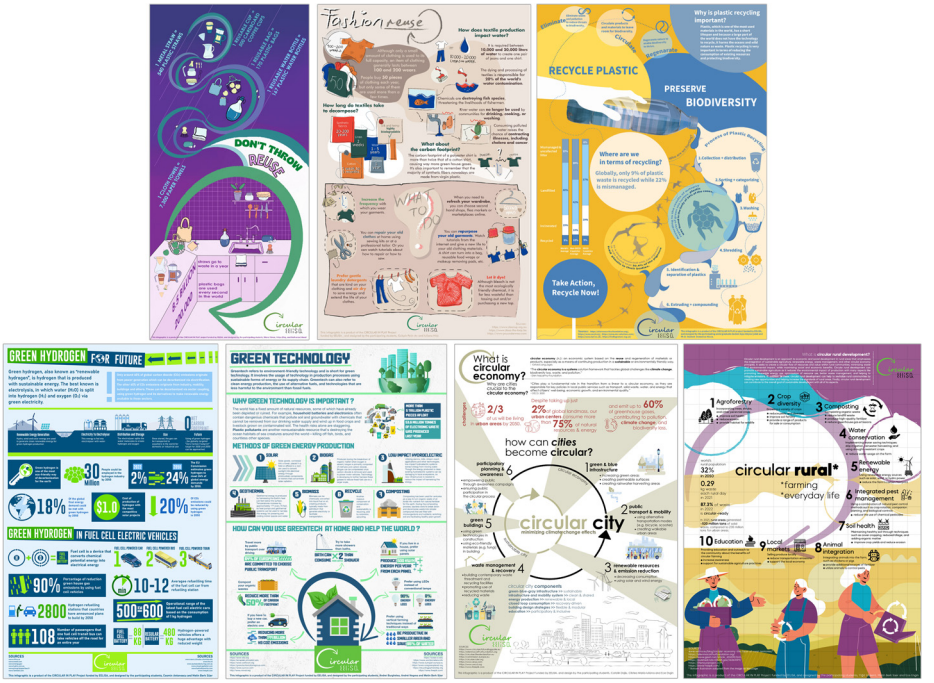
Held as part of the European Researchers' Night 2022, the first workshop, *3VIA 2022: a trivia night on the circular economy*, used trivia activities involving the three main themes of the CE: reduce, reuse and recycle. Kahoot! was the primary platform and gamification tool and each theme was developed and delivered by a different university of the international organizing team in one main room for individual play. The second workshop, entitled *ScapeRoom: a scientific parkour around the circular economy and socio-civic skills*, was organized as part of the 2022 Madrid Science and Innovation Week. The challenges consisted of two custom-designed serious games that used smaller virtual rooms and Google Jamboard to draw and visualize ideas through collective brainstorming moderated by the participating university's professors and researchers. The third open workshop, *R-Express: a circular economy journey to reuse destiny*, was held during the week of the 2023 World Recycling Day as part of an ATHENS Program course on the basics of the CE in the construction sector. It merged the gamification and serious game methods in a challenge entitled "Why? What? How? When?," in which the participants first competed individually in short theme-based Kahoot! sessions and then engaged in groups in moderator-led incremental brainstorming over Google Jamboard.

The three *circular infographics design workshops* were held as follow-up activities of the three open workshops, in which interested participants worked together further to produce infographics on CE themes that they defined. The participants collaborated in international and interdisciplinary groups of —four to six consisting of students, design facilitators and supervisors to define a theme, collect data-based evidence and produce context and messages to convey to the public in the form of an infographic. Over the course of three workshops, a total of seven original infographics were designed under the following themes:

(1) reuse in the domestic kitchen;
(2) reuse in fashion;
(3) plastic recycling;
(4) green hydrogen;
(5) green technology;
(6) the circular city; and
(7) circular rural lifestyles (Figure 2).

The final draft versions were revised based on Circular EELISA Community members' feedback and also reformatted to cater to different online dissemination media, i.e. institutional and private social media channels and websites.

The principal target group of all the workshops was first- and second-year university students from the four participating countries and other EELISA Alliance member universities; however, the audience comprised both faculty and students at all levels of undergraduate and graduate study from the member universities, as well as across and beyond Europe. Overall, CIRCULAR IN PLAY hosted 91 participants with students from 13 universities in 11 countries. To prepare the students for the GBL applications and context, the challenges were preceded by short films and introductory presentations about sustainability and the CE and ice-breaker questions intended to emphasize the diverse profiles and understandings in the audience.



Source: Project archive; figure created by authors

Figure 2. The products of the circular infographics design workshops

In the gamification challenges of 3VIA 2022 and R-Express, the participants were evaluated based on their accuracy and response time while acquiring basic knowledge about the CE. In the serious games of ScapeRoom and R-Express, the teamwork challenge and proposed solutions for the reduction, reuse and recycling of waste that they identified in their daily life were assessed through short presentations from the teams, followed by a collaborative discussion session involving both the students and the participating universities' professors and researchers. Each workshop earned the participants an activity certificate and digital EELISA badges consisting of different SDGs and EELISA impact levels – a novel EELISA recognition framework that feeds into the GBL value of the project setting (Waite *et al.*, 2024; EELISA, 2022).

4.2 Relevance to game-based learning characteristics

The relevance of the CIRCULAR IN PLAY workshops to the GBL characteristics was assessed through the compiled responses of the informed survey respondents. Because the majority of survey respondents partook in fewer than four of the workshop types in question, the coding of data involved the responses only for the workshops involved to rule out response bias and the resulting sums were normalized to enable comparison across different workshops (Table 3). The responses collected indicate the existence of all GBL characteristics except digital immersion, as enriched realities were not incorporated in the case project design.

Table 3. CIRCULAR IN PLAY project activities' compliance with the GBL characteristics

GBL criteria	3VIA 2022 (gamification) $N = 24$, $n = 13$	ScapeRoom (serious games) $N = 25$, $n = 14$	R-Express (gamification and serious game) $N = 17$, $n = 10$	Circular infographics (storytelling) $N = 10$, $n = 10$
Learning support				
Tutorial	92.3	85.7	80.0	80.0
Support	46.2	57.1	70.0	90.0
Challenge/variability	84.6	71.4	90.0	30.0
Assessment				
Reward	76.9	78.6	90.0	40.0
Penalty	46.2	50.0	60.0	20.0
Feedback	84.6	71.4	80.0	30.0
Learner control				
Control over gameplay	23.1	35.7	40.0	60.0
Game choice	30.8	35.7	20.0	20.0
Immersion				
Sensory element	76.9	64.3	70.0	30.0
Digital immersion	N/A	N/A	N/A	N/A
Interaction				
Collaboration	53.8	85.7	100.0	100.0
Competition	100.0	85.7	80.0	10.0
Other communication	46.2	57.1	60.0	50.0
Narrative				
Storyline/game cohesion	23.1	28.6	20.0	50.0

Note: The values are percentages
Source: Table created by authors

In interpretation of participant perceptions of workshops regarding GBL categories, all four workshops were particularly strong in learning support and interaction, thanks to effective moderation and facilitation by challenge organizers and the ability to work in smaller teams. These were followed by the assessment category for the gamification and serious games challenges. Upon closer examination, the data obtained indicate that with the highest median (70%) and average (61.4%) scores, R-Express, the only workshop that used two different GBL approaches, corresponded to GBL the most broadly, closely followed by ScapeRoom, which used two serious games in one workshop. In other words, serious games complied with the GBL characteristics more than gamification challenges thanks to their highly collaborative setting, while the two GBL approaches proved to be more effective than the alternatives when combined in a challenge. Multiple methods of gamification appear to be advantageous in support and collaboration, whereas gamification in trivia form alone is more strongly aligned with instant feedback, sensory element and competition. Circular infographics workshops, which used storytelling and/or narration, are relatively weakly associated with GBL characteristics due to their noncompetitive and relatively rigid structure (ref. game choice) and lack of penalties, although they are strong in collaboration, support and tutorial characteristics. Furthermore, all four infographics design facilitators and the five infographics supervisors who responded to the survey emphasized the strength of the circular infographics workshops in terms of enhanced learning support due to the highly research-driven structure of the storytelling and graphic design processes.

An examination of collected responses regarding GBL characteristics highlights learning support, interaction and assessment as the leading categories for the case workshops, with average category scores of 73.1%, 69% and 60.6%, respectively. In particular, tutorial is the only characteristic in the higher quartile for all workshops, as the participants were provided with prechallenge instructions and in-game directions as necessary. However, some survey respondents stated that the challenge tutorials could have been conveyed in a more efficient way through more thorough in-game verbal instructions for participants who needed them. Tutorial is followed by collaboration and competition in the interaction category, which held the highest relevance of characteristics per individual workshops. Reward was another significant category for responders because of the point-scoring in gamification challenges as well as the EELISA credentials and activity certificates all participants were awarded upon completion of the workshops. Respondents generally evaluated the trivia used in 3VIA 2022 and R-Express as particularly rewarding for the participants because the scores were delivered instantly during the game and thus increased participant engagement and motivation.

On the contrary, all workshops demonstrated low relevance to the learner control category. The workshop organizers emphasized avatar choice and customization in the gamification toolkit as a positive incentive that attracted students' attention in the game and the two project coordinators from ITU and UPM and one supervisor described the self-identification of the themes and tasks in the research and design aspects of the circular infographics as a good example of control over gameplay. Narrative stands out for its low relevance as well because of the intended scope/styles across different workshop types: unlike the circular infographics design workshops, the open workshops of the case project did not target a specific storyline or game cohesion. However, one participant who participated in designing all open workshops likened narrative to a journey and favored the serious game design of R-Express:

> From my point of view, the R-express is the game that better fits the narrative criteria, since it was designed from the beginning with a 'journey' that takes you from one board to another in mind.

Another survey participant, pointing to the overarching narrative flow from the open workshops to the subsequent infographics workshops, praised the CIRCULAR IN PLAY setup, in which interested participants furthered diverse CE ideas from an open workshop in an alternative and more advanced form.

It is interesting to note that the circular infographics workshops held either the lowest or highest relevance to GBL characteristics in comparison to other workshops showcasing gamification or serious games. This is an expected outcome because of their limited participant structure, longer activity duration and more in-depth challenge context. In particular, these workshops were found to be strong in support and collaboration, thanks to the presence of supervisors and graphic design facilitators and the effective team work maintained throughout multiple virtual meetings and background work in week-long workshops. On the contrary, they were found to be relatively weak in challenge, variability and immersion due to a lack of game levels and playful sensory elements, in penalty because of a lack of negative reinforcement tactics and in competition due to a lack of any contest pitting teams simultaneously working on different infographics themes against one another. In their elaborated assessments, the survey participants did not show a significant preference for gamification, serious games and storytelling approaches in terms of collaboration styles (i.e. competition, goal, task or moderation types), implying that in learning CE, there are benefits to all approaches to collaboration and learning, however different they may be.

4.3 Game setting determinants: international, interdisciplinary and online

Among the three game environment characteristics that all workshops held, internationality and interdisciplinarity were favored by the survey participants, with different perceptions of and views regarding the online conduct. In line with EELISA's and thus the Circular EELISA Community's international and interdisciplinary focus, these two aspects were viewed to be sufficiently reflected in the case workshops by all respondents, especially considering that participants from a total of 11 countries attended the project's workshops. Not only the student and moderator groups during workshops but also the challenge organizing teams reflected on the international and interdisciplinary nature of the workshops. The overall coordinator of the project viewed this as a challenge in managing the workshop design process but found it useful for increasing the scope and originality of the challenges designed and reinforcing the anticipated diversity in university collaboration. In terms of internationality, the respondents unanimously disagreed with the proposition that restricting the geographical focus of participants (e.g., only Europe or the four organizing universities) would yield better results in terms of GBL characteristics and workshops' success. In terms of interdisciplinarity, one criticism that arose concerned the "inevitable oversimplification" of the workshop context due to participants' broad disciplinary backgrounds; also noted was that restricting the disciplines of participants (e.g., to only water resources–related engineering fields) might have been more effective in designing richer contexts and increasing participant interaction. Another challenge organizer suggested a contrary view: that the focus was, or should be, on internationality rather than interdisciplinarity in alliances such as EELISA, and that enabling the widest participation from all backgrounds and locations possible thus surpassed the concerns above. A workshop coordinator supported this view, claiming that heterogeneity in participant profiles generated added value to group activities, as had been the case in all CIRCULAR IN PLAY workshops, adding that this was the case:

> […] as long as the level of technical knowledge necessary for participation is not very high, and more so taking into account that the objective of the game is not to increase technical knowledge, but rather to work on the development of personal social, civic and sustainability competencies related to the CE. (also see Waite *et al.*, 2024).

The fact that all workshops were organized and conducted online drew more mixed views from survey participants, whose concerns focused on the workshop participation and participants. Considering the need for internationality, online workshops were found to be undoubtedly effective in attracting high participation due to the bypassed financial, temporal and practical concerns of international physical mobility. As most of the respondents pointed out, today's online tools used in challenges are advanced enough to accommodate successful remote learning activities. However, one respondent suggested that despite the advantages of online conduct, in-person interactions could yield better communication and information exchange among participants, which is among the main objectives of the EELISA communities. One respondent stated that although in person workshops would provide better results particularly in serious games and storytelling, they would result in limitations on the geographical range and/or the number of participants, whereas another claimed that "with good tools and good management of those tools, participants' performance can be maximized whether online or in person."

5. Discussion: game-based learning-based assessments for collaborative education activities with a circular economy focus

As in all contexts examined in the case study, games are mostly associated with having fun (Prensky, 2001). In 3VIA 2022 and R-Express, fast-paced challenges in a trivia game format allowed for an uplifting and motivating workshop setting. Competitive trivia games elicited participants' attention throughout the game. In today's social media-dominated world, where attention-focused characteristics such as sensory elements, rewards and game choice are increasingly sought by users, exploring ways to incorporate these elements into serious games and even storytelling can improve GBL performance (Shen *et al.*, 2009), particularly for international and interdisciplinary audiences who do not know each other and meet online. Continuation of a narrative across successive activities also appeared to motivate participants through familiarity and continuous self-development. These approaches can be traced in the cases from around the world adopting COIL as well, with culturally diverse students (Hackett *et al.*, 2023).

Relevance to fewer GBL characteristics does not necessarily mean that the game-based activity is ineffective or insufficient (Abdul Jabbar and Felicia, 2015). The number of targeted characteristics depends on the aim and expected outcomes of the activity, and what matters when there is compliance with fewer characteristics is a high level of relevance for the targeted criteria. Circular infographics design workshops are a good example of this with their successful deliverables: for noncompetitive and highly collaborative workshops, storytelling or narration is an effective GBL approach, as evidenced by the workshop deliverables. Activities showcasing a high number of GBL characteristics with low level of relevance may appeal to a larger audience or one with diverse expectations; however, they may be more effective if they focus on emphasizing certain characteristics among a larger variety. The case study demonstrated that a combination of multiple GBL approaches and methods were more effective than a single-method approach, with the downside being that it took more effort to design and conduct a more complex challenge.

In all workshops, the collaborative element was a particular advantage for participants, because while they collaborated to solve challenges and steer discussions, the participants

were immersed in multicultural and multidisciplinary interaction and learning. Likewise, the immersion experience was enriched in the case workshops through engagement. Thus, the international collaboration spirit of EELISA appeared to be successfully reflected in the participants, who communicated their ideas fluently on common contextual grounds and despite differences in their locality. Emphasizing the multiculturalism and cultural diversity of the audience and encouraging them to develop diverse CE solutions corresponding to their different backgrounds can be a good strategy for helping participants to appreciate disciplinary diversity as well, as a sentiment that aligns with the aim of establishing a social-constructivist educational approach to collaborative online learning (Guth and Rubin, 2015). In this sense, results of the case study argue against strict restrictions on the internationality and interdisciplinarity of the workshops.

Likewise, in the three workshops, working in groups in smaller rooms allowed for higher and more effective interaction between students and challenge moderators, where they could more easily exchange and generate ideas or perspectives. In the circular infographic workshops where small work groups were defined from the beginning according to the CE themes they preferred, the increased intimacy and focus added an alternative interaction and learning environment for the interested students, as well as the supervisors and design facilitators, supporting the idea that group efficacy in students' learning achievements and awareness of problem-solving increases in well-defined groups (Sung and Hwang, 2018). Thus, in highly diverse settings of European university alliances such as EELISA, group-based GBL activity design may prove to be more successful than mass or individual gaming activities. This premise inherently applies to international education alliances, networks and programs outside of Europe, where international and interdisciplinary university collaborations focusing on universal concepts such as CE seek similar educational diversity and outcomes.

The circular infographics design series also allowed students and researchers to look for CE topics that were not covered in previous workshops. With the help of storytelling, the participants explored alternative methods of research and representation in conveying their ideas and arguments. The participants were perceived to be content to produce solid outcomes from the activity – with their names on the infographics – and incorporate them into their portfolios and online channels, in addition to the EELISA badges they earned toward building credentials supporting their higher education degree (EELISA, 2022). It was suggested that for longer activities such as week-long infographics workshops, in-person conduct rather than online may yield more effective outcomes thanks to increased interaction, immersion and learner control.

6. Conclusions

The findings of this study offer insights for the integration of CE within broader higher education collaborations, particularly in international, interdisciplinary and online settings. Among the GBL characteristics compiled in this study, the case-oriented results underscore the importance of incorporating tutorials and challenges to bolster learning support, implementing rewards and real-time feedback mechanisms to enhance performance assessment, leveraging sensory elements to heighten learner immersion, using collaboration and competition to foster interactive engagement and crafting creative storylines to enrich the narrative dimension of educational experiences. These findings can be used in fields other than engineering and serve as a roadmap for educators and institutions – not only in higher education but also in the industry – seeking to cultivate CE competences within diverse educational contexts, ultimately contributing to the advancement of sustainability initiatives on a global scale.

The higher education ideal of the EU in launching the European Universities Initiative encompasses all relevant international networks and alliances in adopting higher education quality standards and corresponding contemporary methodologies. In the near future, with its solid outcomes apparent in diverse settings and fields, GBL may further prove to be an effective approach to achieving this aim. This study focuses on a GBL-based case project produced within the EELISA framework. Similar research involving a comparative and holistic investigation of all relevant educational alliances in Europe may be useful in improving European educational quality ideals. Adding to this the global ideals of sustainability and a CE, future research on the ways in which sociocivic and green competences influence the wider shift to CE would be effective in improving the greater European community as well as local contexts in diverse European settings. Finally, adoption of a similar research agenda beyond Europe is imperative for the global achievement of this shift and international and interdisciplinary learning environments.

Acknowledgements

The CIRCULAR IN PLAY project was funded by the EELISA Joint Interinstitutional Activities call within the framework of the EELISA European University project, supported by the European Union's Erasmus+ program under GA No. 101004081. The project is also a product of and the Circular and Socio-Civic Learning Hub (CIRC.LE) project, which is also supported by the Erasmus+ programme under GA No. 2021-1-ES01-KA220-HED-000030418. The authors would like to thank the participants and organizers of the project's six educational workshops, without whom this study would not have been possible. They would also like to thank EELISA, CIRC.LE and the Circular EELISA Community for enabling international collaborations to train European engineers in the fields of sustainability and circularity. The European Commission's financial support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the National Agency and Commission cannot be held responsible for any use which may be made of the information contained therein.

References

Abdul Jabbar, A.I. and Felicia, P. (2015), "Gameplay engagement and learning in game-based learning: a systematics review", *Review of Educational Research*, Vol. 85 No. 4, pp. 740-779, doi: 10.3102/0034654315577210.

Andreoni, V. and Richard, A. (2023), "Exploring the interconnected nature of the sustainable development goals: the 2030 SDGs game as a pedagogical tool for interdisciplinary education", *International Journal of Sustainability in Higher Education*, doi: 10.1108/IJSHE-11-2022-0378.

Appiah-Kubi, P. and Annan, E. (2020), "A review of a collaborative online international learning", *International Journal of Engineering Pedagogy (IJEP)*, Vol. 10 No. 1, pp. 109-124, doi: 10.3991/ijep.v10i1.11678.

Arruda, E.H., Melatto, R.A.P.B., Levy, W. and Conti, D.M. (2021), "Circular economy: a brief literature review (2015–2020)", *Sustainable Operations and Computers*, Vol. 2, pp. 79-86, doi: 10.1016/j.susoc.2021.05.001.

Bado, N. (2022), "Game-based learning pedagogy: a review of the literature", *Interactive Learning Environments*, Vol. 30 No. 5, pp. 936-948, doi: 10.1080/10494820.2019.1683587.

Budiul Berghian, A., Lupu, O., Socalici, A. and Birtok Baneasa, C. (2021), "Harnessing the ferrous sludge resulting from steel industry in the context of the circular economy", *U.P.B. Science Bulletin, Series B*, Vol. 83 No. 4, pp. 241-250.

Deterding, S., Sicart, M., Nacke, L., O'Hara, K. and Dixon, D. (2011), "Gamification. Using game-design elements in non-gaming contexts", CHI '11 Extended Abstracts on Human Factors in Computing Systems, p.2425-2428, doi: 10.1145/1979742.1979575.

EELISA (2022), "The EELISA credential is already a reality", available at: www.eelisa.eu/eelisa-credential/ (accessed 12 August 2023).

EELISA (2023), "EELISA brochure", available at: www.eelisa.eu/what-is-eelisa/ (accessed 8 August 2023).

Fowler, F.J. (1995), *Improving Survey Questions: Design and Evaluation*, Sage.

Guth, S. and Rubin, J. (2015), "Collaborative online international learning: an emerging format for internationalizing curricula", in Moore, A. and Simon, S. (Eds), *Globally Networked Teaching in the Humanities: Theories and Practices*, Routledge, pp. 15-27. ISBN 978-1-138-80152-3.

Hackett, S., Janssen, J., Beach, P., Perreault, M., Beelen, J. and van Tartwijk, J. (2023), "The effectiveness of collaborative online international learning (COIL) on intercultural competence development in higher education", *International Journal of Educational Technology in Higher Education*, Vol. 20 No. 1, doi: 10.1186/s41239-022-00373-3. Article No. 5.

Hellerstedt, A. and Mozelius, P. (2019), "Game-based learning: a long history. 1", available at: www.urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-37524 (accessed 20 August 2023).

Jaaska, E., Aaltonen, J. and Kujala, J. (2021), "Game-based learning in project sustainability management education", *Sustainability*, Vol. 13 No. 15, p. 8204, doi: 10.3390/su13158204.

Kalogiannakis, M., Papadakis, S. and Zourmpakis, A.-I. (2021), "Gamification in science education. A systematic review of the literature", *Education Sciences*, Vol. 11 No. 1, p. 22, doi: 10.3390/educsci11010022.

Kapp, K.M. (2012), *The Gamification of Learning and Instruction Game-Based Methods and Strategies for Training and Education (Online-Ausg)*, Pfeiffer.

Khaldi, A., Bouzidi, R. and Nader, F. (2023), "Gamification of e-learning in higher education: a systematic literature review", *Smart Learning Environments*, Vol. 10 No. 1, p. 10, doi: 10.1186/s40561-023-00227-z.

Khoury, M., Evans, B., Chen, O., Chen, A.S., Vamvakeridou-Lyroudia, L., Savic, D.A., Djordjevic, S., Bouziotas, D., Makropoulos, C. and Mustafee, N. (2023), "NEXTGEN: a serious game showcasing circular economy in the urban water cycle", *Journal of Cleaner Production*, Vol. 391, p. 136000, doi: 10.1016/j.jclepro.2023.136000.

Lange, K.P.H., Korevaar, G., Oskam, I.F. and Herder, P.M. (2022), "Re-organise: game-based learning of circular business model innovation", *Frontiers in Sustainability*, Vol. 3, p. 809700, doi: 10.3389/frsus.2022.809700.

Manshoven, S. and Gillabel, J. (2021), "Learning through play: a serious game as a tool to support circular economy education and business model innovation", *Sustainability*, Vol. 13 No. 23, doi: 10.3390/su132313277.

Nadolny, L., Valai, A., Cherrez, N.J., Elrick, D., Lovett, A. and Nowatzke, M. (2020), "Examining the characteristics of game-based learning: a content analysis and design framework", *Computers and Education*, Vol. 156, p. 103936, doi: 10.1016/j.compedu.2020.103936.

Naicker, A., Singh, E. and van Genugten, T. (2022), "Collaborative online international learning (COIL): preparedness and experiences of South African students", *Innovations in Education and Teaching International*, Vol. 59 No. 5, pp. 499-510, doi: 10.1080/14703297.2021.1895867.

Nie, H., Xiao, H.M. and Shang, J.J. (2014), "A critical analysis of the studies on fostering creativity through game-based learning", in Cheung, S.K.S., Fong, J., Zhang, J., Kwan, R. and Kwok, L.F. (Eds.), *Hybrid Learning. Theory and Practice*, Springer International Publishing, pp. 278-287, doi: 10.1007/978-3-319-08961-4_26.

Plass, J.L., Homer, B.D. and Kinzer, C.K. (2015), "Foundations of game-based learning", *Educational Psychologist*, Vol. 50 No. 4, pp. 258-283, doi: 10.1080/00461520.2015.1122533.

Plass, J.L., Mayer, R.E. and Homer, B.D. (2019), *Handbook of Game-Based Learning*, MIT Press eBooks.

Prensky, M. (2001), "Fun, play and games: what makes games engaging", in Prensky, M. (Ed.), *Digital Game-Based Learning*, McGraw-Hill, pp. 16-47.

Shen, C., Wangi, H. and Ritterfeld, U. (2009), "Serious games and fun games: can they be one and the same?", in Ritterfeld, U., Cody, M. and Vorderer, P. (Eds), *Serious Games: Mechanisms and Effects*, Routledge, pp. 48-61.

Stanitsas, M., Kirytopoulos, K. and Vareilles, E. (2019), "Facilitating sustainability transition through serious games: a systematic literature review", *Journal of Cleaner Production*, Vol. 208, pp. 924-936.

Sun, L., Kangas, M. and Ruokamo, H. (2023), "Game-based features in intelligent game-based learning environments: a systematic literature review", *Interactive Learning Environments*, pp. 1-17, doi: 10.1080/10494820.2023.2179638.

Sung, H.Y. and Hwang, G.J. (2018), "Facilitating effective digital game-based learning behaviors and learning performances of students based on a collaborative knowledge construction strategy", *Interactive Learning Environments*, Vol. 26 No. 1, pp. 118-134, doi: 10.1080/10494820.2017.1283334.

Valdés, R.M.A. and Comendador, V.F.G. (2022), "European universities initiative: how universities may contribute to a more sustainable society", *Sustainability*, Vol. 14 No. 1, p. 471, doi: 10.3390/su14010471.

Waite, I.A., Pacios Álvarez, A., Martín Bautista-Cerro, B. and García Navarro, J. (2024), "Circular economy competencies in international higher education settings: a methodological assessment based on digital activity recognition", in García-Peñalvo, F.J., Sein-Echaluce, M.L., Fidalgo-Blanco, Á. (Eds), *Innovation and Technologies for the Digital Transformation of Education: European and Latin American Perspectives*, Springer Link, pp. 275-284, doi: 10.1007/978-981-97-2468-0_27.

Whalen, K.A., Berlin, C., Ekberg, J., Barletta, I. and Hammersberg, P. (2018), "All they do is win': lessons learned from use of a serious game for circular economy education", *Resources, Conservation and Recycling*, Vol. 135, pp. 335-345, doi: 10.1016/j.resconrec.2017.06.021.

Further reading

European Commission (2023), "European universities initiative", European Education Area: Quality education for all, available at: www.education.ec.europa.eu/education-levels/higher-education/european-universities-initiative#action (accessed 1 September 2023).

Frame, A. and Curyło, B. (2022), "Bringing Erasmus home: the European universities initiative as an example of 'Everyday Europeanhood'", *Journal of Contemporary European Studies*, Vol. 32 No. 2, doi: 10.1080/14782804.2022.2134986.

About the authors

Lacramioara Diana Robescu is currently a Professor at the Faculty of Energy Engineering at the National University of Science and Technology Politehnica Bucharest (NUSTPB), where she received her MS and PhD. She earned her habilitation in 2016. She managed as (co-)principal investigator 16 research projects, and two projects involving the institutional development for improving quality assurance and students' skills. She was a member of the scientific committees of different national and international conferences. Her academic activity includes 12 books and more than 120 publications in national and international conference proceedings and journals. She is also the coauthor of three patents indexed in the DWPI.

Imge Akcakaya Waite is currently an Associate Professor in the Department of Urban and Regional Planning at Istanbul Technical University (ITU). She received her BS and MS degrees in

urban planning at ITU and her PhD in urban planning from University of California, Los Angeles (UCLA) with her dissertation entitled "Planning, power, politics: Urban redevelopment in Istanbul." She has participated in EU, UN-Habitat and other internationally and nationally funded research and training projects in institutional and community capacity building, urban and rural governance, sociospatial inclusion, collaborative and participatory planning and circular competence. She has (co-)authored over 50 publications at the intersection of these areas and various planning and education contexts. Imge Akcakaya Waite is the corresponding author and can be contacted at: imgeawaite@itu.edu.tr

Aysegul Akcay Kavakoglu is an architect and Associate Professor in the Department of Landscape Architecture at ITU. Her research interests include design process, computational design, fabric formwork, representation and moving image studies. She graduated from Dokuz Eylül University with a BA degree. She conducted her master studies at Middle East Technical University (METU) and Ecole Nationale Supérieure d'architecture de Paris-Belleville. She received her PhD in architecture from METU, researching the contribution of moving images to the computational design process. She has worked on various architectural design projects and received awards in national architecture competitions.

Diana Mariana Cocarta obtained her BS in environmental engineering and MS in energy generation environmental impact from NUSTPB, where she currently works as a professor. In 2007, she achieved PhDs in energy engineering from NUSTPB (Magna Cum Laude) and in environmental engineering from the University of Trento, Italy. She earned her habilitation in Italy (Italian National Scientific Habilitation/ASN-08/A2 – Associate Professor) in 2020 and in Romania in 2022. She has (co-) authored 12 books and more than 90 publications in IDB- and ISI-indexed journals and conferences. She has managed eight national and international projects.

Liana Ioana Vuta is an Associate Professor at the Faculty of Energy Engineering at NUSTPB. She received her BS in Hydropower and Environmental Engineering, MS in energy generation environmental impact, and PhD in energy engineering at the same university. She has been involved in over 12 R&D and educational projects and the (co-)author of more than 50 scientific papers and books. Her present focus is on the sustainable development of water resources and hydropower, the role of reservoirs in water resource management and the environmental impacts of hydropower projects.