"Scientist as a game": learning geoscience *via* competitive activities

Gemma Musacchio*, Giovanna Lucia Piangiamore, Giuliana D'Addezio, Stefano Solarino, Elena Eva

Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy

Article history
Received November 4, 2014; accepted June 3, 2015.
Subject classification:
Science outreach, Education, Seismic and volcanic hazard.

ABSTRACT

Nowadays, science communication is considered as one of the major challenges that research institutions are required to face. The strategies to attract public interest, the choice of the correct language, and the tools to trigger curiosity are a matter of debate. Research claims a concerning disaffection in older students toward science, which suggests that children are one of the major targets to whom the world of science and research should appeal. "Scientist as a game" is an experience of a hands-on approach that is combined with game-related challenges in the field of geoscience, where effective teaching methods require extensive research. This activity was held for the first time in the 'Giacomo Doria' City Museum of Natural History in Genoa as an open day laboratory, and it was linked to an interactive exhibition realized by Italy's Istituto Nazionale di Geofisica e Vulcanologia (INGV). We set up four laboratory activities that were focused on: (1) where and why earthquakes and eruptions occur on Earth; (2) how volcanoes happen; (3) what the effect of shaking on buildings is; and (4) how to behave correctly in the case of an earthquake. Children were teamed up to score points according to the challenges included within each activity. The feedback of this experience was very positive, as shown by the questionnaires handed out to the participants immediately after each activity, and it reinforces the reviewed research on using games and hands-on activities in education.

Introduction

Earth sciences are of key importance in modern society, in terms of both the broader care of the natural environment and the consciousness of natural hazards. Having a basic knowledge of the crucial themes can help every citizen to make decisions about the socio-economic issues related to resources, the environment and hazards. Indeed, there is a demand by the general public to discuss and become informed about fundamental questions related to the environment, and to natural risk reduction and hazard perception [Bernhardsdóttir et al. 2012, Musacchio et al. 2014, Musacchio et al. 2015ab, Solarino 2015 and references therein]. The success of open-house initiatives has been shared by several research institutions [Burrato et al. 2003, Nostro et al. 2005, Winkler et al. 2005, Armelle et al. 2010, D'Addezio et al. 2014] as a consequence of the need for science literacy, with the by-product of the positive perception of science by society [Fung 2002, Christidou 2010].

However, the communication of science is not an easy task, as it involves skills and techniques that are typical of a broad range fields of study, such as sociology of education and of knowledge, up to dialectics. The topic of effective teaching methods that can encompass broad geoscience studies is under development and still needs extensive research [King 2008]. The choice of the language and the tools (e.g., video, animation, hands-on models, enquiry-based learning approaches, and so on) are among the major issues that need to be addressed to make such communication effective, and these tools should be adequate to both the age and culture of the audience.

In many European countries, scientific institutions are nowadays organizing activities of outreach and education in an attempt to establish the most appropriate way to communicate scientific knowledge, and to determine the effectiveness of the methods, the best target audience, and the social and cultural values to which they should refer [Virieux 2000, Burrato et al. 2003, Cantore et al. 2003, Picq et al. 2003, Bernhardsdóttir et al. 2012, Lanza et al. 2013, Musacchio and Pino 2014, Musacchio et al. 2015a]. One of the basic outcomes is that an active interaction between the world of research and schools is of paramount importance in the education process. Thus, outreach programs should include the chance for school students to visit scientific laboratories, where feasible, and to interact with scientists at different events, such as at science fairs, public exhibitions, or special venues. Moreover, visits of scientists to schools [Solarino 2009a, Solarino 2009b, Musacchio et al. 2012, Piangiamore et al. 2015] can also lead to preliminary interactions. Finally, *ad-hoc* education programs based on the adoption and use of scientific instruments under the guidance of scientists have the advantage that they convert students from spectators to main actors [Zollo et al. 2014, Piangiamore et al. 2015]. These interactions might fill the gap between the worlds of science and of education, a gap that grows deeper as the misconceptions of teachers of the geosciences are passed on to their pupils [Oldershaw 2004, Bernhardsdóttir et al. 2012, Musacchio et al. 2015a]; indeed, the core science textbooks on the market are riddled with errors [King 2010, Bernhardsdóttir et al. 2012].

Due to the predominant cultural heritage of the liberal arts, the Italian education system is strongly imbalanced toward the humanities, and very few schools have specific programs that are preparatory for technical university studies. In such an organization, the time devoted to scientific topics is usually limited to two or three hours *per* week, while the subjects to be taught are very wide (e.g., biology, chemistry, Earth and natural sciences). Although Italy is affected by seismic, volcanic and hydrogeological hazards, these topics do not have 'priority', and often school teachers demand upgraded school materials to update their school programs.

In 2011, the Istituto Nazionale di Geofisica e Vulcanologia (INGV hereinafter), which is a research institution that in Italy has long experience in science outreach [e.g., Burrato et al. 2003, Nostro et al. 2005, Winkler et al. 2005], launched a new outreach activity called *ScienzAperta* (Open Science) (http://www.scienzapertaingv.it/), which is considered the 'spring of science'. This consists of a several-weeks-long period in which students and the general public have access to scientific exhibitions, hands-on laboratories for children, meetings and seminars with researchers, and guided tours to scientific laboratories, to raise their awareness about the Earth sciences in their daily lives. The common goal is to engage INGV researchers in correct, straightforward and efficient communication with the public concerning research and technological innovations [D'Addezio et al. 2014]. This is an initiative at a national level that every year involves several INGV venues.

This paper describes an alternative approach to science education that was carried out within the framework of the *ScienzAperta* 2012 edition at the 'Giacomo Doria' City Museum of Natural History in Genoa, were the INGV held an exhibition called *Come è profondo il mare* (How deep the see is). The exhibition was held over 5 months (from February to June, 2012), during which there were visits by about 18,000 visitors, 4000 of whom were school children. Specific laboratory activities were included within the exhibition that were aimed at children of ages of between 8 and 15 years. These activities were finally included within a game that was called "Scientist as a game", which was designed under the format of learn-by-doing. "Scientist as a game" has been performed on six other occasions within various science venues, which has involved more than 500 students (Figure 1).

The choice of the target age of the attendees was the result of past experience and some pedagogical observations. In activities held in the past, it has been shown that older students are afraid of being judged by others and of being 'excluded' from the group; here, being interested in the Earth sciences, in biology, or in anything

Figure 1. The award winner ceremony at the INGV congress hall in Rome during *ScienzAperta* 2013.

that has to do with school might become a weak point in front of the others. Moreover, the older students do not like to expose themselves to competitions, because if they did not win, then they can lose the respect of the group. Finally, older teenagers are often very negative toward 'the world of adults', and initiatives like ours do not intrigue them enough. Visiting a museum for few hours is certainly not appealing to them, even if the activity within this time frame is organized as 'game'.

On the other hand, we realized that although they do show differences, the behavior and mood of students aged 8 to 15 are actually very similar. The activities included in "Scientist as a game" were designed to take into account the different approaches and culture of the students, so that an individual could express them self. As will be discussed later on, younger children are very intuitive and prompt in manual activities, while older students are more attracted by intellectual activities.

The experience described here has outcomes related to both preparedness for natural hazards and research fields. The topics that we have addressed within the activities described here can be fundamental to raise awareness of hazards, and should contribute to preparedness and disaster resilience. The research problem embraces communication of the geosciences and the raising of awareness of natural hazards in a land that is prone to them, and where this knowledge is often not adequately provided by formal education. Indeed, the geoscience topics included herein are typically lacking or not thoroughly discussed in schools, regardless of the potential existing hazards [King 2010, Komac et al. 2013, Musacchio et al. 2014, Musacchio et al. 2015ab]. It is widely recognized that science outreach activities are a successful tool to help the ill-informed public to discover, gain awareness of, and understand science and technology. Nonetheless, we must indicate that to estimate the level of involvement that any given audience might have is not an easy task: the interest toward the activities might lead to misperception between amusement and educative content. These points will be discussed in the last section of this article.

Hands-on activities

Research has highlighted that all sorts of increasing motivational appeal can significantly raise learning and retention, such as embellishment and actions toward raising curiosity [Berlyne 1978, Lepper and Cordova 1992, Loewy 1998, Lambropoulos and Bratitsis 2014]. Manipulative models, graphically enhanced images, specifically designed story contexts, and/or exciting anecdotes or challenges included within a game can be considered as ways to trigger the interest of students. These are tools that can enhance learning if they draw attention to important topics and some specific aspects of a subject. However, they need to be used with special care so as not to have negative effects on learning, which can occur if they draw attention toward minor, incidental or irrelevant aspects [Lepper and Cordova 1992].

Making learning enjoyable motivates students and helps them to pay attention and to stay focused on the subject. Unfortunately, experience has shown that the success of the formula of 'learn while playing' is proportional to the attitude of the students to this 'play': it can work well with younger pupils, while it might not have similar success with older students. Bearing this in mind, we can say that the interest in an exhibition certainly grows if the students are given the chance to learn-by-doing and not just by reading texts displayed on panels or watching movies and animation.

This idea provided the basis of the laboratory activities that were organized for and with the students who attended *Come è profondo il mare*. This is an exhibition that is designed to explore the Mediterranean Sea, beginning at the early stages of its formation, and moving up to the present day, while providing snapshots of the natural phenomena that contributed to its evolution. Here, earthquakes, volcanoes and tsunamis are discussed within the framework of disasters that have hit the Mediterranean Sea, and that were nonetheless responsible for its evolution. These activities were designed to be complementary to a guided tour of the exhibition, and they are set in an extremely simple way so that the children can replicate them at home. They also address some crucial aspects of the natural phenomena presented in the exhibition. We always have scientists carrying out the activities, which is intended to provide an authoritative voice that puts more emphasis on the accuracy of the information provided. They will have to provide the needed explanation and information for the children to be able to run the activities.

The main four interactive activities (see Appendix for more detailed descriptions) are:

(1) *The plate-tectonics puzzle*: this provides an understanding of the occurrence of earthquakes and volcanoes;

(2) *Shield and strata volcanoes*: this simulates volcanic eruptions linked to those shown in the exhibition videos, and emphasizes the related hazards;

(3) *Let's try to build our own house*: this provides an understanding and some experience of the ground shaking effects on buildings;

(4) *What should I do and what should I take with me in the case of an earthquake?*: This is a training exercise to enhance preparedness in case of an earthquake.

Some of these laboratory activities were run through the whole period of the exhibition, so that the visit to the museum could be organized as a guided tour that was followed by hands-on experience, to help in the retention of the major concepts. In addition, each proposed activity was introduced by explanations from researchers, to provide the children with the necessary skills.

For the *ScienzAperta* special event, all of the activities were linked into a comprehensive education 'marathon', where several teams of students challenged each other by collecting points within each activity in a real, but friendly, competition. Indeed, we found that additional appeal can be provided by adding manipulative activities that are set up within a score and game context, where students can team up and share their abilities to meet targets that scientists arranged to emphasize specific aspects of the subject. Generally speaking, this kind of framework emphasizes the moments to have fun, to sharpen the knowledge and interactivity of the participants. Furthermore, competitions and a social atmosphere make players keen to become involved. In this case, the scientists carried out all of the activities. As indicated, this was intended to provide an authoritative voice, which puts more emphasis on the accuracy of the given information.

Here we describe some crucial aspects of the activities included in the game, while we provide a detailed description in the Appendix.

The plate-tectonic puzzle

Having a real wooden puzzle that represents the tectonic plates can be an interesting hands-on tool to understand the distribution of earthquakes and volcanoes on Earth, to get a feeling for how thick the lithosphere is, to understand where the major plate boundaries are located, and to learn the names of the major plates.

The puzzle we used is a build-up information tool where only the plate motion is the given data, with a brief explanation of plate tectonics theory offered before the activity starts (Figure 2). As well as reassembling the puzzle, the students have to guess the names of the plates, the most likely locations of earthquake epicenters and volcanoes, and position pop-up figures of plate margins accordingly. Wooden labels that display the plate names, cardboard symbols for epicenters, and small play-dough volcanoes give the embellishment elements. Four wooden blocks display the cross sections of the plate margins.

The puzzle parallels some aspects of real plate tectonics, as it is cut to exactly match the major lithospheric plates, and it is stiff enough to suggest that plate break-up is not an easy process. Vectors that represent plate motion suggest the occurrence of the different margins. Additional information needs to be given to allow students to guess the plate names (i.e., the major continents, or place name information) and the dip of the subducting planes.

When introducing the game, the scientists emphasize that the finite thickness of the plate is very small compared to the Earth radius, and that it matches the lithosphere. It can be highlighted that the lithosphere is the most fragile layer of the Earth as it can break up, and within which most earthquake hypocenters are located. It must be explained that the majority of earthquakes and volcanoes occur at the plate boundaries.

Within the game, the teams have the chance to win points according to: (1) the number of earthquake epicentres and volcano cones they have placed in the right positions; (2) the number of plates names they have correctly inferred; and (3) the number of plate margins they have recognized.

Figure 2. Laboratory activities of "Scientists as a game": *The plate-tectonic puzzle*. Small play-dough volcanoes and earthquake epicenters have to be placed according to the plate dynamics.

Shield and strata volcanoes

Volcano models that represent the two different types of volcanoes, as shield and strata volcanoes, are used for simulation of lava and pyroclastic flow. The lava flow simulation (Figure 3a) is the well-known baking soda model, where baking soda represents the magma that surges from the volcano conduit as it is forced by gas pressure, which in the model is represented by carbon dioxide gas produced by sodium bicarbonate reacting with the acetic acid in vinegar. If it is trapped in a confined space, the pressure of the gas will increase until it can force its way out of the volcano model conduit. As the gas comes out of solution, it makes the liquid frothy and forces it to spill out of the vent. Comparisons to real volcanoes can be highlighted, as eruptions occur because the pressure increases in the magma chamber, which ultimately forces the magma to the surface; therefore, a home-made volcano can simulate the main physical aspects of the natural phenomenon.

Baking soda and beans are pumped out of the vent to simulate pyroclastic flow (Figure 3b): the column rises upwards, and once the flux has risen to its maximum height, it is then blown away by the wind and collapses all around the volcano, as well as further away. As baking soda is a light powder, it easily raises upward in a fan-shaped flow, and gravity forces the beans to fall down, to follow a parabolic trajectory. The soda deposition is thicker near the vent and thins rapidly further away. The size of the volcano must be on a scale such that the maximum height the pump can raise the flow up, and discussions on the effects that ash flow can have on aircraft can be raised. Finally the salty taste of the baking soda combined with the light weight of the powder is appropriate to help the students to understand that an eruption can have effects that occur much farther away from the actual vent: they can taste the baking soda that is spread out by wind, even though they are not actually hit by the flow.

Here, basic questions can be used to evaluate the effectiveness of the activity in terms of providing comprehension of the phenomenon and assigning points to the teams within the game. The children will have to make reliable observations on: (1) the most hazardous eruption; (2) the most prevalent physical states within eruptions; and (3) the particle trajectories and the related hazards.

Figure 3. Laboratory activities of "Scientists as a game": *Shield and strata volcanoes*. (a) Lava flow eruption from a shield volcano model. (b) Baking soda powder is pumped out of a volcano vent to simulate pyroclastic flow. The children are holding a paper airplane that is positioned at a flight height that is scaled to the height of the volcano.

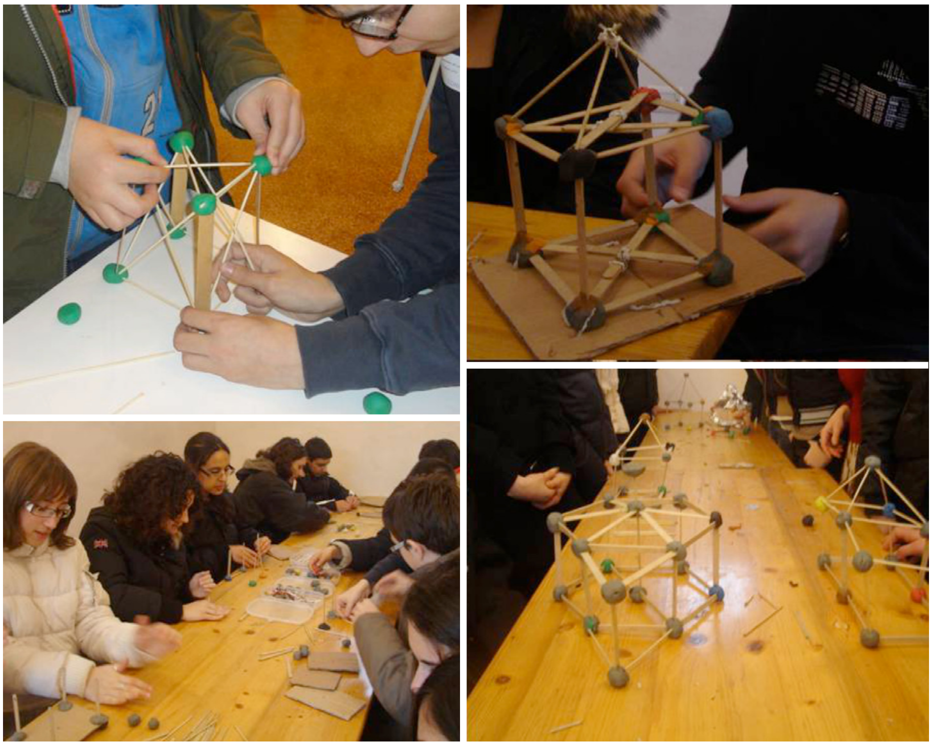

Figure 4. Laboratory activities of "Scientists as a game": *Let's try to build our own house*. Children challenge their abilities to find the best earthquake-proof building.

Let's build our house

Children are provided with sticks, play-dough balls, and strips of aluminium foil, and they are asked to build houses (Figure 4). A simple model of what they will have to do needs to be shown to them while explaining the basic concepts of building resistance and deformation. They will work together within small groups (with no more than 2 or 3 students in each) to add on basic shapes and have buildings that reach lateral extents and heights that might not survive the shaking. When struggling with structures reinforcement, longer sticks or strips of aluminium foil can be used to act along diagonals to support the building of walls. This is an extremely simple simulation of a structural engineering problem that gives insights into what can be done toward risk reduction.

This playful learning activity can trigger thinking toward the most stable geometric shapes and for their use or non-use. The children will definitely try to build pyramids and will discover their strong resistance to shaking; here, the scientists need to ask why towns formed of pyramids do not surround us. A house should resist shaking and provide a comfortable living space. This is the case of cubic buildings, which thus generates box shapes that are repeated and widespread within our towns.

Points are awarded according to the ability of the team to: (1) build the most resistance building that is also suitable as a comfortable living space; and (2) answer basic questions on the most resistant shapes and heights. The fun in the game will help the children to remember the importance of choosing a safe home for their family. To withstand an earthquake, we must build according to building codes, and we need to strengthen existing buildings.

What should I do and what should I take with me in the case of an earthquake?

This activity concerns preparedness in the case of an earthquake. It provides insights into what the appropriate behaviours are during and after the shaking, and what the most valuable supplies are in the case of evacuation. It also takes into account that local officials and relief workers will be on the scene a few hours after a disaster, but that they cannot reach everyone immediately. This activity is divided into two parts: Part A - *What should I do?*; and Part B - *What should I take?*

In *What should I do?*, the children are given cards that depict the possible scenarios during and after the earthquake shaking. They need to be provided with basic explanations before they are asked to think about the appropriate behaviour. Points are awarded according to the number of cards placed inside the 'do's' or 'don'ts' baskets.

The second part of the activity concerns what they should take with them in the case of an emergency. The children will have to put together an emergency kit backpack by choosing among several items provided on a table. The target is to trigger the children into thinking about their daily lives and the comforts that they can live without, and what they really need in the case of an emergency (Figure 5).

To make the game more challenging, mixed in with the basic emergency supplies there are several non-essential items, some dangerous items, such as a cigarette lighter and candles, which might cause fire, along with some truly unnecessary items. We suggest that having an emergency kit ready to grab in the case of the need to evacuate will help them to survive and face the hours outside waiting for help.

Figure 5. Laboratory activities of "Scientists as a game": *What should I do and what should I take with me in the case of an earthquake?* The children have to pick the objects that might be useful in an emergency pack in the case of an earthquake.

The children are provided with a scenario (e.g., a dark cold winter night when an earthquake forces you to leave home) and they need to list a number of details that they need to consider, such as: (1) it could be dark (a rechargeable torch is needed); (2) they will have to walk on rubble (comfortable boots are needed); (3) they might get thirsty or hungry (water and energy foods are needed); (4) it might be cold or raining (a jacket is needed); (5) they might need to signal for help (a whistle is needed; (6) they might be injured (a first aid kit is needed); or (7) they might need some 'comfort items' (a non-essential item can be included).

Each item is given points according to whether or not it belongs to the recommended basic supplies (see Appendix, Table 2), and how important it is. To emphasize that it is extremely important to take just a few basic essentials, points are taken away (or they are reduced) if the children take more than the seven items that they are asked to take.

A game to enjoy science

We have tested the framework of a comprehensive competition that includes the activities within "Scientist as a game" to highlight that science can be enjoyable as a game. The students are teamed up and required to take part in the activities. Each activity allows the teams to gain points that depend on the ability of the participants to fulfil the specific tasks: to reassemble a puzzle, to correctly position earthquake epicentres and volcano cones, to simulate an eruption, to build the most reinforced house, to pick up the essential objects that are needed during an evacuation, and to answer key questions.

The teams were named after the animals that are displayed within the rooms of the Museum of Natural History (e.g., lions, bears, and others) where each activity is carried out. The teams should included students of different ages, as we have seen that the challenges related to each activity are handled correctly depending on the ages of the children. As an example, the plates puzzle is a typical activity where the younger students are will be the faster to assemble the pieces. However, when it comes to placing the geodynamic environments in the correct positions on the puzzle, the older students are usually more skilled.

Each activity has to be run within a given time period, and the students should be involved in discussions and conclusions that allow them to gain more points. To encourage the students to carefully read and to understand the panels shown in the exhibition, a list of questions are also posed, the answers of which are hidden within the displayed texts, and they also add to the final score.

Although the activities are organized as a competition that ends with the declaration of a winning team, we noted that all of the teams are very proud of their results, and will indeed sometimes argue with the scientists about their choices and answers in an attempt to defend their point of view. A general rule to determine whether the activity has enhanced learning was suggested by Lepper and Malone [1987]: the actions that are required for the students to learn the material presented (i.e., to meet the objective of the activity) and the actions required for the students to enjoy the activity should either match up or be mutually reinforcing. Bearing this in mind, we set up each activity so that those that were needed to gain points matched the actions that the students need to take to learn. This match, although not providing an assessment on the effectiveness of education, it does suggest whether the activities did amuse while enhance learning.

We can certainly state that the main targets of the initiative, which among others, were to make the students to use their ability to find information and to make use of logic, have been realized. The students were left free to discuss the answers and the actions they were taking, so that we could verify that logic was among the driving forces in their results. It was also interesting for the scientists to listen to arguments they were put by someone who could look at their work from a different perspective.

Discussion and conclusions

There is a large amount of literature that shows that the subjects we have addressed are strongly underestimated in schools, by both textbooks and teachers [Wisner 2006, Komac 2009, King 2010, Komac et al. 2013, Musacchio et al. 2014, Musacchio et al. 2015ab]. "Scientist as a game" can be considered as an experiment in how to provide additional and/or up-to-date knowledge to students on a subject they might not get the chance to learn fully in school. Simply judged by the discussion the students have within their teams or by the high number of points they gain during the competition, we can reasonably expect they learn most of the concepts that we want them to learn.

The students do learn, for instance: that the tectonic plates are made up of the lithosphere (and not the crust), the only layer of the Earth that can produce earthquakes; that living in a land prone to volcanic or seismic hazards means that they are close to a plate boundary; that some plate boundaries have higher levels of hazard; that living close to a strata volcano can be extremely dangerous, and can require actions to be taken toward risk mitigation; and that thinking about what should be included in an emergency kit can be of great help. All of this information is believed to be fundamental to the raising of awareness of natural hazards and the triggering of risk reduction [Stoltman et al. 2007, Horton 2011, Bernhardsdóttir et al. 2012].

We have found that it is extremely important to set up the correct language, where the words are chosen so that everyone can understand. When we used technical terms, we always offered concrete examples that the students can relate to, so that complex scientific information can be within everyone's grasp without distorting the meaning.

The hands-on approach gives the students a chance to explore and learn by doing. However, as some parts of the activities are more conceptual than manipulative, we also use an inquiry approach, where we do not give the students all of the answers, while suggesting questions instead. One example is the plate-tectonics puzzle, where the basic concepts have to be presented before starting the activity and are used throughout the game to stimulate the development and evaluation of explanations (see Appendix). The experiments are also kept simple and affordable, to be attractive to teachers who might be looking to replicate the activities in their own classrooms, and for the children to want to repeat them at home. It is interesting to see that as the children grow older they lose the ability to observe simple things, such as the shape of a puzzle piece, and when they are asked to build the plate-tectonics puzzle, the younger the student is, the faster they can complete it.

If enthusiasm shown by the children can be used to assess in a qualitative way the appreciation of the activities we can argue that our experience reinforces the research review [Lepper and Cordova 1992]. In a rapidly evolving society, students tend to shy away from traditional methods of learning, although the regular curriculum must be based on standard teaching programs and methods. The introduction of hands on activities has the extra advantage of 'giving the students a break' in the regular flow of information, and giving them the chance to carry out activities by themselves. This not only forces them to apply their knowledge and define the actions that are necessary to carry out the activities, but it also reinforces their view of 'live' science that deals with real and everyday problems. The students also experience their first steps toward the world of research, where a hypothesis is often preceded or followed by activities to reproduce or confirm the findings.

Finally, these activities allow continuous interactions with the researchers, who represent the most reliable and authoritative scientific information context to explain the social impact of science and technology. Research has shown that geoscience education will progress most effectively through the extending of geoscience learning to children, while also educating their teachers in effective implementation of new curriculum initiatives [King 2008].

The issues related to how effective the initiatives described in this study are remain a key question. In particular, estimation of the success in terms of 'improved knowledge' is a critical point, because such an issue depends on many factors, which include the background knowledge of the participants, their expectations, and their own approaches to learning. There is no objective way to assess these, in particular after a single participation. Any improvement (assuming some) can only be estimated in the long term. There no objective way to let the children understand whether they know more, or are better informed, after the experience.

However the main goal of the activities is not to teach 'the science behind' the activities (which is the duty of schools), but to help the children to understand the experimental character of the Earth sciences, to teach them how to pose questions and to reason about the multiple educational aspects that a single activity can exploit. Bearing this in mind, to be able to define the pros and cons of each laboratory during *ScienzAperta* 2013 questionnaire was handed-out to participants. Questions like "Was it difficult to follow/ understand?" or "Was all clear?" simply give information about whether the message was correctly presented, while not indicating whether it was fully understood. Nonetheless only 20% of respondents considered the activities difficult to understand, while all of them perceived them useful and well organized. Interesting indications come from the part of the questionnaires where the children can express their criticism. A few complained about the shortage in time allowed for each activity, some asked for more laboratories, a few complained that when working in groups, the individual "does not do very much", because the actions are shared. The most successful activity was *What should I do and what should I take in the case of an earthquake?* for which 60% of both boys and girls indicated that from this part of the game they achieved useful information.

One aspect that can instead be assessed is the increased awareness about theirs own protection in case of danger. Indeed, the discussions about the behaviour to be adopted during and after an earthquake, and their likely continuation at home or school, provided the evidence that the children did understand the importance of being prepared and being able to react correctly after a natural disaster. Some of the questions and objects in the laboratories of *What should I do and what should I take in the case of an earthquake?* were intentionally designed to promote discussion (e.g., whether to use the telephone to get into contact with parents and relatives, to shut off the gas or electricity) and to converge on a unique viewpoint where safety is the main goal.

Another interesting issue is to estimate how much improvement is gained by carrying out activities like those described here, with respect to traditional methods. Research on science education has extensively shown the effectiveness of hands-on activities [Tan and Wong 2012], even when compared to hands-off, but appealing as education technological methodologies [Sianez et al. 2010], and even if applied to theoretical science as mathematics can be [Barnes and Libertini 2013]. Therefore, in our case, it has not been possible to make such an assessment, except the evidence that the children were not 'bored'. The enthusiasm of the students is indeed a qualitative index, but a quantitative estimate can only be established through comparisons with students who have only been educated through the standard and alternative approaches. This also poses questions about the repetition of the experiment to a wider audience, or for more topics to be included, or even the introduction of these approaches in educational school programs. Indeed, these kinds of activities are generally costly in terms of planning and cannot be carried out very often. They would imply the need for closer cooperation between schools (or society) and research, which is only feasible for pilot projects that are limited in time. It must be noted that part of the improvement is probably due to the presence of one or more researchers, who are 'unknown' to the audience and thus also represent an element of additional 'curiosity'; they probably also get more attention and respect from the students due to their role and importance in the community.

One way to render these projects more accessible without completely redesigning the school–research system might be to convert them into 'virtual' projects by publishing some of them on dedicated web pages. In particular, some of them can easily be exported to the internet, like those that are organized as questions, answers and corrections, while some others would need further arrangement to go 'digital'. However, we firmly believe that any efforts that are possible should be promoted to bring the worlds of research and school as close together as possible; after all, today's students are the potential researchers of tomorrow.

Acknowledgements. The authors acknowledge the 'Giacomo Doria' City Museum of Natural History in Genoa for their hosting of the exhibition, the related activities, the general game and all the support given by the museum director, Giuliano Doria. Activities with schools were run by Museum Educational Association of Genoa. We are thankful to Campo dei Fiori Regional Park for financial support in building some of the laboratory activities. The authors also acknowledge A. Patera for critical reading of the manuscript. Laboratories activities were held several times and within various science venues organized by INGV although not within a game marathon. We thank all the collegues that helped us to run the activities. We are particularly grateful to Rossella Forsinetti, Donatella Pietrangeli, Chiara Badia, Stefano Bucci, Francesca Caprara, Stefania Conte, Valeria Gallotti, Massimo Miconi, Valeria Misiti, Enrico Rocchetti who helped us with the game marathon held in Rome during *ScienzAperta* 2013.

References

Armelle, A., F. Marazzi and D. Tirelli (2010). Introducing students to structural dynamics and earthquake engineering, Physics Education, 1, 76-82.

Banchi, H., and R. Bell (2008). The many levels of inquiry, Science and Children, 46 (2), 26-29.

Barnes, J., and J. Libertini (2013). Introduction to special issue on tactile learning activities, PRIMUS, 23 (7), 585-589.

Berlyne, D.E. (1978). Curiosity and learning, Motivation and Emotion, 2 (2), 97-175.

Bernhardsdóttir, A.E., S. Thorvaldsdóttir, R. Sigbjörnsson, G. Musacchio, R. Nave, S. Falsaperla and M.J. Jimenez (2012). Disaster prevention strategies based on an education information system, Presented at 15 World Conference on Earthquake Engineering, Lisbon, Portugal; http://hdl.handle.net/2122/8148.

Burrato, P., P. Casale, G. Cultrera, P. Landi, R. Nappi, C. Nostro, P. Scarlato, C. Scotto, S. Stramondo, A. Tertulliani, A. Winkler and U. Bonifaci (2003). Geophysics for kids: the experience of the Istituto Nazionale di Geofisica e Vulcanologia, Seismological Research Letters, 74 (5), 529-535.

Cantore, L., A. Bobbio, F. Di Martino, A. Petrilio, M. Simini and A. Zollo (2003). The EduSeis Project in Italy: An Educational Tool for Training and Increasing Awareness of Seismic Risk, Seismological Research Letters, 74, 596-602.

Christidou, V. (2010). Greek students' images of scientific researchers, Journal of Science Communication, 9, 1-11.

D'Addezio, G., G. Rubbia and A. Marsili (2014). The experience of *ScienzAperta*, a week of scientific information and dissemination, In: G. Lollino, M. Arattano, M. Giardino, R. Oliveira and S. Peppoloni (eds.), Engineering Geology for Society and Territory, 7 (1), 103-109.

Fung, Y.Y.H. (2002). A comparative study of primary and secondary school Students' images of scientists, Research in Science and Technological Education, 20, 199-213.

Horton, J. (2011). Natural disasters - taking a longer term view, Lancet, 377, 5-11.

King, C. (2008). Geoscience education: an overview, Studies in Science Education, 44 (2), 187-222.

King, C.J.H. (2010). An analysis of misconceptions in science textbooks: Earth science in England and Wales, International Journal of Science Education, 32, 565-601.

Komac, B. (2009). Social memory and geographical memory of natural disasters, Acta Geografica Slovenica, 49, 199-226.

Komac, B., M. Zorn and R. Cigli (2013). European education on natural disasters - a textbook study, Natural Hazards and Earth System Sciences Discussions, 1, 2255-2279.

Lambropoulos, N., and T. Bratitsis (2014). Weaving User Immersive Experiences: Scientific Curiosity and Reasoning with Bodily Feelings Mapping and Evolution, In: P. Zaphiris and A. Ioannou (eds.), Learning and Collaboration Technologies. Technology-Rich Environments for Learning and Collaboration, 62-71.

Lanza, T., M. Crescimbene, F. La Longa and G. D'Addezio (2013). Bringing the Earth into the scene of a primary school: a science theatre experience, Science Comunication, 36 (1), 131-139.

Lepper, M.R., and T.W. Malone (1987). Intrinsic motivation and instructional effectiveness in computer-based education, In: R.E. Snow and M.J. Farr (eds.), Aptitude, Learning, and Instruction: 111. Conative and affective process analyses, Hillsdale, N. J., Erlbaum, 255-296.

Lepper, M.R., and D.I. Cordova (1992). A desire to be taught: instructional consequences of intrinsic motivation, Motivation and Emotion, 16 (3), 187-208.

Loewy, E.H. (1998). Curiosity, imagination, compassion, science and ethics: do curiosity and imagination serve a central function?, Health Care Analysis, 6 (4), 286-294.

Musacchio, G., M. Maistrello and D. Piccarreda (2012). Ricercatori in aula: esperienze di divulgazione delle scienze della Terra [Scientists in the classroom: Earth sciences outreach experiences], Quaderni di Geofisica, 101, ISSN 1590-2595 (in Italian).

Musacchio, G., and N.A. Pino (2014) Laboratory activities for seismic and volcanic hazards education: a challenge for scientists, In: G. Lollino, M. Arattano, M. Giardino, R. Oliveira and S.Peppoloni (eds.), Engineering Geology for Society and Territory, 7, 89-93.

Musacchio, G., A.E. Bernhardsdottir, M.A. Ferreira, S. Falsaperla and the UPStrat-MAFA Outreach Working Group (2014). Long-term disaster-prevention strategies based on education, In: G. Lollino, M. Arattano, M. Giardino, R. Oliveira and S. Peppoloni (eds.), Engineering Geology for Society and Territory, 7, 77-81.

Musacchio, G., S. Falsaperla, A.E. Bernhardsdóttir, M.A. Ferreira, M.L. Sousa, A. Carvalho and G. Zonno (2015a). Education: can a bottom-up strategy help for earthquake disaster prevention?, Bulletin of Earthquake Engineering; doi:10.1007/s10518-015-9779-1.

Musacchio, G., S. Falsaperla, F. Sansivero, M.A. Ferreira, C.S. Oliveira, R. Nave and G. Zonno (2015b). Dissemination strategies to instil a culture of safety on earthquake hazard and risk, Bulletin of Earthquake Engineering; doi:10.1007/s10518-015-9782-6.

Nostro, C., G. Cultrera, P. Burrato, A. Tertulliani, P. Macrì, A.Winkler, C. Castellano, P. Casale, F. Di Felice, F. Doumaz, A. Piscini, P. Scarlato, M. Vallocchia, A. Marsili, L. Badiali, A. Bono, S. Stramondo, L. Alfonsi, E. Baroux, M.G. Ciaccio and A. Frepoli (2005). Using earthquakes to uncover the Earth's inner secrets: interactive exhibits for geophysical education, Advances in Geosciences, 3, 15-18.

Oldershaw, C. (2004). Strengthening teaching and learning of geological changes in Key Stage 3 science, National Strategies, DfES reference 0496-2004 G, 108 pp.

Piangiamore, G.L., G. Musacchio and N.A. Pino (2015). Natural hazards revealed to children: the other side of prevention, In: S. Peppoloni and G. Di Capua (eds.), Geoethics: The Role and Responsibility of Geoscientists, Geological Society, London, Special Publications, 419.

Picq, T., J.L. Berenguer and J. Virieux (2003). French Educational Seismological Network: "Sismo des Ecoles", Seismological Research Letters, 74, 588-595.

Virieux, J. (2000). Educational Seismological Project: EDUSEIS, Seismological Research Letters, 71, 530-535.

Sianez, D.M., M.A. Fugère and C.A. Lennon (2010). Technology and engineering education students' perceptions of hands-on and hands-off activities, Research in Science and Technological Education, 28 (3), 291-299.

Solarino, S. (2009a). Are educational initiatives in schools effectively contributing to prevention?, EMSC Newsletter, 24, 10-12.

Solarino, S. (2009b). Il terremoto a scuola, Emmeciquadro, 37, 108-112 (in Italian).

Solarino, S. (2015). How to strengthen public trust in geosciences, Geological Society, London, Special Publications, 419, 117-124; doi:10.1144/SP419.14.

Stoltman, J.P., J. Lidstone and L.M. DeChano (2007). Capacity building, education, and technical training, In: J.P. Stoltman, J. Lidstone and L.M. Dechano (eds.), International Perspectives on Natural Disasters: Occurrence, Mitigation, and Consequences, Springer, Dordrecht, 457-462.

Tan, A.L., and H.M. Wong (2012). Didn't get expected answer, rectify it: teaching science content in an elementary science classroom using hands-on activities, International Journal of Science Education, 34 (2), 197-222.

Winkler, A., C. Nostro, P. De Santis, C. Castellano, L. Arcoraci, M. Berardi, A. Carosi, A. Meloni, E. Baroux, L. Alfonsi, A. Marsili, G. Cultrera, P. Ficeli, A. Bono, F. Di Felice, A. Piccio, D. Riposati, F. Di Laura, F. Di Stefano, S. Palone, A. Tertulliani, P. Macrì, A. Piersanti, A. De Santis, M. Vallocchia, A. Piscini, L. Badiali, F. Doumaz, P. Burrato, A. Frepoli, P. Scarlato and M.G. Ciaccio (2005). Interactive exhibits for geophysical education: uncovering the secrets of the Earth, WSEAS Transactions on Advances in Engineering Education, 4, 375-381.

Wisner, B. (2006). Let Our Children Teach Us! A Review of the Role of Education and Knowledge in Disaster Risk Reduction, ISDR System Thematic Cluster, Platform on Knowledge and 20 Education, Bangalore.

Zollo, A., A. Bobbio, J.L. Berenguer, F. Courboulex, P. Denton, P., G. Festa and D. Giardini (2014). Workshop and laboratory-based approaches. The European experience of educational seismology, In: V.C.H. Tong (ed). Schools and Public Engagement, Series: Innovations in Science Education and Technology, vol. 21, Springer, 340 pp.

Corresponding author: Gemma Musacchio,
Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy;
email: gemma.musacchio@ingv.it.

Appendix: Activities plan

1. The plate-tectonic puzzle

Objective

The major learning target is to understand the occurrence of earthquakes and volcanoes on Earth. Additionally, discussions can include the thickness of the lithosphere and its mechanical properties. Pre-requisites need to be taken into account according to the ages of the students. Younger students (i.e., up to 9 years old) are just provided with a description of the movements that the lithosphere plates have and with the concepts that earthquakes and volcanoes are distributed accordingly. Older students are provided with descriptions of the plate margins and vectors that represent the plate movements, and with the information that the plates do not necessarily coincide with the continents and oceans, although they are often named after them.

Materials

- A world map on a 2 cm to 3 cm thick wooden plate that is cut along the plate boundaries, like a puzzle.
- Small play-dough volcanoes.
- Cardboard symbols for earthquake epicenters.
- Labels with the names of the major plates.
- Four wooden blocks that show sketches of the plate boundaries: divergent margins, oceanic-to-oceanic lithosphere convergence, oceanic-to-continental lithosphere convergence, and continental-to-continental lithosphere convergence.

Procedure

Actions

Students younger than 8-9 years old (elementary school, 3rd-4rd grade) will only be challenged to reassemble the plate puzzle. They will have to place the volcano cones and earthquake epicenters according to the plate tectonics. Older students will have to guess the names of the plates and place the volcanoes and earthquake epicenters in the right positions according to the Earth dynamics, and not to geography. The scientist needs to provide information to enable the students to ask about the plate names: possible suggestions are the relationships between the tectonic plates and the continents that they host. Additionally, they will be required to guess the type of margin according to the plate motion vectors plotted on the map, and place the corresponding wooden block sketch at the margins.

Discussion

Here the discussions represent an evaluation of the acquired competence, and the requirements that the students need to meet are, according to:

1. Place volcanoes and earthquake epicenters according to plate tectonics.
2. Infer the names of the major plates. In case of doubt, they can ask for suggestions, while the points they can win will decrease accordingly.
3. Place the plate boundary sketches according to the plate movements.

Evaluation

The evaluation is carried out on the basis of the actions the students take to meet the requirements. We give 1 point for each volcano, earthquake epicenter, plate name the student placed correctly. We gave 3 points for each sketch properly placed. When student needed suggestion we gave a minus 2 point each. This provides an estimation of the effectiveness of the learning activity.

2. Shield and strata volcanoes

Objective

The major learning target is an understanding of the hazards related to lava and pyroclastic flow. Additional learning targets that can be fulfilled by the activity are: (1) the relationships between volcanic activity and cone morphology; (2) the energy required for an eruption to occur; and (3) the distribution of lava and pyroclast around a vent. The pre-requisites should be considered according to the ages of the students. However, general descriptions of the volcano structure and the eruption mechanisms need to be provided in advance.

Materials

Volcano models have to be prepared before the activity starts. These can be made of any kind of play-dough or clay, as long as the typical shapes of shield and strata volcanoes are represented. However, when the activity is not part of a complete set-up, and when the audience includes young pupils (6-9 year olds), the volcano cones can also be modelled as part of the activity. Each pupil will have to build their own play-dough volcano, taking into account how volcanoes grow and evolve through their lives.

Procedure

Action

Lava flow - baking soda and vinegar are used to simulate low viscosity and gas-driven lava flowing down the flanks of a shield volcano. The vinegar is col-

Lava flow	Pyroclastic flow
Baking soda	Baking soda
White vinegar	Various sized beans
Red coloring powder	Pebbles (less than 5 mm in size)
An empty bottle	A funnel
	A paper airplane
	An inflatable boat pump

Table 1. Eruption simulation (materials needed).

ored red with the use of a coloring powder. Inside the shield volcano vent, a small container (3-4 cm in height) without a lid (i.e., a half sphere of child's plastic egg or a bottle cap) is glued to the crater. The baking powder is placed inside the container and the vinegar is added to promote the chemical reaction.

Pyroclastic flow - A mixture of baking soda powder and beans represents the pyroclasts and is used to fill in the strata volcano conduit. A pump is connected with the conduit that has to force the mixture out of the vent and high up in the air, to reproduce the shape of the ash cloud and the distribution of pyroclasts around the vent. A paper aeroplane is positioned at a height that is in scale with that of the volcanic cone, to represent the flight height of aeroplanes.

Discussion

We use a structured enquiry-based approach here [Banchi and Bell 2008], where the questions and procedures are provided, while the task is to generate an explanation that is supported by the evidence collected in the procedure. The questions that can be posed to guide the enquiries are the following:

1. What kind of eruption is the most hazardous
2. Why?
3. What is the difference between lava flow and pyroclastic flow in terms of the physical phases that mostly occur?
4. Where does the ejected material build up the most?
5. What can we do to reduce risk exposure?

The experiment can answer each of these questions, and the students will have to make their own observations.

Evaluation

The evaluation is on the basis of the answers given to the above questions. A correct answer gave 5 points to be summed up to the final score. This provides an estimation of the effectiveness of the learning activity.

3. Let's try to build our own house

Objective

The major learning target is to understand the ground-shaking effects on different types of buildings. However, this activity can provide the following additional understanding and skills: (1) the existing relationship between the type of construction, the materials used, and the resistance to seismic shaking; (2) how to critically observe your own house or school; and (3) how to improve the response of your own house to ground shaking.

Pre-requisites need to be considered according to the ages of the students. The children must create their own house in a 'safe' city by taking into account whether they live in a seismic zone or not. Which house will not collapse after the 'earthquake' shaking?

Materials

- Play-dough balls of the same size.
- Wooden sticks of different lengths and thicknesses.
- Strips of aluminum foil.

Procedure

Action

The children are asked to build houses using the wooden sticks and play-dough balls (Figure 4), but the houses have to resist the shaking of an earthquake. Actions need to be taken to reinforce the buildings. The sticks are of different lengths (i.e., to be positioned along the diagonal of the face of a cube) and thicknesses (to experience different parameters linked to resistance to the shock). Strips of aluminum foil can be used to brace the walls of the buildings.

After building their homes, the children can jiggle the table support to simulate more and more intense earthquake shaking. Some houses will collapse, others will only be damaged, a few will remain unscathed. The scientist will have to trigger the student comments in terms of what are the characteristics of the most stable buildings, in terms of (a) their shape, (b) the reinforcement techniques, and (c) the elastic properties of the materials chosen.

Discussion

Keeping in mind a structured enquiry-based scenario, several questions that can be posed are:

1. What are the characteristics of a safe house?
2. What kind of building is the most hazardous, and why?
3. How does the geometric shape affect the stabil-

ity of a building?

4. How important are the building materials?

5. What can we do to reduce risk exposure of our own house?

The experiment can answer each of these questions, and the students will have to make their own observations. This representation of different types of buildings is a simple but effective experience to simulate the effects of an earthquake on a city. The children will try to build their houses with different basic shapes such as cubes and pyramids. They will add more and more complicated structures, to reach lateral extents and heights that might not survive the shaking. The most stable geometric shape we can think about is a pyramid. Although this is a very well-founded building shape, it is not very functional, and it does not optimize the living-space (making a pyramid town is therefore uneconomical and uncomfortable). On the other hand, the cube is a practical and stable shape to live in, to make the best use of the space. The cube is the most wide-spread geometric shape in buildings in modern towns.

The scientist should trigger discussion on how we can strengthen our houses, working on their resistance to earthquakes (e.g., curbs, tie rods, tension straps, anchors). The fun in the game will help the children to remember the importance of choosing a safe home for their family. To withstand an earthquake, we must build according to the building codes and we need to strengthen existing buildings.

Evaluation

The evaluation is given on the basis of the answers the groups give to these questions. Proper answers to the above questions gave 5 points each. This provides an estimation of the effectiveness of the learning activity.

4. What should I do and what should I take with me in the case of an earthquake?

Objective

The major learning target here is to enhance preparedness and resilience in an earthquake scenario, promoting the importance of safe behavior in the case of an earthquake. Knowledge of the appropriate behavior in the case of an emergency is fundamental for prevention, therefore this activity gives insight to the children while playing a game. The activity is divided into two parts: Part A - *What should I do?*, and Part B - *What should I take with me?*

Part A - **What should I do in the case of an earthquake?**

Materials

- Playing cards that give simple scenarios that might arise within and after the shaking.
- Billboard.
- Box for correct behavior.
- Box for incorrect behavior.

Procedure

Action

The children are given the cards where the scenarios during and after earthquake shaking are shown. They have to decide which situation is appropriate and discard the one they are not supposed to follow. The teams gain points according to their responses. Each card gives insight and in-depth discussion on what to do to prevent the danger of objects falling during the shock, to evacuate the building in the safest way, and other similar aspects. The student comments are discussed together with the scientist, to reinforce the simple, yet important, basic rules that support the use of common sense in difficult situations.

Knowing what to do in the case of an earthquake represents our defense against disasters. This is an important leverage resource to avoid disasters. We emphasize also that those who know what to do are also helpful to the entire community.

Discussion

The scientist has to explain every card, whether or not they belong to an appropriate or non-appropriate behavior. The students will have to think about the importance of human behavior when a disaster is taking place, and about the benefit to the entire society if prevention and safety become a rule.

In particular, all of the most common circumstances are included on the cards, with several pitfalls to complicate matters, such as:

1. If you are in one place or another (e.g., outdoors, at home, at school).

2. When you adopt the same behavior (e.g., during or after the shock, in one place or another).

Part B - **What should I take with me in the case of an earthquake?**

Materials

- A backpack.
- Several everyday life items that can trigger discussion on their usefulness in the case of evacuation. These items are listed in Table 2 according to whether they are essential to survival, useful but not essential, or not necessary.

Essential to survival	Useful but not essential	Not necessary
Whistle	Torch and batteries	Cigarette lighter
Dynamo torch	Mobile phone	Candles
Radio	Electronic game	Slippers/ flip-flops
Water	USB pen drive	Cosmetics
First aid kit	Hard disk	Bars of soap
Sugar or chocolate	Laptop	Hand cream
Light jacket or small blanket	Glasses	Deodorant
Walking boots	Mask to breathe	Sunglasses
	Aspirin/ paracetamol	Torch and batteries
	Disinfectant wipes	Milk
	Wind-proof jacket	Carbonated soft drinks
	Rain hat	Packets of pasta
	Gloves	Jewelry
	Book	Watch
	Newspaper or magazine	Camera
	Wallet	
	Money	
	Car	
	Soft toy	
	Playing cards or other games	
	Sweets	
	Snacks	
	Cans of tuna	
	Documents	

Table 2. Objects to choose from in the case of an emergency.

It is important that objects such as a cigarette lighter, deodorant, first aid kit, aspirin, hand cream and others are empty or non-functional, to prevent the children from getting hurt.

Procedure

Action

This activity concerns what to take with you in the case of an emergency: the preparation of an emergency backpack that includes all that you need, and no more. The set-up is that there is a strong earthquake coming, so what items might you need if you have to leave your home? We have various objects on a table, as listed in Table 2, to trigger the children to thinking about their daily life. There are items they can live without and others that they really need in the case of an emergency (Figure 5). The children are asked to pick seven objects, on the basis that they might have to leave home for several days, that it might be cold and dark, and that they might need to walk across rubble. They need to decide carefully which objects are most appropriate to their survival in the case of this emergency, and to put these into the backpack of their team. Every item has a points score.

Discussion

The idea behind this is that if just after the earthquake, in a few seconds everybody had a backpack that included the most important things, like a whistle, a dynamo torch, a radio, a first aid kit, water, sugar or chocolate, a light jacket or blanket, and walking boots to wear, we would be ready to face hours outdoor waiting for help. We might even become small civil protection operators, or small fire fighters, able to help and comfort the people around us. To make the game more challenging, we include several objects that might be thought to be useful but that are not essential, such as a mask to breathe, disinfectant wipes, gloves, a wind jacket, glasses, a mobile phone, documents, wallets, money, an electronic game and other (soft) toys, a USB pen drive or hard disk, a laptop, a car, cards or other games, a book, newspapers or magazines, and a torch and batteries. Finally there are the items that are not necessary, such as a cigarette lighter, candles, cosmetics, soap, hand cream, deodorant, jewelry, watches, sunglasses, slippers or flip-flops, a camera, carbonated soft drinks, milk, and packets of pasta.

At the end of the game, the children will have the chance to think about what really matters and how unnecessary certain items are that we might consider essential for everyday life. What is the use of a mobile phone without the electricity to recharge it? What is the use of soap without water? What is the use of pasta if we cannot cook it?

Evaluation

The evaluation is given on the basis of the answers the groups give to these questions. We gave 5, 2 or zero points whether the object was classified essential, useful but not essential or not necessary, respectively. This provides an estimation of the effectiveness of the learning activity.