USING MYSTERIES OF MAGIC TO ENGAGE STUDENTS IN THE LEARNING PROCESS

Games and simulations as new problem-solving tools

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Abstract

Using games in education has been identified as a powerful tool. If we combine playing with the interest induced by the unknown we are able to get even more surprising results. Our proposal shows some activities designed and developed having those two principles in mind. Moreover, we add another important element: multidisciplinarity.

Our project 'From the Science of Magic to the Magic of Science' (#magsci) uses magic tricks to present key concepts in Science. It deals with different formats: lectures and workshops in schools, non formal education in museums and civic centers, the theoretical study of the interphase between magic, science and education, the Mooc 'Magic, Science and avowable secrets" (#magcimooc) as well as some magic tricks designed to learn Science through apps and web pages.

Presenting 'mysteries' and puzzles with everyday objects (bank notes, calendars, food, ...) allows us to create an atmosphere that induces the student to be eager to know the secret behind those prodigies. We have developed activities for 'The Magic of the Periodic Table' and 'The Magic of Food'. We will include practical examples.

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Introduction

The use of games in education is widely spreaded and there are different publications that acknowledge and advice the use of this learning technique [Marquis 2013]. Most times the object of study are videogames or, for instance, traditional mathematical riddles and puzzles. We extend the concept of game to a more general related framework: a role playing where students and teachers act as public or magicians in a magic performance. The key in this case is using a mystery as a thread to engage students into different key areas in science. Usually people want to know what is the secret hidden in a magic trick and a lot of times that secret is just a scientific fact or mathematical property. We take the advantage to engage students when they question why is that 'magic' phenomenon happening. In that moment they are eager to study and understand the science that provokes that effect.

One must note that three levels of Public Outreach in Science may be considered. First, one that tackles Public Awareness of Science; second, another that includes Public Understanding; and third, Science Education at all levels. Even though the use of Magic fosters public awareness of science, our main aim is to increase understanding of key concepts in Science, and to enhance learning, mainly at the primary and secondary levels. Indeed higher education may be considered, but difficulty of concepts and methods in tertiary education goes beyond the scope of an entry procedure involving magic performances.

Hereafter we will explain our project 'From the Magic of Science to the Science of Magic' (#magsci), how it was developed, what it consist of, and the way it is organised. Later, we will focus on a special action inside the project: a MOOC on science and magic (#magcimooc). Finally, we will pay attention to some practical examples of tricks and games that appear in the MOOC but also they can be used in presential, face-to-face workshops.

1.- The project 'From the Magic of Science to the Science of Magic'

EU's Horizon 2020 initiative has pointed out that there are fewer students interested in STEM areas. Since magic is deeply related with the latest technological and scientific discoveries, it is a good vehicle for getting more interest into science and technology from young students. In fact, technical issues like turning up a lamp were presented as a magic trick in the 19th century as a magical fact: the illusionist (Robert Houdin) claimed he turned up a candle. At that time people did not have electricity at their homes, so they were not used to lamps and it seemed to be something magical (i.e., impossible within natural behaviour). It is part from the popular culture that magicians use mirrors to get surprising effects. In fact, Arthur C. Clarke, physicist and science fiction writer, stated his 'third law' in the following way: "Any

sufficiently advanced technology is indistinguishable from magic". We can take advantage of this and prepare a mystery for almost any lesson in the curriculum. For instance, a lesson on electricity or optics can be introduced after performing a magic trick related to those areas.

Since we were aware of the problem with STEM and we had already checked that the use of some magic tricks was useful to help understanding of mathematical concepts, we thought on a this global project (nicknamed #magsci) relating science and magic: the science explains the magic but at the same time the magic needs the latest scientific developments. Nowadays turning on a light is not at all magic, because it is part of our everyday experience. But, for instance, remote controls had been used in magic up to a recent time, just when they were introduced in mainstream TV sets and easily produced. In the last year, it was published in the news that scientists had designed an invisibility cape. It was a consequence of research in special materials, but it seems to be magic. All in all, we began to collect examples and design different activities relating science and magic.

Even though the concepts we work with are the same, we improve the scientific culture of people. For instance, when we make a activity on 'the magic of the periodic table' we think on different levels of target audience: if we make a workshop in a civic center we just expect the people know there is something where natural elements appear in a sorted way, in agreement with some of their properties (i.e., public awareness). A similar activity, when presented at a school, has different objectives: children should know there is something called periodic table and play with its elements whereas high school students will do searches in the table and discuss some properties of elements (i.e., public understanding).

Our project deals with different levels of interaction with people. It affects education in a general way since we do not only deal with formal education, but we also work in spreading scientific knowledge for the citizenship through public outreach and nonformal education. Also it is developed at different levels of complexity.

- The magic of the Periodic Table: The dual characteristic of the Periodic Table of the Elements allows to adapt classical magic games and also to create new ones. We show a collection of fun, entertaining, and educating activities on PTE. On stage, we complement mathematical magic with spectacular, fast chemistry experiments - humour and audience participation is indeed a key performing issue.

- I Meeting on Science, Magic and Education: This meeting discussed how to best use magic and illusionism to improve science awareness and science culture. It gathered researchers, university and secondary/primary teachers, and amateur and professional magicians having shows based on science principles. It was complemented by a Magic Gala and a Magic Scientific Walk through Girona.

- MOOC on Science & Magic: This Massive Online Open Course (http://magcimooc.net) provides basic knowledge of magic techniques, especially those based in science facts. We also use illusionism to explain difficult concepts found in Science education, and show how to use magic to engage students and citizens into Science. Finally, we provide some clues on magic, psychology and communication. We will comment in deep this MOOC in another section in this paper.

- The Magic of Food. We use magic and illusionism in an interactive, demo session session, quite attractive and interesting for both children and youngsters, even for a general audience. It is also relevant towards promoting a healthy nutrition. We try to educate in science while eating, i.e., to promote that children and youngsters know about the most basic concepts of healthy nutrition, and that they learn the basic nutritional strategies. Moreover, we provide games related to magic and science by means of mobile apps of desktop applications, with the goal of introducing gamifying experiences in Science learning.

- Summer Campus on Science and Magic: Students from High School interested in science and magic will be eligible to participate in a Summer Campus on July 2016. By means of different activities they will merge their scientific knowledge with artistic skills, showing that both science and art are compatible. This Campus constitutes an educational enrichment using magic as a tool. In parallel it will show some innovative tendencies in illusionism produced because of science achievements.

Even four out from the five above described actions deal with activities in presence of people and hands on activities, the Internet is essential for their diffusion. Moreover, activities are always implemented in such a way that they continue on the internet. Usually pictures are taken and quickly spreaded by means of tweets. Participants in this way are part of the show, they switch from passive learning to an active participation. They also look for the pictures and find the rest of the work: they get engaged into the specially designed online activities.

#magsci is a wide project but involves different tasks; iti also uses different formats for each of them. For instance, we pay attention to popularizing science, sometimes in a classical way (papers, usual talks, collaborations with mass media, …) but we also are interested in innovation in science dissemination, so we have moved from making scientific itineraries in a city to magical-scientific itineraries where we show parts of a city (we already have implemented these visits to Girona) and at the same time we explain science and perform magic tricks, some of them adapted to the singularities of the city we are visiting.

Since this is a joint project involving two universities, we also organize academic activities. It includes traditional talks and seminars but also teacher training. We think that this task is essential to get young people interested into STEM subjects.

We have also a preference for conferences and meetings that offer the possibility of performing or including a magic, scientific event in some way. The key point is posing questions to people and leading them to inquire why a 'magical' phenomenon happens and what is the 'trick' that remain hidden behind the effect. In this sense, we have participated in 'Ciencia en redes' (Madrid) and 'Jornadas D+i' (Zaragoza). We also have attended different international events whose target is both near education and science popularization: Science and you (Nancy), Science on Stage (London), Science is Wonder-ful (Brussels, in the 10th anniversary of European Researcher's Night), Teaching Enquiry with Mysteries Incorporated (Leiden), and Science Piknik (Warsaw). Our experience with all these meetings and events has convinced us that Magic constitutes an universal language and that our method runs in the same way in every visited place, so we feel it can be applied all over the world.

The project is not at all just a collection of tricks. On the contrary, in addition to being university scholars we are (amateur) magicians, so we must keep the secret of the tricks unless there is an important reason to reveal it. Education is one of these important situations. The power of illusions to engage people into science deserves revealing some secrets. In fact this is the way how new magicians are also engaged into (good) magic: once they show a special interest they are guided into better and more difficult magical effects. Thus, this relationship between science and magic works in both directions.

2.- The Mooc 'Science, Magic and Avowable Secrets'

This mooc is a key part in our project on science and magic. In fact, it was the beginning of that project. This group had previous experience in preparing a MOOC on basic chemistry and another MOOC on Science Communication 2.0 [Duran 2013, Duran 2103a, Duran 2014, Duran 2015, Duran 2016, Vieta 2014a, Vieta 2014b]. Since we had already carried out outreach activities on science and magic, we thought it could be interesting designing a MOOC on science and magic: on one hand the word 'magic' can attract the attention of a fair amount of people, so we can make a really massive course. On the other hand, we had already experience in dealing with the interphase between science, magic and education because we had taught in personface to face, physical courses for teachers and students.

The only remaining task was designing an attractive MOOC. Usually magic tricks are not revealed, but in this case it is necessary to do so, as we commented in the previous section. This MOOC deals with history of magic and the relationship between science, magic, technology and education and how this idea is implemented. This idea is not at all new: the oldest mention to a card trick founded in a book appears in 'The viribus quantitatis', a book written by Luca Pacioli and Leonardo Da Vinci around 1508. This book presents a collection of magic tricks (that can be performed with cards and ropes), numerical puzzles and logical riddles. It was written just to put in a formal and perdurable way a lot of resources that could be useful to introduce some difficult concepts or, at least to provoke interest in the matter.

This MOOC (whose hashtag is #magcimooc) is not only an example of online learning [Waldrop 2013], but also a formal project itself that involves innovation in learning. The preparation of this MOOC is a constituent part of two projects (2015 and 2016) financed by Spanish FECyT. The Regional Government of Catalonia financed also the specific preparation of this MOOC. Finally, it is considered as a secondary MOOC in an Erasmus+ Project entitled "Low-Cost MOOC Production", whose primary MOOC has the title "Making MOOCS on a budget" (http://moocs4all.eu).

#magcimooc is also an exercise of collaboration between two quite different universities: Madrid Polytechnic and Girona, separated by more than 700 km and with different environment, purpose and characteristics. This notwithstanding, the MOOC serves both communities, and is actually targeted to various communities. First, to the Spanish-speaking

countries; second (in development) to local Catalan language speakers and to a global English-speaking audience.

This MOOC contains short videos showing the 'magical' effect that have been recorded especially for this course. It also provides the explanation of the tricks in different formats: sometimes we have a video with the explanation, but we also explain the science on which the trick is based by means of slide presentations (screencasting sometimes) or even with links to external materials. There is however an important limitation: we never reveal a trick just after showing the effect. This is to maintain the interest and prevent dropouts, since usually the idea that explains a magic trick is a simple one, far too simple for a lay audience. We do not want to spoil the trick, but use it as a tool to provoke thinking and inquiring into science. In fact, we begin revealing secrets once passed the first test, just to be aware that the people following the course in that point have enough interest to deserve knowing the secret. Moreover, most people that arrive so far in the MOOC will keep following it until it finishes.

This #magcimooc consists of eight chapters:

- 1.- History. Scientists as 'magicians'. Magic seeks surprising facts, unknown by the general public. At the same time the latest scientific achievements are known only by few people, so magicians can take advantage of it and incorporate those unknown scientific or technological facts in their performances.

- 2.- The science of curiosities. There are scientific facts that do not are as strong as they can be considered as magic but they catch our attention. In this module we talk about riddles, puzzles and science curiosities.

- 3.- Magic with fewer secrets. Here we begin dealing with magic. Here we describe chemical reactions that appear in cooking, visual deceptions made with optical illusions, special paper constructions, such as flexagons, and perceptual paradoxes.

- 4.- Science explains magic. Here we describe some scientific facts that are used by illusionists. In this module we deal with notions on optics, magnetism, superconductivity and neuroscience.

- 5.- Magic for introducing science. There are some scientific concepts that are difficult to understand. Sometimes it is possible finding a magic trick that helps introducing those concepts. In this module we deal with both concepts and good tricks that can be used to introduce them in an easier way.

- 6.- Mathematical, physical and chemical magic. Here we present magic tricks adapted to official curricula of mathematics, physics and chemistry. They work as a motivational tool for both students and teachers.

- 7.- Magic and communication. The way in which magical effects are presented is useful in science communication as well as in interpersonal communication. Magic is also a tool to develop transversal competencies.

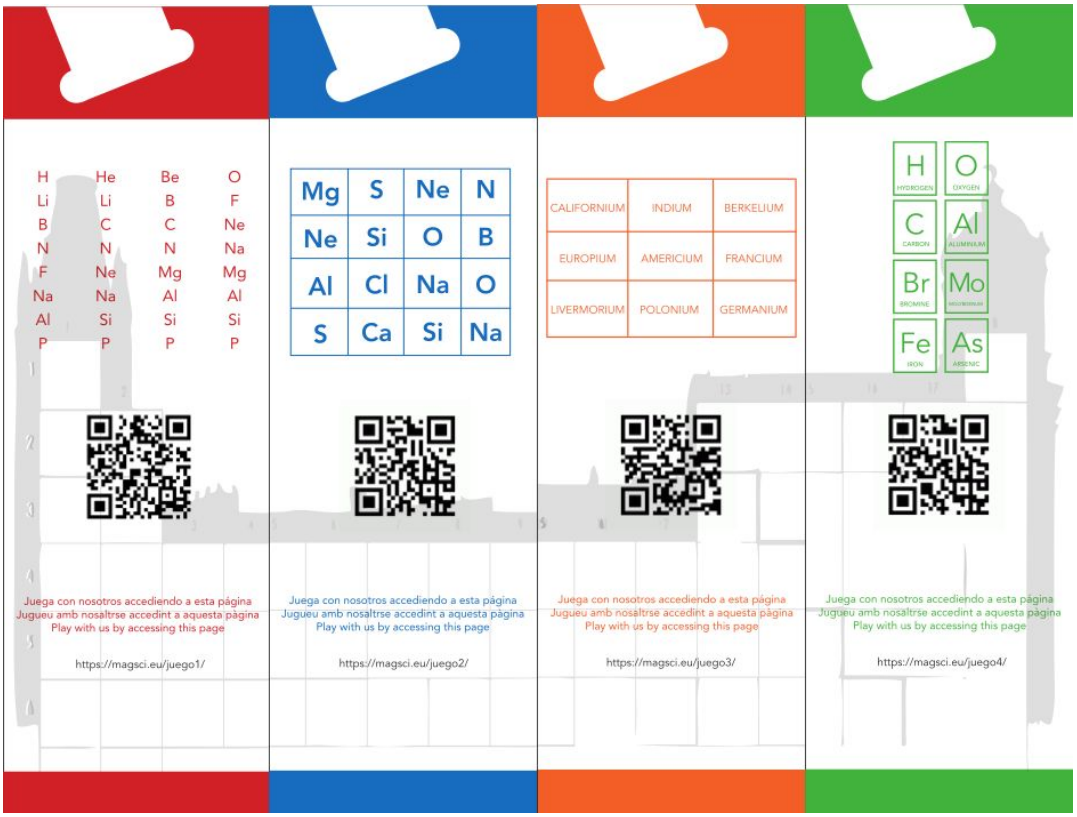
- 8.- Magics, scientists and miracles. We finish the mooc with testimonies of professionals related with games and magic as well as interviews of scientists.

Every chapter begins with a short descriptive video and a motivational activity related to the it contents. The aim of this motivational game is to increase the attention of participants by creating a mystery: something surprising that gives a reason to think in deep on the phenomenon. Sometimes an experiment is presented but in other occasions it is merely a magic trick that can be played 'at distance'. For that purpose, mathematical magic tricks provide a source of examples where magic resides on properties of numbers, binary system or divisibility rules. On the other hand, physical and chemical demonstrations are usually magical by its very nature. In all cases we tried to use materials that can be found at home or they are easy to find. The learning process does not finish when the participant finishes the lesson and solves the final test: we want them to reproduce the facts described in the videos. This is the key to learning: understanding and practising.

3. Some examples of open educational resources

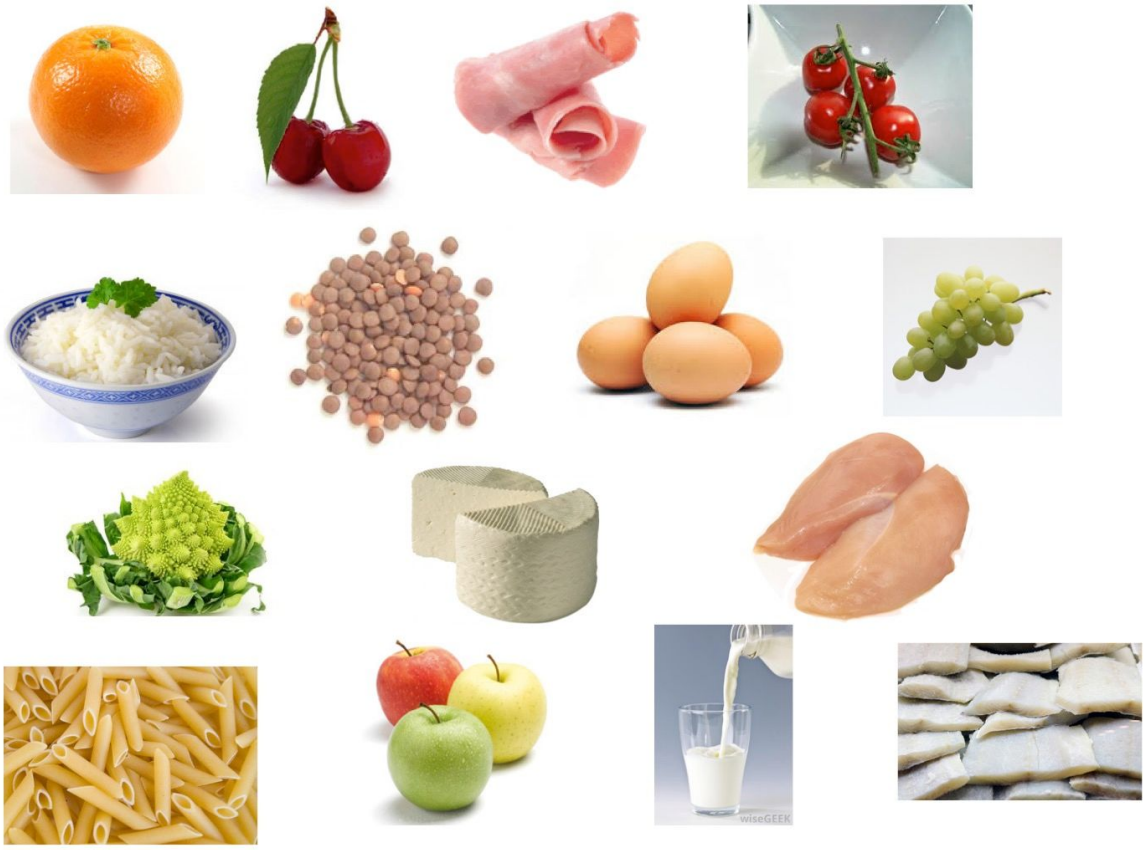
#magcimooc will be located in the MiríadaX platform, but before starting the course there, we prepared a webpage with announcements of the course, the steps we followed in its design, an explanation video, and some motivational tricks. We wanted to engage people into the course from the very beginning. The first trick we recorded was a 'calendar trick' that can be found in
http://magcimooc.net/juego-del-calendario/

Later, we thought of combining videos and virtual materials with real ones, so we decided to design four (paper) bookmarks including brief explanations and instructions, but that included the project URL and a QR code leading to the video containing the trick. There four bookmarks belong to the particular project "The Magic of the Periodic Table", whose target is high school and university students, beside a more general, adult audience.

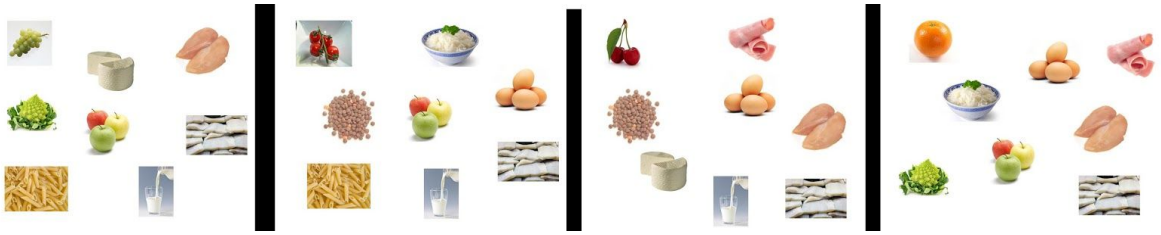


The best description for the tricks and the methodology we use involves scanning those QR codes and beginning the steps described in the selected trick. The tricks are based in mathematical properties but they want to be multidisciplinar: they deal with the Periodic Table of Elements since it is a good example that show where natural numbers appear in nature, and allow for entertaining combination of one- and two-letter symbols and numbers.

We have also designed some other tricks specifical for the project. For instance, there are very well known mathematical tricks that rely on properties of binary numbers. We have adapted those to our workshop ‘The magic of food’ whose purpose is both to entertain and to promote healthy food (fruit and vegetables, carbohydrates, dairy, and protein). Here we give an example, where one must choose one of the following foods:



The participant is asked if the chosen food is represented in the following pictures, and write down 1 below the image is the chosen food appears in the picture, while write down 0 if it does not appear.



For instance, if ‘eggs’ are chosen, one would write 0111 (eggs appear in the three rightmost pictures). The representation of 0111 in the binary system is the same as 7 in decimal, so the scientist-magician must only look for the seventh food in the big image to conclude that, in fact, the chosen food is ‘eggs’.

4. The novelty of building up a MOOC

Building up a MOOC is not just about setting up a learning path and creating open educational resources [Watters 2015]. The authors themselves learn about details and innovative procedures. As opposed to traditional classroom-centered teaching where lessons, exercises and materials are the outcome of a wealth of existing knowledge, online learning using a novel approach (i.e., magic) requires a deep evaluation of methods, competences to be acquired by students, audience characteristics, and target students behaviour. It is very easy to register for a free MOOC, but also quite easy to drop out and lose retention.

Thus, as opposed to traditional classroom-centered (even flipped classroom teaching), in online learning involving new areas or new methods, maximizing student registration and student retention becomes an enormous task [Pappano2012]. Even for very well organized and created MOOCs, clever use of exercises, forums, badges, quizzes and other forms of assessment and especially engagement are of utmost importance. In our MOOC involving magic, retention is catalyzed by delaying secret revelations to later modules and thus keeping students' interest in the course.

Instructors' involvement in a MOOC is not only at an academic level - they become also entrepreneurs. Almost all aspects of the course development depend on their own (provided the technical platform frees them from technical nightmares, like MiriadaX or EdX do). Building up a MOOC allows instructors to develop their innovative potential and apply their ideas to any field of knowledge.

The idea when building the MOOC was contribute to provide contents free to use, reuse, and redistribute without legal, social or technological restriction, so we are creating Open Educational Resources (OERs). Even the MOOC is hosted in MiríadaX (and it is necessary logging in and joining the course to follow it) most of its contents are accessible in an open way. In http://magcimooc.net and the similar YouTube channel, it is possible to watch the videos produced for the course. However, they do not constitute in themselves a course: activities, complementary material and tests only appear in the platform, but having the teaching materials in a different place facilitates its spread and use in different projects for different people.

5. Future steps

MOOCs have opened a window to a bright landscape in education at all levels. Probably one of the key competences that will be taught in future primary school will be the competence of online learning. We think that MOOCs are well worth trying. Building the #magcimooc MOOC has involved a lot of work, but has been also quite satisfying.

Thus, we will go on with this collaborative projects involving open learning, combined with in- person activities. The mysteries of magic are also interesting for students that improve

their communication skills participating in science fairs and helping in lectures and shows. The project is evolving towards a ‘school of science communicators’. One of its branches is the development of an ‘online school of science communicators’.

During the development of #magcimooc and the general #magsci project, we have started introducing gamification [Maniscalco 2016] as a motivational tool. For instance, in the Girona Science Fair for elementary school students, our group tackled 25-student groups by dividing them into two teams and providing scorning and badges. Slight modifications of magic tricks and suitable storytelling had to be devised, and will be the subject of a future communication.

We have also developed games involving the Internet and thus using tools that digital native students are used to. We already have some data for an activity involving the connection between the Periodic Table of the Elements and poker cards, which allow us to think that online and offline games are two faces of the same coin, both leading to increased engagement, awareness of Science and event better learning. Games and simulations as new tools to solve problems are indeed an idea that must be further explored.

6. Final remarks

One might think that revealing a small number of magician secrets to students is questionable. Given that many tricks are based on mathematical properties or physical/chemical facts, the small drawbacks of revealing a little secret are far than compensated by the beauty of the mathematical procedure or the awe of the scientific explanation, i.e., by the increase of knowledge of students and overall their Scientific Culture, which is our ultimate goal. In any case, no professional-grade magician secrets are actually revealed. Should any students wish to get a deeper insight into Magic, they should join a Magic Circle. Likewise, should any students wish to increase their Scientific formation, they should register for further particular scientific courses.

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