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Conference Paper · October 2015

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Board games to learn complex scientific concepts and the "Photonics Games" competition

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Abstract: Board games can be useful supports for the exposition and explanation of complex scientific concepts. In the past years we realized and tested three different board games of this kind, presented on the occasion of three different editions of the "Festival della Scienza di Genova" (and of other minor events) in the form of giant live-version board games: "Quantum Race", for the introduction of Quantum Mechanical principles such as wavefunctions, delocalization, collapse and tunnel effect (2011), "Lab on a chip", for an introduction to the immune system and to Nanobiotechnologies (2012), "Time Race", for the introduction to Special Relativity and to the concept of time dilation (2014). Each game has been played by about 1000 participants, mainly students, with excellent results concerning growth of interest and comprehension on the themes. In the ambit of the European Project Photonics4All and of the UNESCO International Year of Light 2015 we are now trying a step forward with a competition for high school Italian students concerning the creation of didactic board games on the themes of light and photonics to be held in the 2015-2016 autumn-winter period. We present in detail these activities with obtained and expected results and issues.

Keywords: Board games, Science dissemination, Quantum Mechanics, Relativity

1. Introduction

Some scientific concepts present difficulties in the exposition and explanation to non specialists (Perkins 1999, Meyer 2003, Perkins 2010) mainly because 1) they are far from the everyday experience of people and 2) it is difficult to find examples and analogies which can help their introduction in the absence of adequate mathematical tools. Typical examples can be found in Quantum Mechanics and in Relativity Theories.
Games expressly developed for this task (Gee 2007a, Gee 2007b, Whitton 2010, Whitton 2012), in particular board games in our specific case (Gobet 2004), can be a valid support in the spreading and teaching of such concepts. Let us start by recalling some simple and general considerations on board games and their impact:

- The playful and immersive nature of board games facilitates attention and concentration of players;
- During the game there is a "suspension of disbelief" and players are prepared to accept concepts even far from their everyday experience;
- Thanks to competitiveness and will to win the players are urged to deeply understand the rules behind the game;
- The typical downtimes of a board game promote reflection and discussion among players;
- These downtimes also allow the inclusion of clarifications and explanations in a natural and not disturbing way from teachers or scientific animators during the game.

With these considerations in mind we developed a series of three different board games all based on the main idea that the knowledge elements to be learned should not be simply inserted in the game as external elements (as for example occurs in a quiz game) but must be the core around which to build the entire game structure, in particular its rules. These rules must however remain simple and immediate despite the complexity of the inspiring concepts. The game design process took place empirically, through trials and repeated changes, exploiting some prior experience in the creation of "conventional" board games and keeping in mind the above mentioned principles. These board games have been presented and extensively tested in different occasions, in particular in the form of "live games" (on a giant board with human pawns) during three editions of the Festival della Scienza di Genova, the main Italian Science Festival with about 400000 participants in the last edition.

2. Quantum Race

In the microscopic world of atoms and molecules there are anti intuitive rules very different with respect to our classical macroscopic world's ones, rules described by Quantum Mechanics (Muller 2002, Sakurai 2011) instead of classical physics. Quantum Race (Figure 1) is a game developed as a support to introduce and explain fundamental quantum mechanical concepts such as the delocalization of a particle and its "collapse" under an observation, the tunnel effect and the quantum teleportation.

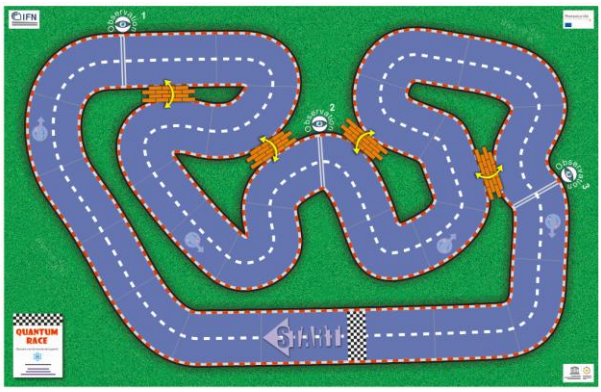

Figure 1: The board of the game Quantum Race.

It was presented as a live game (on a board of 70 m^2) during the Festival della Scienza di Genova 2011 (Figure 2) and was played by about 1000 participants, mainly students from 8 to 18 years.

Figure 2: Quantum Race match in live version.

It is a typical race-game with cars moving along a track divided in cells. Each car is split in six numbered parts. When all these parts are together in the same cell (for example at the beginning of a match) they represent a “classical” car, but during the game they can be spread along the track with a "grab and seed" rule similar to the classical "mancala" game. In this case it is reproduced the "bizarre" delocalization of a quantum particle. When an observation line is crossed a "collapse" occurs: a dice is thrown and all the pieces of each car return together in the same cell, the cell containing that part with the outcome number. This mimics the effect of the observation on a delocalized quantum particle and the return to the classical condition. Walls between different parts of the track can be crossed thanks to a dice roll, reproducing the tunnel effect. And, in particular positions, two pawns with the same number can be exchanged suggesting the quantum teleportation.
The game is very simple (it has been played with no problems by six year old children) and at the same time amusing and intriguing. Two animators helped the players during the matches using suggestions and analogies to illustrate and explain the principles behind the game. Some quick sample interviews have shown increased interest in the topic and an increased understanding of the basic concepts presented.

3. Lab on a Chip

Lab on a Chip (Figure 3) is a board game developed to explain the immune system and the use of nanotechnologies for its study (Chin 2007).

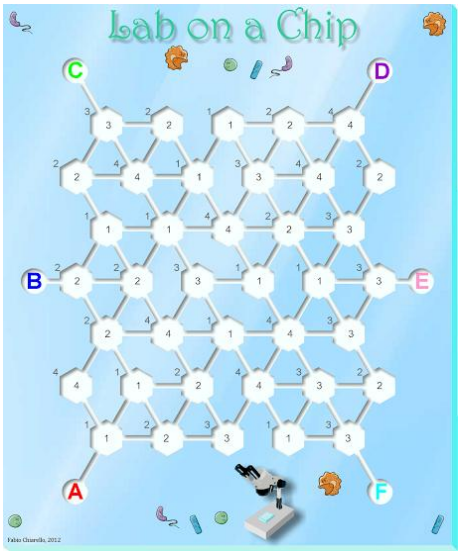

Figure 3: The board of the Lab on a chip game.

It has been also presented as a live version (on a 64 m^2 board) during the Festival della Scienza di Genova 2012, and it has been played by about 800 participants, also in this case mainly students from 8 to 18 years (Figure 4).

Figure 4: Lab on a chip match in live version.

The giant board reproduces a "lab on a chip", an artificial labyrinth of microchannels where the interaction between immune system macrophages and bacteria is studied. The players take the role of bacteria or macrophages and move in the labyrinth according to simple rules, the first ones with the aim to exit the labyrinth, the others with the aim to catch the bacteria.
Also in this case the matches are accompanied and followed by the suggestions and explanations of two scientific animators, and the observed impact on motivation and understanding of players is good.

4. Time Race

Time Race (Figure 5) is a board game developed to illustrate concepts of Theory of Relativity, in particular Special Relativity and the time dilation effect (Bell 1976). The flow of time is not the same for all observers: an observer moving at very high speed with respect to another one experiences a slowdown in the flow of time as if every second were dilated. This is the so called time dilation described by the Special Relativity, a phenomenon well established and verified but far from our daily experience because perceptible only at speeds close to that of light, at 300 000 km/s.

Figure 5: The board of the Time Race game.

The game was presented as a live version (on a 40 m^2 board) at the Festival della Scienza di Genova 2014, and it was played by about 1000 participants, mainly students from 8 to 18 years (Figure 6).

Figure 6: Time Race match in the live version.

It is a race game where the track consists of a series of nodes connected by branches. Players can move between connected nodes by a number of steps given by their velocity, a velocity that can be varied at any round. Some branches present speed limits in order to simulate the necessity to take larger paths at higher speeds. Each player has a tachymeter and a personal clock, and during the moving the clock is incremented by a quantity of time depending on the speed (smaller for higher speeds) in order to simulate the time dilation. When a player crosses the finish line his clock is "stopped". At the end all the clocks are compared and used to define the ranking of winners. This mechanism can generate paradoxical situations, for example the first arrived can be the last classified according to his personal clock. These situations are perfect hints to explain and discuss time dilation and relativity, a task performed by two scientific animators that attend the game.

5. Impact

The fast flow of people is a characteristic feature of events like the Festival della Scienza di Genova; it allows a large number of participants but makes difficult a serious evaluation of the game impact. In the first two editions we limited the evaluation to quick sample interviews to participants. For the last game (Time Race) we organized a fast anonymous survey with general information (sex, age, occupation etc.), questions on amusement and appreciation and a self-assessment on the comprehension of the presented topics before and after playing. A complete analysis is in preparation but we can anticipate here some main results. The survey has been completed by 591 participants (294 men and 297 women) with a mean age of 14 years (6 years the youngest, 50 years the oldest). The self-assessment was based on three questions, 1) general knowledge on relativity, 2) difference between special and general relativity, 3) knowledge on the time dilation phenomenon, considered before and after playing, with a possible score from 1 to 5. We obtain an overall average rating on the three questions of 1.93 (before) and 3.18 (after), with a relative increase of 64.7%. In Figure 7 it is reported the histogram relative to this overall result, which points out the good impact of the game.

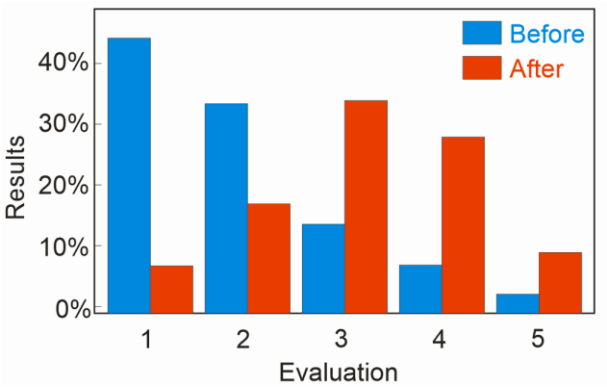

Figure 7: Histogram showing the results of the self-assessment on the themes of Time Race before (blu) and after (red) the match.

6. The "Fotonica in Gioco" (Photonics Game) competition

We are now considering a further step based on the direct involvement of students and general public in the creation of scientific board games. This activity is part of a wider project started at January 2015, the European Photonics4All Project, whose intent is the use of conventional and unconventional media for the awareness of people towards light technologies and photonics. The game-creation activity will be articulated in different tasks in the 2015-2016 period:

1) Organization of a competition opened to high school Italian students for the creation of board games related to the themes of light in all the possible aspects (art, culture, energy saving, science, technology, applications etc.). The competition will be held in connection to the "Premio Archimede 2016", the main Italian prize for board games designers.

2) Creation of a reference website with information, practical suggestion, tips and tricks on the board game design and on the themes of light (the site is actually online in Italian, www.fotonicaingioco.it).

3) Practical laboratories for the introduction to scientific board games creation and development.

4) Presentations and conferences in schools, science festivals and games festivals.

All these activities will be carried out in close cooperation with specialists in the field of board game design and expert board game authors.

6. Conclusions

The use of board games entirely built around complex scientific concepts has given good results in the three example here reported. They have shown to be particularly useful in:

1) intriguing and motivating players towards the considered issues;

2) catching the players interest toward the explanations given by the animators;

3) giving examples and analogies which are a fundamental support for these explanations;

4) pushing players to a deeper understanding of the essential aspects.

In the next future we will explore the direct involvement of public in the creation of board games of this kind as a learning support for complex scientific arguments.

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