

Fotonica in Gioco: A Game-Design Contest for Science Communication in Italian High Schools — Results from the Fifth Edition

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Abstract: Game design is increasingly recognized as an effective approach within game-based learning for promoting active engagement with scientific concepts while fostering creativity, collaboration, and problem-solving skills. Fotonica in Gioco is a national contest for Italian upper-secondary schools that invites students to design and prototype educational board games on scientific themes, using game design as a tool for science communication and interdisciplinary learning. The initiative, already presented in previous conferences, has progressively developed into a structured educational activity involving teachers and students in the creation of original tabletop games aimed at translating scientific topics into playable experiences. This work focuses specifically on the fifth edition of the contest (2024–2025), whose theme was “Challenges”, encouraging students to explore contemporary scientific, technological, environmental, and societal issues through game mechanics and narrative design as part of a theory-informed evaluative case study. In this edition, 18 original board-game prototypes were developed by student teams from different Italian schools, addressing a variety of topics such as sustainability, technological innovation, and future global challenges. We briefly outline the structure and educational framework of the contest and summarize the outcomes of the fifth edition. Attention is devoted to the educational value of the game design process, which requires students to research scientific topics, reinterpret them in accessible forms, and integrate them into coherent rule systems and gameplay dynamics. The study also reports results from voluntary post-activity questionnaires completed by 57 students and 10 teachers, investigating engagement, perceived learning outcomes, and attitudes toward both science topics and the creative design process. The results indicate stronger perceived effects on creativity, project management, and teamwork than on formal curricular learning, while also identifying difficulties in time management and rule formalization. These findings contribute to the ongoing evaluation of the initiative and highlight the potential of board-game design contests as tools for science communication and game-based learning in secondary education.

Keywords: Game design based learning, Science communication, STEAM education

1. Introduction

Game-based learning (GBL) is widely recognized as an effective pedagogical framework for fostering engagement, motivation, and active knowledge construction across educational contexts. Within this field, a key distinction exists between learning through games and learning through making games: while the former emphasizes interaction with designed systems, the latter places learners in the role of authors, requiring them to externalize knowledge, formalize rules, structure feedback systems, and translate abstract concepts into coherent interactive models (Kafai, 2006; Plass, Homer, & Kinzer, 2015). This distinction is especially relevant in STEAM education, where conceptual complexity benefits from systems-oriented and model-based approaches.

The pedagogical rationale for student-authored game design is grounded in constructionism, according to which learning is strengthened when learners actively construct meaningful artefacts that can be shared, tested, and iteratively refined (Papert, 1980). Designing a game is therefore not only a creative exercise but a process of epistemic modeling: learners identify core concepts, reduce complexity without trivializing content, and encode them into mechanics, goals, and constraints. This supports conceptual restructuring, metacognitive reflection, and systems thinking, making game design particularly suited to inquiry-based and interdisciplinary STEAM education (Kafai & Burke, 2015; Arnab et al., 2015).

Recent literature has increasingly framed Game Design–Based Learning (GDBL) as a distinct branch of game-based learning, particularly in contexts where higher-order competences such as collaboration, design literacy, and critical reasoning are central (Plass et al., 2015; Whitton, 2010). In this perspective, the educational value lies not only in gameplay outcomes but in the design process itself, which requires iterative abstraction, testing, peer negotiation, and the integration of domain knowledge into structured systems.

Within this framework, educational board games offer specific advantages. Compared with digital environments, tabletop game design lowers technical barriers to prototyping, foregrounds social interaction, and makes systems immediately visible and manipulable through tangible components and negotiated rules. These affordances are especially relevant in formal educational settings and provide the conceptual basis for Fotonica

in Gioco, which positions students not simply as players but as designers of educational board games that communicate scientific concepts. Accordingly, this study examines the fifth edition of Fotonica in Gioco as an exploratory evaluative case study. It asks how participating students and teachers perceived the educational value and main difficulties of the design process, and which disciplinary and transversal outcomes they associated with the activity.

2. The Fotonica in Gioco Competition

CNR Institute of Photonics and Nanotechnologies launched Fotonica in Gioco in 2015 as a biennial national competition for Italian upper secondary schools aimed at fostering the design of original educational board games on STEAM-related themes (Chiarello, 2015; Chiarello & Castellano, 2016; Chiarello & Castellano, 2017). Conceived as a structured Game Design – Based Learning (GDBL) intervention, the initiative combines science communication, design practice, and inquiry-based learning by engaging students in the collaborative construction of playable models that translate complex scientific concepts into rule-based systems. Its broad thematic framing was intentionally designed to support interdisciplinarity and widen participation beyond science-specialist tracks, enabling contributions from students in humanities, arts, technical, and vocational curricula. Across its five editions, the competition themes were:

Edition	Period	Theme	English Translation
1	2015–2016	Luce e fotonica	Light and Photonics
2	2017–2018	Trasformazioni: come cambiano le cose	Transformations: How Things Change
3	2019–2021	“Che cosa è ombra e lume, e qual è di maggior potenza” (L. da Vinci)	“What Are Shadow and Light, and Which Is More Powerful”
4	2022–2023	Guardare oltre	Looking Beyond
5	2024–2025	Sfide	Challenges

Pedagogically, the intervention follows a constructionist approach: students produce a public, testable, and revisable artefact, while inquiry and collaborative learning occur through topic research, negotiation, rule formulation, playtesting, and revision. The pedagogical aims of the programme include: introducing and testing GDBL methodologies in formal education; promoting the practical manipulation of abstract models through game mechanics; supporting systems thinking and scientific critical reasoning; fostering transversal competences (e.g., collaboration, communication, negotiation, and problem framing); increasing awareness of sustainability and development challenges; and stimulating interest in STEAM pathways, creativity, and responsible innovation. Additional relevant educational outcomes include the development of epistemic agency, design literacy, and argumentation skills, which are increasingly recognised as central to contemporary STEAM education.

Operationally, the competition opens each September with a national call disseminated to Italian secondary schools; student teams then work until February to design and submit a complete board-game prototype, supported by optional remote mentoring sessions and written resources provided through the competition website (www.fotonicaingioco.it). By the end of the school year, a jury selects three finalist teams, each receiving an equal financial award to support educational and cultural activities, including participation in the final event. The three finalist games are then exhibited and presented by the students in Venice during the award ceremony of the prestigious Premio Archimede, where, in a dedicated session, the final ranking (first, second, and third place) is publicly announced and the winners are formally awarded. This hybrid structure — combining school-based design, expert feedback, public exhibition, and formal recognition — positions Fotonica in Gioco as a robust example of curricular integration between game making, science outreach, and transformative STEAM pedagogy.

3. The Fifth Edition

In the fifth edition of Fotonica in Gioco (2024–2025), upper-secondary students were invited to design an original board game around the open theme Sfide (“Challenges”), interpreted across environmental, scientific, social, and cognitive domains. The 18 submitted prototypes were (Fig. 1): Biodiversity heroes; Climopoly; Ecomemory_2030; Escape game; Eulero; Greenova; La formula della felicità; L'era delle scelte; Marketing Planet;

Noi, futuro; Pangemonium; Roulette periodica; Scalata sociale; Sfida tra le stelle; Thoughtless; Trova la coppia; Verso il 2030: la sfida della sostenibilità; Δοδεκάθλον (dodecatlon).

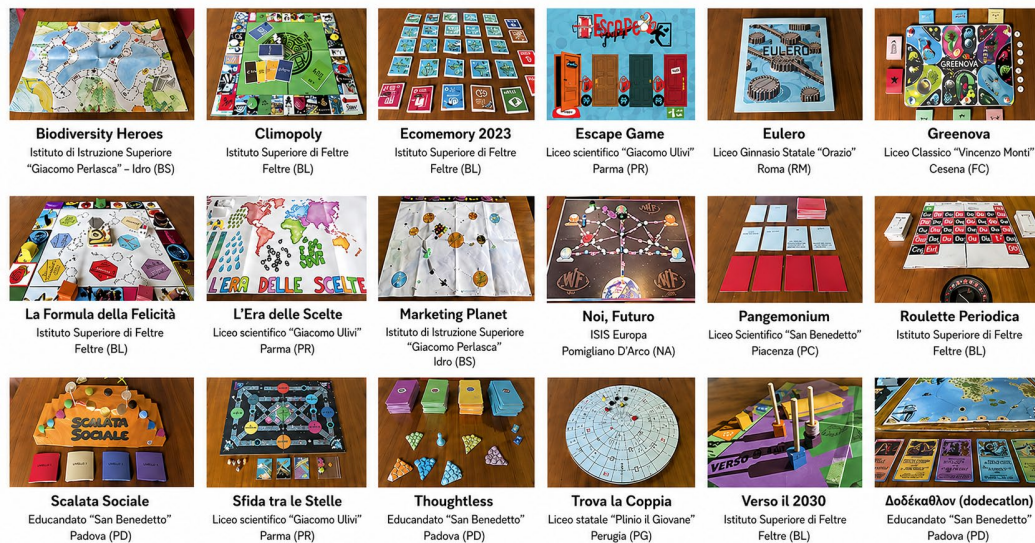


Figure 1: Images of the board-game prototypes submitted to the fifth edition of Fotonica in Gioco

These games demonstrate substantial thematic diversity and a coherent alignment with the competition's educational aims, despite participants' complete inexperience in game design. Students developed their games autonomously, with no prior formal training in game design and relying exclusively on written guidelines and organizational mentoring, making the overall quality of the submitted prototypes particularly noteworthy.

The notion of "challenge" was consistently translated into systems of problem solving, strategic choice, and knowledge application: sustainability and ecological transitions were central in Climopoly, Ecomemory_2030, Verso il 2030: la sfida della sostenibilità, Greenova, and Biodiversity heroes; scientific reasoning and disciplinary knowledge were foregrounded in Roulette periodica, La formula della felicità, Trova la coppia, and Eulero, which was awarded first prize; social and ethical decision-making informed Scalata sociale, awarded second prize, L'era delle scelte, and Pangemonium, awarded third prize; while Noi, futuro, Planet marketing, and Sfida tra le stelle explored technological futures and space-related scenarios through strategic progression and mission-based play.

Across the corpus, dominant mechanics included dice-based movement, card-driven events, quiz validation, set collection, resource management, and mission systems, often combined in hybrid forms that embedded assessment directly into progression. Particularly relevant is the spontaneous emergence of design solutions consistent with established game-based learning frameworks — goal-oriented feedback loops, meaningful decision-making, and embedded formative assessment — despite the novice status of participants (Plass et al., 2015; Arnab et al., 2015; Kafai & Burke, 2015). These results support the interpretation that minimally scaffolded student-led game design can produce mechanically coherent and pedagogically meaningful artefacts, consistent with the educational potential of constructionist and design-based approaches in STEM-oriented game-based learning.

Overall participation involved 18 submitted games from 9 Italian cities, developed by 166 students and 18 teachers; the estimated gender distribution was approximately 60% female (about 100 students) and 40% male (about 66 students). Participating schools represented a broad range of Italian upper-secondary educational tracks, including Istituto Tecnico (technical institute), Liceo Classico (Classical Lyceum), Liceo Scientifico (Scientific Lyceum), Istituto Tecnico Economico – Amministrazione, Finanza e Marketing (technical economic institute – administration, finance and marketing), Liceo Artistico (Arts Lyceum), Istituto Professionale (vocational institute).

4. Methodology

This exploratory evaluative case study focuses on the fifth edition of Fotonica in Gioco. The unit of analysis was the 2024–2025 competition, involving 18 submitted games, 166 students, and 18 teachers. Separate voluntary and anonymous post-activity questionnaires were administered to students and teachers. They combined five-

point Likert-scale items with open questions addressing overall appreciation, perceived learning outcomes, transversal competences, difficulties, and suggestions for improvement. Closed responses were analysed descriptively through mean ratings; open responses were reviewed to identify recurrent observations and to contextualise the quantitative findings, rather than being subjected to a formal qualitative thematic analysis. Because participation was voluntary, the respondents formed a self-selected subset, and no pre/post measure or comparison group was used. The findings therefore concern perceived outcomes and cannot establish causal effects or be generalised to the entire participant cohort.

5. Results

The post-activity evaluation was based on voluntary and anonymous surveys administered after participation to students and teachers (with different questions); accordingly, responses represent only a self-selected subset of the overall cohort and must be interpreted cautiously. The post-activity survey collected 57 student responses and 10 teacher responses, thus sampling only part of the participant population. Student respondents were aged 14–18 years (mean 15.7), with a similarly female-skewed distribution (66.7% female, 31.6% male, 1.7% undisclosed). Overall appreciation was high (3.88/5), and willingness to participate again was also positive (3.72/5). Perceived impact (Figure 2) was strongest on soft skills, particularly project management (3.68/5), and teamwork (3.51/5), with creativity and problem solving rated at 3.79/5, whereas perceived support for formal curricular learning was more moderate (2.93/5). This pattern suggests that students primarily experienced the activity as a collaborative and competence-oriented design process rather than as direct disciplinary reinforcement. This interpretation is consistent with constructionist accounts of game making, in which learning opportunities arise through planning, negotiation, modelling, testing, and revision; however, the lower curricular-learning rating also indicates that links between game design and formal disciplinary objectives may need to be made more explicit.

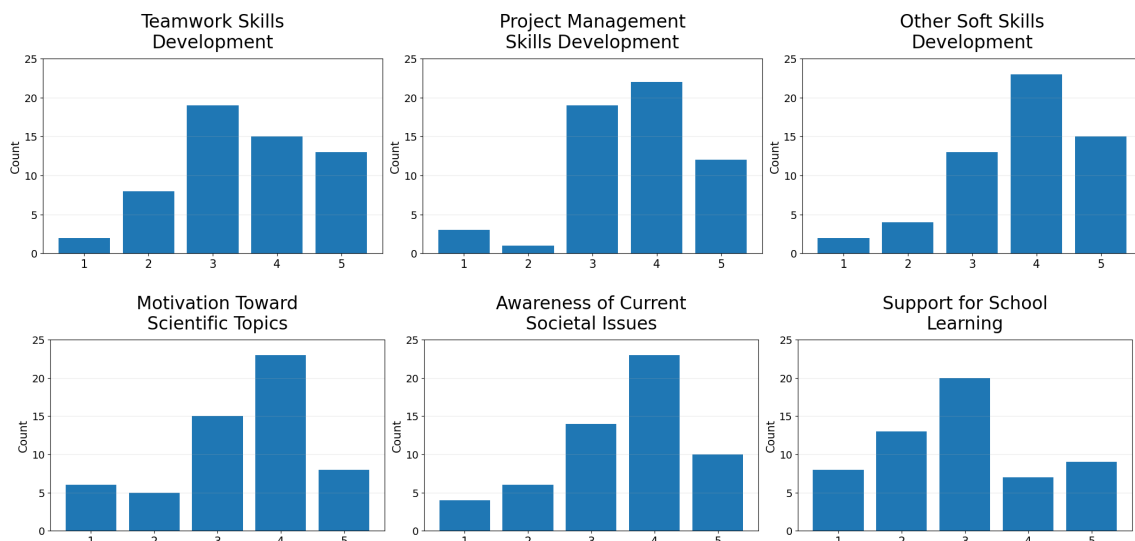


Figure 2: Mean student ratings of perceived educational impact across selected dimensions (Likert scale 1–5)

Illustrative open comments were consistent with this interpretation: students frequently referred to “developing creativity,” “working with others,” and “meeting new people,” while teachers emphasized that the activity required students to “collaborate toward a common goal.” Reported difficulties were concentrated on time management (3.11/5), rule formalization (2.91/5), and idea generation (2.88/5), while understanding the contest itself was comparatively less problematic (2.12/5). Open comments also highlighted relevant criticalities, including requests for more stimulating themes, more structured mentoring, and concerns regarding limited originality in some submissions. These difficulties identify specific points for additional scaffolding: intermediate milestones may support project pacing, while rule templates, examples, and earlier playtesting may assist teams in formalising coherent game systems. The requests for mentoring also suggest a need to balance student autonomy with more structured design support. Overall, these findings align with established literature on game making as a constructionist and game-based learning practice, supporting previous evidence concerning its potential to foster engagement, collaboration, and higher-order competences, while also indicating the need for stronger scaffolding in creative divergence and project pacing (Kafai & Burke, 2015; Plass et al., 2015; Whitton, 2010).

6. Limitations and Future Directions

The study is limited by voluntary questionnaire participation, reliance on self-reported perceptions, and the absence of pre/post measures, a comparison group, or an independent assessment of disciplinary learning. The submitted prototypes were also not evaluated through a standardised research rubric linking scientific content, game mechanics, and learning objectives. Future editions will therefore consider more structured mentoring, intermediate design milestones, and earlier playtesting. Future research should combine perception questionnaires with direct measures of learning and systematic analysis of the games, while seeking a larger response sample that permits comparisons across school types and participant groups.

7. Conclusion

The fifth edition of Fotonica in Gioco suggests the educational relevance of student-authored board-game design as a structured game-based learning practice for science communication in secondary education. Even with limited scaffolding and no prior design experience, students were able to produce conceptually grounded and mechanically coherent game artefacts. Survey respondents perceived the activity as particularly supportive of creativity, collaboration, project management, and problem solving, while also revealing the importance of stronger support in project pacing and idea development. Taken together, these findings support Game Design–Based Learning as a promising framework for integrating science communication, design literacy, and participatory STEAM education in formal school contexts. More broadly, the structure and outcomes of the initiative suggest that similar board-game design competitions may represent a transferable and replicable educational format, adaptable to other disciplinary domains and school contexts.

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Ethics Declaration: Participation in the contest and in the related evaluation activities was voluntary; questionnaire data were collected anonymously, analyzed only in aggregate form, and processed in compliance with GDPR (EU 2016/679). The study involved no medical procedures or sensitive personal data, and all activities were conducted within standard educational settings under teacher supervision.

AI Declaration: AI-based tools were used to support data analysis, drafting, and language revision during the preparation of this manuscript. All AI-generated outputs were critically reviewed, verified, and edited by the authors, who take full responsibility for the final content.

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