

Learning by Game Design: An Interdisciplinary Framework for Participatory and Innovative Higher Education

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Abstract: *Learning by Game Design* is an interdisciplinary teaching innovation project developed at the University of Parma, Italy. It integrates game design into higher education as a structured pedagogical methodology rather than as an occasional motivational device. Beginning with a critique of traditional university teaching — which often struggles to sustain engagement, inclusion, accessibility, and active participation — the project frames game design as a learning environment that enables complex thinking, collaboration, and the use of multiple forms of representation, in line with active learning and Universal Design for Learning principles. Built around a multidisciplinary team spanning entomology, citizen science, economics, law and data protection, game science, and cultural heritage education, the project aims to build a scalable and transferable model for university teaching. The paper describes the project architecture, reports on an exploratory pilot implementation in a Citizen Science course and its subsequent extension to three further courses in economics, data science, and cultural heritage education, and discusses implications, limitations, and future validation needs for participatory pedagogy, interdisciplinary curriculum design, and the use of analog games in citizen science contexts.

Keywords: Learning by game design, Game making in higher education, Interdisciplinary teaching innovation, Participatory pedagogy, Citizen science education

1. Introduction

University teaching faces persistent structural challenges: declining student engagement, limited inclusion of diverse learning needs, and difficulty in fostering active participation and transversal competences. These observations are not new, but they remain unresolved in many higher education contexts, where transmissive instructional models continue to dominate despite decades of research advocating for more participatory approaches (Bonwell & Eison, 1991; Freeman et al., 2014).

Against this background, a growing body of literature has investigated the potential of games and game-based learning (GBL) to enhance engagement, motivation, and learning outcomes in formal educational settings (Gee, 2003; Prensky, 2001). However, much of this research focuses on games as finished products rather than on game design itself as a pedagogical process. A distinct and arguably richer strand of work, grounded in constructionist theory (Papert & Harel, 1991), positions the act of making games as a particularly powerful learning experience — one that activates complex thinking, collaboration, creative expression, and metacognitive reflection (Kafai & Burke, 2015).

This paper presents Learning by Game Design, an interdisciplinary teaching innovation project developed at the University of Parma that draws on this constructionist tradition. The project frames game design not as an occasional motivational device, but as a structured pedagogical methodology capable of addressing the limitations of conventional university teaching and creating bridges across disciplinary boundaries. The paper is organised as follows: Section 2 situates the project within relevant theoretical frameworks; Section 3 describes the project architecture and its multidisciplinary team; Section 4 reports on the pilot implementation within a Citizen Science course and its extension to three further courses; Section 5 discusses results, implications, and limitations; and Section 6 outlines future directions and conclusions.

2. Theoretical Background

2.1 Active Learning and Constructionism

The shift from passive to active learning in higher education has been extensively theorised and empirically supported. Active learning approaches — in which students engage in meaningful activities and reflect on what they are doing — consistently outperform traditional lecture-based instruction on measures of conceptual understanding, skills development, and long-term retention (Freeman et al., 2014; Prince, 2004). Within this broad paradigm, constructionist theory (Papert & Harel, 1991) offers a particularly compelling account of how learning happens through the creation of shareable artefacts. When learners construct something — a model,

a story, a game — they are not merely applying knowledge but generating it, externalising it, and submitting it to social scrutiny.

Game design is a paradigmatic constructionist activity. Designing a game requires makers to articulate the rules, roles, constraints, and goals of a system; negotiate these with collaborators; and test them through iterative play. Each of these steps involves complex cognitive operations — abstraction, formalisation, and feedback interpretation — as well as communicative and collaborative competences that are central to contemporary conceptions of learning (Kafai & Burke, 2015; Salen & Zimmerman, 2004).

2.2 Universal Design for Learning and Inclusion

A second theoretical pillar of the project is Universal Design for Learning (UDL), a framework that advocates the proactive design of flexible learning environments able to accommodate learner diversity (CAST, 2018). UDL emphasises multiple means of representation, action and expression, and engagement — precisely the dimensions that game design naturally activates, given its simultaneous reliance on visual, spatial, verbal, and procedural languages. Game design is therefore not only a constructionist tool but also an inclusive one, capable of reaching students who may not thrive in conventionally text-heavy academic settings.

2.3 Game-based Learning and Game Making

Research on GBL in higher education has accumulated substantial evidence that well-designed games can improve engagement, motivation, and domain learning across a variety of disciplinary contexts (Gee, 2003; Plass, Homer, & Kinzer, 2015). Escape rooms, in particular, have attracted growing attention as a game-based format for education across disciplines, with systematic reviews documenting their potential to foster active learning, problem-solving, and collaboration (Veldkamp et al., 2020). Our own prior work in this area demonstrated that collaborative game play significantly outperforms individual play in terms of both learning performance and engagement indicators, including behavioural and neurophysiological measures collected within a museum-based escape game experiment involving 118 secondary school students (Bisanti et al., 2022). These results confirmed the role of collaboration as a key driver of learning in game contexts, a finding that informs the co-design emphasis of the present project.

Moving from playing to designing games introduces an additional layer of pedagogical value. Kafai and Burke (2015) describe constructionist game making as an approach through which learners simultaneously acquire content knowledge, develop design skills, and gain insight into the learning process itself. Applied to higher education, this suggests that asking students to design a game about a topic is not merely an engaging activity but a diagnostic and generative one: it reveals what students understand and where gaps remain, surfaces misconceptions, and creates occasions for collaborative sense-making.

2.4 Games for Social Change

A further theoretical lens for this project is the framework of Games for Social Change, which understands games as communicative artefacts capable of raising awareness, challenging preconceptions, and supporting attitudinal and behavioural change (Mariani, 2014). This framework becomes especially relevant when game design is applied within citizen science contexts, where participation is not only cognitive but also social and civic. Designing a game about citizen science mobilises reflective processes that extend beyond content learning and touch on questions of participation, agency, and civic responsibility.

3. The Learning by Game Design Project

3.1 Institutional Context and Project Architecture

Learning by Game Design was developed within the University of Parma's institutional support programme for group projects on innovative teaching and the development of teaching professionalism (Action 2). The project addresses the macro-theme of innovative teaching methods and learning environments, with a specific focus on design methods and technologies for teaching mediation.

The project's core assumption is that game design, when embedded in a carefully structured pedagogical framework, can support deeper participation, foster transversal competences, and create bridges across disciplinary boundaries. Rather than collecting isolated good practices, the project aims to build a scalable and transferable model for university teaching — one that can be adapted across different disciplinary contexts and institutional settings.

3.2 The Multidisciplinary Team

A distinctive feature of the project is its genuinely multidisciplinary team composition. Members bring together expertise in ethology, entomology and environmental monitoring, citizen science, behavioural economics, game theory, game science, private law and data protection, and games and cultural heritage education. This diversity reflects the project's conviction that designing learning activities through game design requires the integration of different disciplinary languages. The team's interdisciplinary composition is itself a model for the kind of collaborative, boundary-crossing work that the project aims to foster among students.

3.3 Phased Implementation

The project is structured around a phased implementation model. The first phase centres on training through workshops on game design principles and active pedagogy, followed by interdisciplinary co-design sessions among the participating instructors. A pilot implementation was developed within a Citizen Science course (described in Section 4.2), and the format has since been extended to three further courses --- Economics of Globalisation, Sensitive Data Treatment, and Cultural Heritage and Museum Education --- described in Section 4.4. The final stages, still to be completed, include systematic impact evaluation and dissemination through guidelines, an operational toolkit, and open educational resources.

4. Pilot Implementation and Extension Across Disciplinary Contexts

4.1 Research Design and Data Collection Approach

At this stage, the Learning by Game Design project is best understood as a feasibility and process-oriented pilot rather than as a controlled or fully instrumented empirical study. Its purpose is to test whether game design can function as a viable pedagogical activity across disciplines and to observe, directly, what the design process reveals about student understanding, rather than to produce generalisable outcome measures. Accordingly, none of the implementations reported below used pre/post questionnaires, standardised learning measures, or control conditions. Data consist of (i) facilitator field observations taken during the sessions, and (ii) the design artefacts produced by students themselves — rule sets, prototypes, and presentation materials. Analysis is qualitative and interpretive, based on close reading of these artefacts and on facilitator reflection, consistent with design-based and constructionist research traditions in which the artefact is treated as a primary unit of analysis (Papert & Harel, 1991). This is a deliberate methodological choice at an early project stage; Section 5.4 discusses the limitations that follow from it and the steps planned to address them.

4.2 The Citizen Science Pilot: Course and Participants

The first pilot implementation took place within “Citizen Science: New Approaches and Tools for Integrating Scientific Research and Society,” a transversal elective course in the Bachelor’s degree (Laurea Triennale) in Natural and Environmental Sciences at the University of Parma, taught in Italian in the first semester. Fifteen students were enrolled in the course; eight took part in the pilot activity itself, held in November 2025 across two two-hour sessions, and worked in two small design groups.

The first session began with a short theoretical introduction to game studies and gamification, drawing on key conceptual distinctions from the literature — including the definition of play as the voluntary attempt to overcome unnecessary obstacles (Suits, 1978) and the understanding of a game as a system in which players engage in an artificial conflict defined by rules and resulting in a quantifiable outcome (Salen & Zimmerman, 2004). This framing was immediately followed by a practical activity: students played and discussed selected board games, attending not only to the experience of play but also to the mechanics, rules, and design choices underlying them.

The second session shifted entirely to co-design. Students were asked to design a board game about citizen science: to formulate an idea, define rules and develop mechanics. The facilitator’s role was to prompt reflection rather than provide answers — to ask questions about design choices, to surface tensions between what the game implied and what citizen science actually involves, and to use the design process as a lens for making participation dynamics visible.

4.3 The Citizen Science Pilot: Outcomes

The pilot produced two rough prototypes: “Missione Citizen Science,” a trivia-style game organised around four thematic areas of citizen science (biodiversity, climate, health, and space/technology), and “EcoQuest,” a Munchkin-inspired card game in which players take on the role of citizen scientists collaborating against

environmental threats. From a design standpoint, these were early-stage artefacts, far from playable in a refined sense. Their value, however, lay not in their level of finish but in what they revealed.

The trivia game reproduced a transmission model of knowledge — a quiz format that implicitly framed citizen science as a body of facts to be learned rather than as a practice to be engaged in. The Munchkin-like game introduced roles, competition, and uncertainty, but struggled to represent the collaborative and contributory dimensions of citizen participation. These limitations made visible aspects of citizen science that students had not yet fully integrated: the distinction between data collection and collective sense-making, the importance of motivation and belonging in sustaining participation over time, and the tension between individual contribution and community goals.

This is consistent with the constructionist framing, and resonates with our earlier findings on collaborative escape games, which showed how the game context can reveal and address gaps in domain knowledge in ways not available through conventional instruction (Bisanti et al., 2022).

4.4 Extension to Further Courses

Following the pilot, the same format — a short theoretical framing followed by a co-design session — was adapted and delivered in three further courses during the second semester of the 2025/2026 academic year, extending the experimentation beyond citizen science into economics, data science, and cultural heritage education (Table 1).

Table 1: Overview of course-based implementations of the Learning by Game Design format

Course	Degree Programme	Language	Period	N. Enrolled	N. Involved
Citizen Science	BA, Natural and Environmental Sciences	Italian	Nov. 2025	15	8
Economics of Globalisation	BA, Economics and Management	English	Mar. 2026	72	30
Sensitive Data Treatment	MA, Data Science	English	Feb. 2026	90	40
Cultural Heritage and Museum Education	BA, Educational Sciences	Italian	Feb.–Mar. 2026	32	~20

In Economics of Globalisation (Bachelor’s degree in Economics and Management, taught in English), thirty students worked in eight groups to design a game addressing a specific concept in international trade theory. Several groups adapted the mechanics of existing commercial games: “Uno Trade Game” reworked UNO’s card play to model comparative advantage and voluntary trade; “H-O Link,” built on Tetris Link, used piece allocation to represent factor endowments in the Heckscher–Ohlin model; and a modified Jenga, “Trade War,” used the game’s collapsing tower to dramatise the cumulative instability produced by retaliatory tariffs. Other groups designed original mechanics, including “Game of Two” (the gravity model of trade) and “Economic Fight Club” (the political economy of protectionism and lobbying). As in the citizen science pilot, the games were of uneven polish, but consistently showed that students could translate abstract theoretical constructs — comparative advantage, factor proportions, strategic interaction — into playable, rule-based systems, suggesting that the diagnostic and generative value observed in the original pilot extends to a substantively different discipline, student population, and course level.

Sensitive Data Treatment (Master’s degree in Data Science, taught in English) was delivered using the same format, involving forty students; systematic analysis of the artefacts produced is still in progress at the time of writing and is not reported here.

In Cultural Heritage and Museum Education (Bachelor’s degree in Educational Sciences, taught in Italian), approximately twenty students produced several prototypes with a marked attention to accessibility and multisensory design: “S.S. Museo,” a collection game in which players learn to recognise an artist’s style and which includes a set of tactile cards; “I Tesorieri delle Memorie Perdute,” a team-based geography game in which groups place heritage-site cards on the correct continent and country using progressive clues; and an unnamed board-game adaptation of a race format built around Parma’s cultural heritage sites, combining tactile word-recognition tasks, collaborative drawing, and embodied activities designed with attention to accessibility for players with sensory or cognitive differences. As with the Economics of Globalisation groups, a systematic analysis of these artefacts is left to future work; they are reported here only to illustrate the range and thematic focus of this extension.

5. Discussion

5.1 Game Design as Shared Pedagogical Language

One of the most significant outcomes of the Learning by Game Design project, even at this early stage, is the emergence of game design as a shared pedagogical language across disciplines. Team members working across entomology, economics, law, game science, and cultural heritage education found in game design a common vocabulary for discussing teaching: rules as learning objectives, mechanics as instructional strategies, players as learners, and feedback loops as formative assessment. This shared language facilitated curriculum co-design conversations that might otherwise have been impeded by disciplinary jargon and institutional silos.

This finding is consistent with design-based research perspectives that emphasise the role of boundary objects — artefacts shared across communities of practice — in supporting interdisciplinary collaboration (Star & Griesemer, 1989). Game designs, as artefacts that can be created, discussed, played, revised, and transferred, function as particularly productive boundary objects in educational innovation contexts.

5.2 Alignment with Institutional and Social Priorities

The project's framework aligns with several priorities that are increasingly prominent in European higher education discourse: interdisciplinarity, inclusion and accessibility (via UDL principles), sustainability (through citizen science applications), social responsibility (through the Games for Social Change framework), and internationalisation (through Erasmus+ connections). These alignments are not coincidental: they reflect a deliberate attempt to situate pedagogical innovation within a broader institutional and social context and to demonstrate that methodological choices in teaching carry implications that extend beyond the classroom.

5.3 Transferability and Scalability

A key design criterion of the project has been transferability — the ability to apply the model across different courses, disciplines, and institutional contexts. The phased implementation plan, teacher training workshops, and planned dissemination toolkit are all aimed at ensuring that the framework is not dependent on the particular composition of the founding team, but can be adopted and adapted by instructors who were not part of the original design process. This concern for scalability distinguishes the project from many GBL initiatives that remain contextually specific and difficult to replicate. The extension to three further courses, reported in Section 4.4, offers an initial test of this transferability claim across disciplines, course levels, and languages of instruction, though its evaluation remains exploratory in the sense discussed below.

5.4 Limitations

The scope of the evidence presented here reflects the project's current stage — an exploratory, process-oriented pilot, as outlined in Section 4.1. Data collection relied on facilitator observation and artefact analysis rather than on structured instruments such as pre/post questionnaires or control conditions; the findings are best read as evidence of feasibility and pedagogical process, within the specific groups involved. The qualitatively analysed sample — the Citizen Science pilot — was small, and participation across all implementations was voluntary rather than randomised. The two most recently delivered courses (Sensitive Data Treatment and Cultural Heritage and Museum Education) are so far reported only in terms of scale (Table 1), pending systematic analysis of their artefacts. Finally, as all implementations to date have taken place within a single university, claims about transferability to other institutional contexts remain to be tested. These are precisely the gaps that the project's next phase, described in Section 6, is designed to close through structured data collection alongside the qualitative approach used so far.

6. Future Directions and Conclusions

Following the Citizen Science course pilot, the Learning by Game Design approach is being extended to two further citizen science contexts. The first is the BUILDERS project, a European initiative on invasive alien species that includes a citizen science component; the second is BioUniversity Parma, a citizen science project focused on biodiversity monitoring on the University of Parma campus. In both cases, the aim is to use analog games and co-design processes not only to sustain participant engagement over time, but also to create games about citizen science itself — artefacts that allow participants to examine the dynamics of participation, the distribution of roles between scientists and citizens, and the conditions under which civic engagement in research becomes meaningful and durable.

Unlike the implementations reported in Section 4, both BUILDERS and BioUniversity Parma are being planned from the outset to include structured data collection: brief pre/post questionnaires on topic knowledge and participation attitudes, and systematic qualitative coding of the design artefacts against a shared rubric, allowing comparison across contexts and a more evidence-based assessment of the framework's impact than was possible at the pilot stage.

The longer-term trajectory of the project includes a connection to the Luna Framework, an Erasmus+ initiative that is developing a simple, accessible system for supporting novices in conceptualising and designing board games. The citizen science game design activities described in this paper will serve as a playtest context for the Luna Framework's tools and guidelines. Major developments in this direction are anticipated for 2027–2028.

The pilot and its implications raise two questions that will guide the project's further development. The first concerns ethics and process: what makes a participatory game design process genuinely inclusive and equitable? Who has a voice in the design process, whose knowledge is validated, and whose perspectives risk being marginalised? These questions are intrinsic to any project connecting game design to citizen science and to the aspiration for social change.

The second question is evaluative: what should we measure beyond engagement? Existing GBL research has prioritised engagement and motivation as outcome variables, partly because they are tractable and intrinsically valued. However, the framework proposed here aspires to outcomes that are more difficult to operationalise: learning, empowerment, and action. Developing appropriate assessment instruments for these outcomes is a priority for the next phases of research.

This paper has presented Learning by Game Design as a structured, interdisciplinary framework for pedagogical innovation in higher education. Drawing on constructionist theory, Universal Design for Learning, and the Games for Social Change tradition, the project positions game design as a learning environment that enables complex thinking, collaboration, and multi-modal representation — not as a motivational overlay applied to pre-existing content. The pilot in the Citizen Science course, and its subsequent extension to three further courses in economics, data science, and cultural heritage education, demonstrated the potential of game design to function as a diagnostic and reflective lens across disciplines, making visible what students understand and where gaps and simplifications emerge. These findings remain exploratory: they rest on facilitator observation and artefact analysis rather than on structured evaluation, a limitation the project's next phase is designed to address. Future work will extend the framework to new citizen science contexts through BUILDERS and BioUniversity Parma, introduce systematic data collection alongside the qualitative approach used so far, and pursue the goal of designing an analog game about citizen science itself, capable of supporting communities, sustaining reflection, and contributing to meaningful participation in research.

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Ethics Declaration: This paper reports on a teaching innovation project and a pilot course activity conducted within the normal scope of university teaching at the University of Parma. The activities described did not involve clinical research, sensitive data collection, or procedures requiring formal ethical clearance. No personal data were collected from participants for research purposes.

AI Declaration: AI tools were used during the preparation of this paper. Specifically, a large language model (Claude by Anthropic) was used to support the revision and editing of the text, including checking for typographical errors, reference consistency, and language quality. All intellectual content, arguments, theoretical framing, and conclusions are the authors' own. The authors take full responsibility for the accuracy and integrity of the work.

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