

# Games Design as Learning Tool for Science: the Photonics Games Competition Experience

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**Abstract:** Board Games have proved to be effective motivational and learning tools, in particular for Science and for STEM in general (Science, Technology, Engineering and Mathematics). In the ambit of the EU Project Photonics4All and of the UNESCO "2015 International Year of Light" we exploited not only the playing experience but also the process of creation of original board games with the objective to foster interest in Science among youth and general public and as learning tool for complex scientific topics such as Photonics. The adopted methodology is based on a series of laboratories of Scientific Board Game Design held in schools and Science Festivals (with an amount of about 800 participants overall), together with a national competition for High School Students, "Photonics Games", which involved about 430 students from all-over Italy that realized 28 original board games on light and Photonics. The results of these experiences are particularly interesting, with a very positive feedback from participating teachers and students from the point of view of impact, involvement, and also quality of produced games. We present the results of this activity and discuss issues and perspectives.

**Keywords:** Board games, board games design, science, outreach

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## 1. Introduction

Board games can be excellent learning tools for Science (Gobet, De Voogt and Retschitzki 2004, Shanklin and Ehlen 2007, Salen 2008, Treher 2011, Berland and Lee 2011, Whitton and Moseley 2012, Yoon et al. 2014), in particular for complex and abstract scientific concepts such as Quantum Mechanics and Relativity (Chiarello 2015, Chiarello and Castellano 2016), with a range of applications from outreach and awareness activities for general public to teaching in schools. This is possible thanks to a series of reasons: (a) the immersion and motivation given by the game experience; (b) the availability of metaphors and illustrations that support teachers and learners in the introduction of abstract concepts; (c) the "suspension of disbelief" that helps in overcoming mental inertia (a common problem in Science learning); (d) the presence of "downtimes" (for example waiting for the opponent's move), which fosters reflection and discussion.

In this work our main objective is to consider a further possibility offered by board games, exploiting not only the game experience but also the use of the game design process as an immersive motivational and learning tool for Science, with a "learn by doing" approach in mind (Castells 2000, Prensky 2007). In this case learners are challenged in the realization of a board game designed to illustrate and explain a specific scientific topic. We illustrate and discuss a series of experiences in this direction. The opportunity for this study was given by the European Project "Photonics4All" (Photonics4All 2015), started in 2015 in occasion of the UNESCO International Year of Light with the goal to increase awareness on the Photonic Revolution in general public, young and students, entrepreneurs and decision makers. Photonics is the science and technology of light manipulated at photons level, and it is a common idea that "if the last century was the era of electronics, the twenty-first century is probably the era of photonics" (Lifante 2003). For this reason it is of fundamental importance to raise awareness on this theme. The main idea of Photonics4All is to exploit different channels to reach public in a capillary way: conventional media (press, television, social media) but also alternative tools such as apps for smartphones, videos, and board games concerning the "Photonics Games" activity.

Concerning the adopted methodology, the activity is articulated in three main synergic actions: a series of public events based on the use of a didactic board game ("Quantum Race"), a laboratory for the development of board games on light ("Photonics Games: hands-on"), and a competition for the creation of original board games on light and photonics ("Photonics Games: the competition"). These actions will be presented in the following section, with details on their specific objectives, adopted methodologies and obtained results.

## 2. Public events: "Quantum Race"

Quantum Race is a board game designed to illustrate some basic principles of Quantum Mechanics such as the wave-particle duality, the collapse of wavefunctions, the tunnel effect, the quantum teleportation (Gilmore

1995, Sakurai and Napolitano 2011, Chiarello 2014). It simulates a car race with very special "cars", each of them composed by six parts that can be "spread" (delocalized) along the racetrack and then can return in a single position randomly chosen. The game's rules, while very simple, still allow matches with non trivial dynamics. The game has been extensively tested in the past in different contests with good results (Chiarello 2015). In the ambit of Photonics Games it has been mainly used to increase awareness and interest in science and photonics and to promote the entire Photonics Games activity, in particular in occasion of games Festivals and similar events with a large public mainly composed by young people interested in games, comics and computers: "Carrara Show" (Carrara, Italy, May 2015), the "European Researchers Night" (Rome, September 2015), "Romics" (Rome, April 2016), "Comicon" (Naples, April 2016). The game was used in two distinct (but substantially identical) versions: a series of more practical conventional tabletop games, and a giant version of about 10 m<sup>2</sup> mainly used for its visual impact. These activities were followed by scientific animators who encouraged people to play, explained the game rules, and exploited the game experience to solicit the curiosity and interest of players and introduce and explain the scientific subjects. Each event was accompanied by a public conference on the thematic of light and photonics and on the promotion of the game activity.



Figure 1: The board of the game Quantum Race in the giant (left and center) and tabletop versions (right).

A first preliminary evaluation on the impact of this activity is given by the feedback from animators, who reported an excellent response in term of opening and fostering of interest in photonics and science in general. A more accurate analysis is still in progress.

### 3. Laboratory: "Photonics Games: hands-on"

The main idea of this creative laboratory is to encourage and give instruments for the creation of original didactical board games on light and photonics. The goal is to directly engage people in a practical and creative task that requires immersion and reflection on the scientific thematic considered. The laboratory was proposed at the Genova Science Festival 2015 (Festival della Scienza di Genova, October 2015) and involved about 650 participants in 10 days, with the creation of about 150 different games. Each session lasted 90 minutes and involved from 2 to 5 groups of about 5 participants, supported by two scientific animators properly prepared. The session was divided in a first instructional part of about 30 minutes and a final practical part with the effective creation of the game prototype. In the first part the animators presented a very simple game model (such as "the game of goose" and "snakes and ladders") and dissected and deconstructed the game's structure and mechanics, underlining the important elements and how they can be rethought and reassembled in more original forms. In the same time it was presented the theme of photonics, with the introduction of elements and suggestions on light (light an life, energy saving and photovoltaic, optical phenomena, light and arts, speed of light, applications of light etc.). After that the groups started their work, provided with the necessary material for the game creation: paper, scissors, glue, markers and colors, and a series of typical elements of the games imaginary: pawns, dices, chips, tokens, small houses, meeples etc. Participants could bring home their games in order to give a continuity to the experience. At the end an anonymous surveys was distributed to participants in order to evaluate the impact of the laboratory.



Figure 2: Laboratory "Photonics Games: hands on" (left and center), and one of the created games (right).

Despite the difficulties of a laboratory of this kind the results are particularly interesting: the produced games are nice and imaginative (although often simple and naive) and shown some degree of reflections and immersion in the considered topics (obviously limited by the very short time available for the laboratory), and the participants appeared motivated and curious on the themes of light. Also in this case the feedback is given by the animators, while a complete analysis of the survey is in preparation.

#### **4. Competition: "Photonics Games"**

The climax of the Photonics Games activity is the realization of a competition for Italian High School students whose aim is the creation of an original board game on light and photonics. The first phase of preparation and promotion was based on social media, direct contacts with teachers, schools and relative associations, active participation to public events and festivals, together with the intensive exploitation of the activities previously presented (paragraphs 2 and 3). The competition started on October 2015 and the candidate games were due by January 31st 2016.

About 28 games participated to the competition, with the involvement of about 430 students from 16 Italian cities. The first phase of evaluation just ended, with the selection of the top ten games and, among them, of the best three: "Helioscape" (describing the generation and escape of photons from the core of the sun), "Marama" (a management game on research and application of light, "marama" means "light" in Maori language) and "Rainbow Race" (a game on the nature and effects of light). These three finalists will participate to the final award ceremony in Venice (October 2016), in occasion of the Premio Archimede 2016, the main Italian competition for game designer.



**Figure 3:** The three finalists of the competition "Photonics Games": Helioscape (left), Marama (center), Rainbow Race (right).

The first results are particularly encouraging: the participation was three times higher than expected for a competition of this kind. The proposed games are very nice and present original elements and a strong communication capability. The theme of light is well considered and inserted in the games. The overall impression is of strong motivation and interest. These preliminary results come by the feedback from the jury that examined the games, by direct contacts with the teachers coordinating the participating students, and by an anonymous survey distributed to these teachers. A number of 19 teachers out of the 22 involved answered to the questions, evaluating different points with values from 1 to 5. In summary, the impact of the competition's experience in the understanding of the phenomena of light and photonics received an average evaluation of 4.16/5.00, the raised interest in science 4.42/5.00, the overall positive impact on students 4.53/5.00, the comprehensive assessment on the experience 4.58/5.00.

#### **5. Conclusions**

Board games can be a powerful tool for outreach and learning of science. We investigated their use in the particular field of Photonics, in the framework of the European Project "Photonics4All". Our activity was articulated in three main synergic actions: the use of the didactic board game Quantum Race for scientific outreach in public events, a laboratory for the creation of board games on light, and a competition with the same purpose. While a complete analysis will be possible only at the end of the "Photonics4All" Project, we can already draw some conclusions. The first results of the game activities are particularly positive, as witnessed by active participation of people, both in playing and in creating original scientific games; All the three proposed activities proved to be a strongly motivating occasion for reflections and immersion in the considered scientific theme. However particular attention must be used in order to drive the participants' efforts towards a motivating and non frustrating experience, by balancing the creative and amusing contributions with the considered scientific contents and concepts. In the future we plan to propose the experience for thematic and scientific contents other than Photonics and light considering also different formats and methods.

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