https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

An innovative *STEM* outreach model to foster the next generation of geoscientists, engineers, and technologists (OH-Kids)

Adrián Pedrozo-Acuña*[1,2], Roberto J. Favero Junior[1,2], Alejandra Amaro-Loza[1], Roberta K. Kurek Mocva[1], Juan A. Sánchez-Peralta[1,2], Jorge A. Magos-Hernández[1,2], Jorge Blanco-Figueroa[1]

[1]*Universidad Nacional Autónoma de México, Instituto de Ingeniería, Av. Universidad 3000, Coyoacán, 04510, Mexico City, Mexico.*

[2]*Mexican Institute of Water Technology (IMTA), Paseo Cuauhnáhuac 8532, Col. Progreso Jiutepec, Morelos, Mexico.*

Abstract

Childhood education programmes aiming at incorporating topics related to science, technology, engineering, and mathematics (STEM) have gained recognition as key levers in the progress of education for all students. Inspiring young people to take part in the discovery and delivery of science is of paramount importance not only for their well-being but also for their future human development. To address this need, an outreach model entitled *OH-Kids* was designed to empower educators and pupils through the development of high-quality STEM learning experiences based on a research project. The model is an opportunity for primary school learners to meet geoscientists while receiving the take-home message that anyone can get involved in scientific activities. The effort is part of a research project aimed at the real-time monitoring of precipitation in Mexico City, which is a smart solution to rainfall monitoring using information and communications technologies. The argument behind this effort is that in order to produce the next generation of problem-solvers, education should ensure that learners develop an appreciation and working familiarity with a real-world project. Results show success at introducing the role of researchers and STEM topics to 6–12-year-old learners.

* Corresponding author now at Mexican Institute of Water Technology
Email: apedrozoa@ii.unam.mx

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

1. Introduction

Inspiring young people to take part in the discovery and delivery of science, technology, engineering, and mathematics (STEM) has been proved to contribute significantly not only to their well-being, but also to their future human development (Bertram and Pascal, 2016; Morgan et al., 2016; Friedman-Krauss et al., 2018). However, the current system uses teaching and learning methods that tend to develop geoscientists, engineers, and technologists only by mere chance. It seems that, in far too many cases, teachers and/or syllabi unintentionally deter potential STEM learners—especially girls—due to the way they choose to teach science, mathematics, design, and technology.

Moreover, in several countries, such as the United Kingdom, STEM topics do not appear on the timetables of pupils of primary or lower secondary age (Bianchi and Chippindall, 2018). This is also the case in Mexico, where promoting and improving student engagement on these topics constitutes a great challenge for teachers. This is ascribed to the lack of professional guidance for early childhood educators, who rarely receive in-depth professional training for teaching STEM (Breneman et al., 2009).

Primary and secondary education have been found to be significant periods for developing students' interest in science and technology (Maltese et al. 2014). At these stages, pupils' interest in science is closely related to the level of appreciation of its applicability in their lives. Therefore, it is important to incorporate activities in the classroom that convey the wider relevance of science to everyday life (Sheldrake et al., 2017). This may encourage students' aspirations towards science and engineering careers (Regan and DeWitt, 2015).

On the other hand, scientific and technological education is evolving rapidly with the advancement of the digital age, so it is inevitable for pupils and academics to transit to the development and use of new strategies that allow the overcoming of observed difficulties in the teaching-learning process (Souza et al., 2018). The generation of new strategies of STEM communication to children constitutes a critical step towards improving not only their learning experience, but also their teaching practice.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

It has been acknowledged that promoting the relevance and utility of science to students enhances their interest in science and boosts their attainment (Rozek et al., 2015; DeWitt and Archer, 2015; Savelsbergh et al., 2016; Sheldrake, 2016). In this regard, a good strategy for promoting meaningful learning is the development and implementation of educational activities through the exposure of pupils to a real-world application of STEM (Smith et al., 2005). The argument behind this effort is that, in order to produce the next generation of problem-solvers, education should ensure that learners develop an appreciation of and a working familiarity with STEM disciplines and human-environmental systems (Breneman et al., 2018).

This study presents an innovative teaching experience to enhance positive effects on the attitude of students towards STEM disciplines (Savelsvbergh et al., 2016). The outreach model entitled OH-Kids was designed to empower educators and pupils through the development of STEM learning experiences focused on water resources and based on a research project.

The initiative is part of the real-time Hydrological Observatory of the National Autonomous University of Mexico's Institute of Engineering (OH-IIUNAM), which comprises a research project aimed at the real-time monitoring of precipitation in Mexico City (Pedrozo-Acuña et al. *in review*). The system represents a smart-water solution comprised by the application of information and communications technologies within an urban environment. Notably, the framework highlights the integration of geoscientists from hydrology, meteorology, and geology, as well as technologists and various practical engineering specialists (hydraulics, electronics).

The outreach model OH-Kids was born from the interaction of the team behind this research project with primary school educators. This communication resulted from the installation of 54 stand-alone stations to measure precipitation in Mexico City, 15 of which were installed on the rooftops of primary schools and nine on the rooftops of secondary schools. In the primary schools, the equipment installation process prompted the interest of educators and pupils in the apparatus and the wider application of science and engineering in the project. This research project was therefore seen as an opportunity to develop an innovative approach focused on improving the attitudes of the students towards science and engineering.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Applied in several primary schools and one science fair in Mexico City, the programme has a design strategy based on principles relevant to all researchers working with educators in settings that include families from different social backgrounds. The paper is organised as follows: Section 2 presents a methodological description of the outreach model, Section 3 introduces the results of the implementation of this programme; finally, Section 4 summarises the main conclusions.

2. OH-Kids: a *STEM* outreach model

The OH-Kids outreach model comprises a collaborative and effective researcher-educator-learner communication strategy—built around principles of engagement and guided discovery learning—to encourage STEM subject uptake. In this sense, the model was designed following an approach that involves the exposure of learners to a real-world-application STEM project using games and hands-on activities as educational and didactic tools (Parson and Miles, 1994; Poljak et al., 2018). Our proposal for the model design was based on different documented efforts that had an effect on classroom practice and child outcomes (Design-Based Research Collective 2003; Drago-Severson 2009; Zaslow et al., 2010).

Following Rogers et al. (1988), the activities are designed on the basis that involvement of children is beneficial for their learning process, using their innate curiosity as a starting point (McIntyre, 1984 and Piaget, 1971). Educational games and activities have been recognized as a valid strategy to enhance student engagement and develop key skills that may be applicable in other contexts, such as the ability to work as a team (Butucha, 2016; Garris et al., 2002). Students learn as a consequence of playing, which promotes meaningful learning (Croxton and Kortemeyer, 2018).

The creation of a learning experience that promotes participation and science teaching in an active learning environment has positive effects on all children regardless of their literacy and social origin. Indeed, this approach has been found to create a rich learning environment that is accessible to all the students in the classroom (Fantuzzo et al., 2011; Sarama et al., 2012). Furthermore, studies have shown that there is a correlation between positive experiences in science as a child and a strong interest in and a positive perception of science as an adult (Falk et al., 2017).

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Geoscience Communication
Discussions
Open Access
EGU

The intention of the OH-Kids outreach model is to enhance thinking skills related to STEM disciplines with a focus on water resources in the classroom, in addition to highlighting the use of science and engineering for everyday life and the wellbeing of society. The OH-Kids model can serve as an example to other researchers and teachers interested in childhood STEM education. It can also support different learners in other settings, such as museums and science centres.

The model's main objectives are:

a) To enable pupils to meet a scientific team and find out what scientists do and how research is carried out
b) To improve understanding of hydrology, specifically the water cycle, and the relationship between water and cities
c) To enhance children's experience of science and technology
d) To demonstrate links between topics covered in school curricula and research projects in the real world
e) To know the extent to which this methodology results in changes in learners' enjoyment and perception of science and scientists.

The model is akin to a workshop and includes two types of activities. The first one is related to traditional academic strategies: a short lecture that explains the real-world problem and associated concepts. The second one consists of interactive and ludic activities that are implemented within the classroom as didactic tools for teaching the STEM disciplines involved in water resources. All activities are organised in a circuit that enables the alternation of an academic activity with one of a more ludic nature, which can be considered as one of the innovations of this outreach model.

In order to assess modifications in pupils' perceptions of some basic concepts related to water resources, as well as their perceptions of science and scientists, resulting from the application of our model, we designed a diagnosis and final questionnaire. Similar instruments have been documented to establish attitudes within educational research (Muller et al., 2013; OECD, 2016). Tables 1 and 2 show the questions incorporated in these questionnaires. The first five questions were designed to examine how their perception of water concepts changed after their participation, while the last four served to evaluate how much their attitude towards science had changed.

Table 1. Diagnostic evaluation questionnaire of learners' perceptions to science, scientists and basic concepts related to water resources.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Geoscience Communication
Discussions

Name:		Grade:		
Mark with an 'X' the box that better represents your reply.				
	Not at all	**A little**	**Somewhat**	**A lot**
1 Can you explain the water cycle?				
2 Do you know the meaning of water footprint?				
3 How important is to measure precipitation?				
4 How much do you know about the instrument to measure rainfall located in your school?				
5 Do you know where to consult rainfall data for Mexico City?				
6 Do you think that science is interesting?				
7 Would you like to become a scientist?				
8 Do you agree with this sentence? Science is difficult.				
9 Do you like to carry out experiments?				

Table 2. Final evaluation questionnaire to assess changes in learners' perceptions to science, scientists, and basic water resources concepts.

Name:		Grade:		
Mark with an 'X' the box that better represents your reply.				
	Not at all	**A little**	**Somewhat**	**A lot**
1 Do you understand the water cycle better now?				
2 Can you help reduce the water footprint?				
3 How important is to measure precipitation?				
4 Can you explain how a disdrometer works?				
5 Do you know where to consult rainfall data?				
6 Do you think that science is interesting?				
7 Would you like to become a scientist?				
8 Do you agree with this sentence? Science is difficult.				
9 Do you like to carry out experiments?				

The diagnostic questionnaire is applied before the workshop, which allows establishing a baseline of students' perceptions in relation to science and their level of understanding of basic water science concepts. After all activities, the final questionnaire was applied to obtain feedback from the students about the subjects seen. This evaluation instrument helps to infer the students' perceptions towards water science, scientists, and technology before and after its application.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

In summary, the OH-Kids workshop incorporates a series of activities implemented in a successive order (shown in Table 3) along with the time duration and number of students per each activity. The total time for this workshop is 120 minutes per classroom or group of 30 students, considering the application of the evaluation instrument. All activities are developed by the scientific project team; however, teachers are also encouraged to work with the team to encourage active pupil participation.

Table 3. Sequence of *OH-Kids* workshop activities along with time duration and number of students.

Order	**Activity**	**Duration (minutes)**	**Number of learners**	**Number of groups**
1	Diagnostic questionnaire	15	30	1
2	Short introductory talk	15	30	1
3	Water bingo/memory	15	6	5
3	Urban water physical model	15	6	5
3	*"Hydro-thon"*, a water and technology board game	15	6	5
3	Meet and play with a real optical disdrometer	15	6	5
3	Water and technology quiz	15	6	5
4	Evaluation questionnaire	15	30	1
Summary per classroom Total		120	30	1

The activities workshop starts with a short talk introducing real-time rainfall monitoring at urban scale and concepts related to water science and technology (i.e. water footprint, hydrological cycle, precipitation, cloud formation, etc.). This mini talk is aimed at highlighting the importance of water for the planet, the cities, and their own lives.

In the sequence, the group of students is divided in five sub-groups of six students for the application of the activities circuit. This subdivision is carried out to enable the participation of all learners within each activity and to improve teacher–learner relationships, which contributes to a better learning process. In addition, it is acknowledged that low-, medium-, and high-ability students all benefit when being taught in small heterogeneous groups. The learning process of low-ability students may especially suffer risks in homogeneous, teacher-led groups (Wilkinson and Fung 2002).

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Geoscience Communication
Discussions
Open Access

The whole circuit comprises a range of interactive and ludic activities of short duration (15 minutes), which are shown as shaded cells in Table 3. These activities are performed simultaneously by each student subgroup, which alternates between different activities every 15 minutes. These activities incorporate the work of a facilitator per activity, who supports students who are not willing or able to participate without help. Once all the smaller groups have completed the five activities, the students are regrouped into one plenary session to conclude the workshop and apply the final evaluation questionnaire. Figure 1 illustrates a flow chart of the order of activities during the OH-Kids workshop.

Figure 1. Schematic view of the order of activities performed during the *OH-Kids* workshop.

Considering that each person learns in a different way, the idea of using a circuit of ludic and interactive activities in the workshop is to provide students with different sensory-motor stimuli to increase intellectual engagement (i.e. Windschitl et al., 2018). Informal learning settings, such as the one developed here, have been identified as opportunities to enhance students' knowledge and to optimize the connection between science and everyday life (Martin et al., 2016). The five activities of the circuit were created considering visual and tactile stimuli, as well as observation, attention, memory and concentration. In addition, they were put together to reinforce the concepts

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

introduced in the initial talk and to spark interest in STEM disciplines, using evidence and demonstrations from the research project as a basis (Renninger and Su, 2012).

Perhaps the most important characteristic of the workshop is that it enables new ways of imparting knowledge related to a real research project to children, fostering the use of wonder as a pedagogical tool for emotional and aesthetic engagement with science (Gilbert and Byers, 2017). What follows is a brief description of each activity:

2.1 Water bingo and memory games

The development and widespread use of games began a revolution in thinking about their potential role for non-entertainment domains. Moreover, it has been acknowledged that many students may not respond strongly to instruction that they do not perceive as engaging. This is why the use of games has been regarded as a useful pedagogical approach to help engage students (Bodnar et al., 2016). Educational games may provide students with a motivating and stimulating environment while providing them with immediate feedback to promote learning (Zyda 2005). In particular, card and board games improve communicative skills and promote active learning through interaction with other players (Neame and Powis, 1981; Richardson and Brige 1985). The use memory gaming is recognized as an activity that stimulates basic cognitive functions, such as attention, concentration, and memory (Connolly et al. 2012).

Considering this, the workshop incorporates one activity related to the use of classical memory games and bingo adapted to reinforce words and concepts related to research projects and STEM. Water bingo is a variation of the bingo game, which uses images on boards and cards instead of plain numbers on ping-pong balls. Figure 2-a shows the boards and cards used for the game. Every image has a name related to hydrology concepts, such as hydrologic cycle, hyetograph, watershed, type of precipitation (drizzle, rain, hail, and snow); meteorology concepts, such as thunderstorm, hurricane, floods, and climate change; and technological terms (solar panel, weather radar, raspberry pi). It also includes OH stations represented with emblematic pictures.

The board contains sixteen random images and the deck of cards is composed of a set of 31 different images (concepts), one for each card. Figure 3 shows an image of a group of students playing water bingo. To start the game, each player gets one board and the instructor randomly

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Geoscience Communication
Discussions

selects a card from the deck, calling out the definition instead of reading the card name. For example, the instructor says: "it's a small and affordable computer" and the players mark with a red token the raspberry pi image on their boards. The first player to complete the board and shout "bingo" wins the game.

The water memory game contains 10 pairs of cards with different images related to the same concepts and terms of the bingo game. Figure 2-b shows an image of these cards. Throughout the game, players are encouraged to try to remember the concept associated with each card image.

Figure 2. Water bingo boards and cards (a) and memory cards (b) designed for the workshop.

Figure 3. Group of students playing water bingo during one of the workshops.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

2.2 Urban water physical model

Physical models located in laboratories have been an essential part of undergraduate and, in some cases, graduate programs in engineering (Feisel and Rosa, 2005). They have been recognised to serve an educational purpose, providing physical intuition (van Os et al. 2010), and are assumed to reflect the empirical nature of science (Millar, 1998). Given the importance of this pedagogic tool, we considered the use and construction of a simple urban water physical model in our workshop to illustrate how heavy rainfall saturates an urban drainage, producing floods. Our physical model consists of a small-scaled city within a glass case, a miniature urban drainage, and rainfall simulator (Figure 4).

The drainage system is made up of four orifices that represent the sewers, which are connected with PVC drainage pipes. For the rainfall simulator, PVC pipes and two water pumps (low- and high-flow rate) are used. This system allows us to simulate three rainfall intensities through flow combinations: light, moderate, and heavy rainfall. With the physical model, we can simulate the development of urban floods, i.e., when a city's sewage system and drainage pipes do not have the necessary capacity to drain away the amount of rain that is falling. Figure 5 illustrates a small group of students actively participating in the activity.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Figure 4. Details of the urban water physical model constructed for the OH-Kids workshop.

Figure 5. Group of students participating in the urban physical model activity.

The OH-Kids team encourages the pupils to discuss floods, for instance, how widespread they are, how they affect cities and people, and how their effects can be mitigated. They foster debate and argumentation to reflect aspects of scientific inquiry, such as reasoning and justification (Sheldrake et al., 2017). The response of students to this activity clearly shows an enhanced interest in and perceived utility of science, as observed in recent educational research (Savelsbergh et al., 2016).

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

2.3 The *Hydro-thon* game

This game was created by the OH-Kids team inspired on the Mexican board game "Maratón", created by Sergio Schaar in the '70s with the aim reinforcing the school knowledge of players. This game is a carefully designed activity to introduce topics related to climate, hydrology, engineering, and technology to 6–12 year-old learners. In this sense, it may be used as a didactic tool for teaching STEM involved in water-related issues.

This game is easy to play, because the rules are simple and can be quickly learned. Furthermore, it requires few physical resources: a board, question cards, and a dice. Therefore, this game is useful in any educational environment regardless of social realities. This game is available for download as part of the supplementary material of this paper.

Hydro-thon can be played by a minimum of two players and by up to eight players grouped in pairs. Figure 6 illustrates the game board (a game matt, rather), which comprises 40 cells of six different colours that represent each category of questions. These categories consist of the following topics: 1. Climate Science (blue), 2. Technology (red), 3. Water Education (green), 4. Urban Water (pink), 5. The Water Cycle (orange), and 6. Climate Change (yellow). The questions are organized according to level of knowledge (basic, intermediate, and advanced).

The player (or pair of players) moves on the game matt, starting at the home cell (OH-Kids cell), as many cells as indicated by the dice throw. The resulting cell (identified by colour) determines what category of question that player needs to answer. Within a category, the question is selected according to the difficulty level of the participants. This allows the youngest pupils to answer basic questions. If the player answers the question correctly, he or she moves one cell forward. In contrast, if the answer is not correct, the player stays at the same cell. Figure 7 shows a group of children playing *Hydro-thon* during a workshop. In summary, the game reviews how well concepts were understood by the students in a relaxed atmosphere.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Figure 6. The *Hydro-thon* game matt.

Figure 7. A small group of students playing *Hydro-thon* during one of the workshops.

2.4 Meet and play with a real optical disdrometer

This is another key activity within the workshop, which allows students to experience with a real rainfall measurement instrument from the OH-IIUNAM research project. This activity enables

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

students to witness how precipitation is measured by the optical instrument through a fun challenge.

Students "generate rainfall" by activating a water spray bottle within the measurement area of the instrument. The data acquisition system designed especially for this activity acquires rainfall variables, such as intensity, raindrop diameters, and fall velocity. The information is immediately displayed in a screen minute by minute. The data acquisition system used in the demonstration is similar to the one used in the real research project.

Students feel enthusiastic about the challenge, trying to do their best in order to obtain a maximum amount of rainfall or calculate the raindrops simulated with a water spray bottle. After the challenge, the OH-Kids team explains the functioning of the disdrometer in order to complement their learning. Occasionally, students repeated the same mistake of spraying perpendicularly to the laser beam instead of orthogonally, because rain falls perpendicularly to the ground. All information is transmitted in a playful and fun way, so that students can understand and feel motivated to participate. Figure 8 shows a group of students carrying out this activity, with the screen monitor displaying the real-time rainfall variables measured.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Figure 8. A group of students participating in the "Meet and play with a real optical disdrometer" activity.

This activity has a double benefit: on the one hand, it allows the contextualisation of concepts provided during the introductory talk and, on the other, it sparks students' curiosity for technology. It also teaches how a scientific question (e.g., how is rainfall measured? are all the drops the same size?) can be answered through the interaction of different technological disciplines, such as electronic, computing, and hydrologic engineering. It demonstrates as well the different levels of complexity of practical applications and real-life environmental problems, which are often overlooked by traditional lectures.

In summary, this hands-on activity—based on an exploratory learning environment that allows students to challenge their knowledge and awaken their curiosity—creates a propitious setting for self-discovery and develops self-criticism about the unknown. This environment provides an internal reward to the student, achieving personal fulfilment, and can change initial perceptions of the topics in question. Therefore, this activity can be considered as an excellent tool for -teaching how rainfall is measured.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

2.5 Water and technology quiz

Among the technological activities designed for the reinforcement of key water science and hydrological concepts is the implementation of a quiz game. It has been recognised that students can learn academic content and have fun while playing educationally relevant games. Moreover, games can promote teamwork and cooperation (Steinberg, 2011) and help build their academic confidence (Education World, 2015).

According to Bacon (1987), games can be classified in various model stages; for example, a single-stage model comprises the simplest experimental learning process, whereas in a two-stage model game the experience is followed by reflection. The quiz developed for our workshop may be categorised as a two-stage model. This game is displayed in an interactive monitor, and consist of ten questions about water and technology. Players need to answer the quiz sequentially and a point is given for each correct answer. Considering the learning process, this game replicates an exam-like situation, but in an interactive setting. Figure 9 shows a group of students playing the quiz game during one of our workshops.

Among the main benefits associated with the implementation of games for educational purposes, is the immediate feedback and letting the students know that they are making progress (Bodnar et al., 2015), as attested by the water and technology quiz. In addition, the engagement of students has been recognised as especially important in science and engineering education, making it possible when applying a technological activity, where many times traditional lectures fail (Drew, 2011).

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Figure 9. A group of students playing the water and technology quiz during one of the workshops.

3. Results and Discussion

The methodology of the OH-Kids model was evaluated by comparing diagnostic and final questionnaires applied during the workshop. This enables us to verify if this workshop produces changes in learners' enjoyment and perception of science, scientists, and basic water-resources concepts. This workshop was applied in six different schools located in Mexico City that represent a sample of N = 344 primary school students (aged 6-12 years), so the results integrate answers from the whole sample.

Figure 10 presents the compiled statistics of before-and-after answers to the questions related to water concepts by the whole sample of 344 students (questions 1-5 in Tables 1 and 2). This figure demonstrates the efficiency of the workshop on key water concepts that were not clear to the students at the beginning of the workshop. For instance, before the workshop, results show that only 30% of all the students answered "a lot" to the question of how much they know about the water cycle. The reply to this question after the workshop rose to 75.6% of students being able to answer "a lot". The same occurred with the question related to the water footprint, which is a more elaborate concept than that of the water cycle. In this case, 65.7% of the students admitted not knowing anything at all on this matter; however, after the workshop, this value reduced to

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

only 5.8% of the students. In the case of measuring rainfall, before the workshop only 53.5% recognised its importance, while this number rose to 88.95% after the workshop.

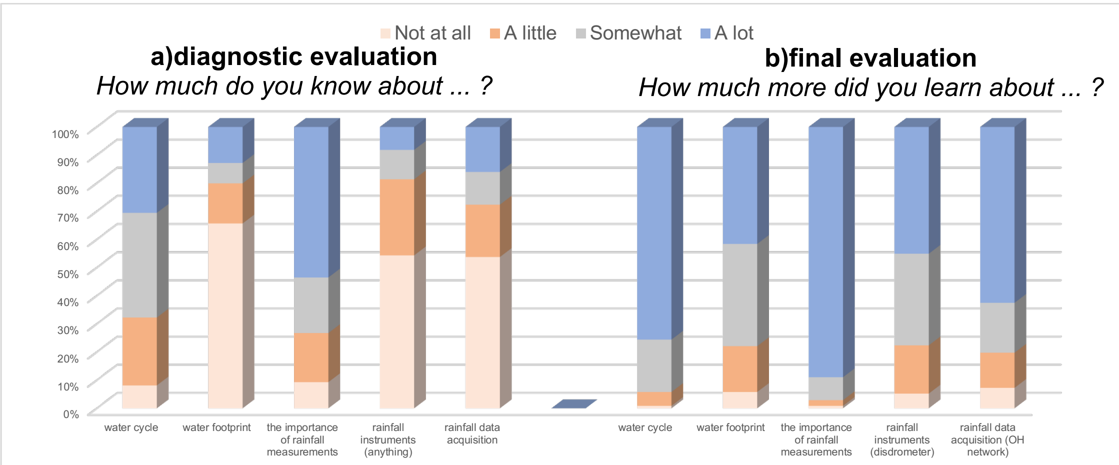

Figure 10. Compilation of answers to questions related to water concepts before (a) and after (b) the workshop.

One of the objectives of the workshop was to change the student's perception of what a scientist is and does, therefore we designed a series of questions in order to assess whether this workshop could contribute to increase the numbers of students who would be keen on becoming a scientist. In this sense, Figure 11 shows the compiled percentages of answers related to this topic (questions 6-9 in Tables 1 and 2) considering the whole sample, where it is evident that there is less variation in the students' responses. Results indicate that prior to the workshop, 76.45% of all students thought science was interesting, with this number increasing to 82.45% after the workshop. Indeed, before the workshop, 33.13% of students answered "a lot" to the question asking whether they would like to become a scientist, and the percentage of students giving the same answer to this question after the activities increased to 47.68%.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

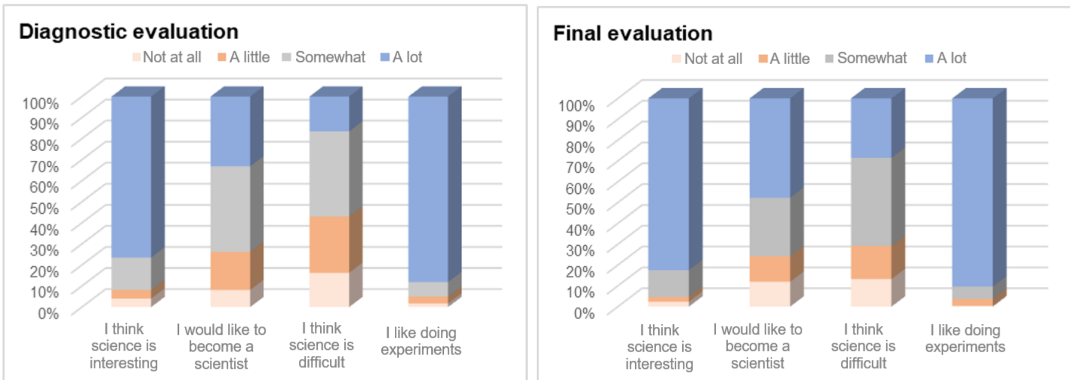

Figure 11. Compilation of answers to questions related to perceptions of science and scientists before (a) and after (b) the workshop.

From the comparative results of each question, along with the perception of the OH-kids team, it is possible to infer that the activities 'Urban water physical model' and 'Meet and play with a real optical disdrometer' presented a significant contribution to the apparent change in students perceptions of the subjects. As expected, the changes in the answers to questions 1, 2 and 5, may be associated with the efficiency of the short introductory talk, such as the quiz and the remaining ludic activities (bingo, memory, and *Hydro-thon*), which provided reinforcement of the concepts).

Although changes in percentages before and after the workshop are slight in general, numbers demonstrate that the workshop did in fact have a positive influence on students' ideas and subjects. In general, all students were clearly engaged by the interactive and ludic activities and hands-on experiments, which enhanced their curiosity and sparked their interest in water science and technology.

The confirmation provided by these numbers was further established through personal interviews with educators from all the schools that were visited. In all cases, it was recognised that the workshop was novel at introducing scientific concepts and activities into the classroom. The contextualisation of science through the explanation of a real research project with the implementation of different strategies that included hands-on activities and games provided a fuel for enthusiasm and energy in most students. In addition, it helped to pass the message to students with different skills and attitudes towards science.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

This initiative is observed as a promising first step towards establishing a research–practice partnership between a research institution and different primary schools in the city, which, by the way, have agreed to host an in-situ rainfall monitoring station within their facilities. Thus, we were able to cross the boundaries between schools, universities, and researchers, imparting knowledge in a ludic way in order to share information and expertise. Our approach was oriented towards leveraging everyday issues (e.g. lack of water, rainfall measurements) and the skills of a diverse group of students to show them that their innate curiosity is the much-needed fuel for research.

It should be noted that it is not the intention of the workshop to replace the classroom instruction, but to provide another learning strategy. In a similar way, games have been reported not to displace classroom instruction, books, and tests (Shapiro, 2014). However, our workshop is a viable venue for educators to provide the differentiated learning experiences that students require to find their inner motivation and fulfil their potential. The workshop will be carried out in the following years to continue the engagement of more students in a robust, relevant, and sustainable way that can be upscaled.

4. Conclusions and final remarks

Childhood education aiming at incorporating topics related to STEM have gained recognition as key levers in the progress of education for all students. STEM activities are an effective platform for providing rich learning experiences that are accessible to students from all backgrounds.

This study used activities related to a real research project to provide a motivational design of math and science classes. The objective was to enhance the attractiveness and accessibility of STEM topics related to water science in an informal setting, followed by comprehensible teaching and a connection to students' everyday experiences.

This study presented an outreach model entitled OH-Kids, which was designed to empower educators and pupils through the development of high-quality STEM learning experiences. The model presents an opportunity for primary school learners to meet 'actual' scientists and, at the

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

same time, receive the take-home message that anyone can get involved in problem-solving activities related to science, regardless of their ability.

The results from the OH-Kids workshop in a sample of 344 students (6-12 year-olds) show that the activities and applied techniques of the workshop provided apparent changes in the initial perceptions of some students about concepts and ideas about science and scientists. This was shown by the comparison of answers between the diagnostic and final evaluation questionnaires.

Furthermore, the results suggest that including different ways of communicating knowledge related to STEM disciplines broadens students' interest and motivation.
Our strategy can be considered as an adequate tool for blending communicational boundaries of technical and scientific knowledge between universities and community schools. Often, these boundaries are fixed and do not allow communication between knowledge and application or problems and solutions.

It is acknowledged that even a slight change in the students' perception of STEM disciplines can have very positive implications for their future interest in the subject.
Therefore, it is necessary to extend this type of methodologies to take educational research activities,—such as our workshop—to a wider audience. For instance, a worthwhile direction for future work would be to explore the implementation of this workshop among marginalised communities.

5. Acknowledgements

The authors thankfully acknowledge the support from Secretaría de Ciencia, Tecnología e Innovación de la Ciudad de México through project number SECITI/091/2018 and the support of Dirección General de Asuntos del Personal Académico at UNAM through research grant PAPIME No. PE101418. Authors are also grateful to Emilio García Díaz from the Mexican Institute of Water Technology for his time invested in the language revision.

6. References

Bacon, S.,B.: The Evolution of the Outward Bound Process. Colorado Outward Bound Press, Denver, USA, 1987.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Bertram, T., Pascal, C.: Early childhood policies and systems in eight countries. International Association for the Evaluation of Educational Achievement (IEA). Cham: Springer, 2016.

Bianchi, L., Chippindall, J.: Learning to teach engineering in the primary and KS3 classroom. A report for the Royal Academy of Engineering, ISBN: 978-1-909327-41-2, Available to download from: www.raeng.org.uk/tinkering , 2018.

Bodnar, C.A., Anastasio, D., Enszer, J.A., Buerkey, D.D. : Engineers at play: Games as teaching tools for undergraduate engineering students. The research Journal for engineering Education. Vol105(1), 147-200 pp., https://doi.org/10.1002/jee.20106 , 2016.

Connolly, T.M., Boyle, E.A., MacArthur, E., Hainey, T., Boyle J.M.: A systematic literature review of empirical evidence on computer games and serious games. Comput Educ., 59, 661–86, doi:10. 1016/j.compedu.2012.03.004, 2012.

Croxton, D., and Kortemeyer, G. : Informal physics learning from video games: a case study using gameplay videos Phys. Edu. 53 015012, 2018.

Design-Based Research Collective: Theme issue: The role of design in educational research. Educational Researcher, 32(1), 21–24, 2003.

DeWitt, J., and Archer, L.: Who Aspires to a Science Career? A comparison of survey responses from primary and secondary school students. International Journal of Science Education, 37(13), 2170–2192. http://dx.doi.org/10.1080/09500693.2015.1071899, 2015.

Drago-Severson, E.: Leading adult learning: Supporting adult development in our schools. Thousand Oaks, CA: Corwin Press, 2009.

Drew, C.: Why science majors change their minds. New York Times. ED16 http://www.nytimes.com/2011/11/06/education/edlife/why-science-majors-change-their-mind-its-just-so-darn-hard.html , 2011.

Education World: Teaching with games. Retrieved from http:// educationworld.com/a_curr/strategy/strategy065.shtml, 2015.

Falk, J.H., Pattison, S., Meier, D., Bibas, D., Livingston, K.: The contribution of science-rich resources to public science interest. Journal of Research in Science Teaching, pp 422-445, https://doi.org/10.1002/tea.21425 , 2017.

Fantuzzo, J. W., Gadsden, V. L., & McDermott, P. A. : An integrated curriculum to improve mathematics, language, and literacy for Head Start children. American Educational Research Journal, 48(3), 763–793, 2011.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Feisel, L.D., Rosa, A.J.: The role of laboratory un undergraduate engineering education. Journal of Engineering Education, 121-130pp, 2005.

Friedman-Krauss, A. H., Barnett, S. W., Weisenfeld, G. G., Kasmin, R., DiCrecchio, N., & Horowitz, M.: The state of preschool 2017: State preschool yearbook. New Brunswick: National Institute for Early Education Research, 2018.

Garris R., Ahlers R. and Driskell J. E.: Games, motivation, and learning: a research and practice model Simul. Gaming 33 441–67, 2002.

Gilbert, A., Byers, C.C.: Wonder as a tool to engage preservice elementary teachers in science learning and teaching. Science Education, Vol.101, (6), 907-928pp, https://doi.org/10.1002/sce.21300, 2017.

Maltese, A., Melki, C., Wiebke, H.: The nature of experiences responsible for the generation and maintenance of interest in STEM. Science Education, 98(6), 937–962. http://dx.doi.org/10.1002/sce.21132, 2014.

Martin, A.J., Durksen, T.L., Williamson, D., Kiss, J., Ginns, P.: The role of a museum-based science education program in promoting content knowledge and science motivation. Journal of Research in Science Teaching, 1364-1384. https://doi.org/10.1002/tea.21332 , 2016.

McIntyre, M.: Early childhood and science. Washington, D.C.: National Science Teachers Association, 1984.

Millar, R.: Rhetoric and reality: What practical work in science is really for. In J. Wellington (Ed.), Practical work in school science. Which way now? (pp. 16–31). London: Routledge, 1998.

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S.: Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. Educational Researcher, 45(1), 18–35, 2016.

Muller, CL, Roberts, S, Wilson, RC, Remedios, JJ, Illingworth, S, Graves, R, Trent, T, Henderson, J, Wilkinson, J, Wilkinson, M & Desai, A.: The Blue Marble: a model for primary school STEM outreach. Physics Education, 48(2), 176-183. DOI: doi:10.1088/0031-9120/48/2/176, 2013.

Neame, R.L., Powis, S.A.: Towards independent learning: curricular design for assisting students to learn how to learn. J Med Educ 1981; 56: 886–893, 1981.

OECD: PISA 2015 results (Volume I): excellence and equity in education. Paris: OECD Publishing. http://dx.doi.org/10.1787/9789264266490-en, 2016.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Parson, K. A., Miles, J. S.: Bio-Pictionary—a scientific party game which helps to develop pictorial communication skills J. Biol. Educ. 28 17–18 (https://doi.org/10.1080/00219266.1994.9655358), 1994.

Pedrozo-Acuña, A., Magos-Hernández, J.A., Sánchez-Peralta, J.A., Amaro-Loza, A., Breña-Naranjo, J.A.: Real-time and discrete precipitation monitoring in Mexico City: implementation and application, IAHR, Hydrosenssoft Madrid, Spain, 2017.

Piaget, J.: Science of education and the psychology of the child. New York: Viking Press, 1971.

Poljak, N., Bisilj, A., Brzaj, S., Dragovic, J., Dubcek, T., Erhardt, F., Jercic, M.: Physionary—a scientific version of Pictionary. Phys. Educ. 53(6), 2018.

Regan, E., and DeWitt, J.: Attitudes, interest and factors influencing STEM enrolment behaviour: An overview of relevant literature. In E. K. Henriksen, J. Dillon, & J. Ryder (Eds.), Understanding student participation and choice in science and technology education (pp. 63–88). Dordrecht: Springer. http://dx.doi.org/10.1007/978-94-007-7793-4_5., 2015.

Renninger, K. A., & Su, S.: Interest and its development. In R. Ryan (Ed.), The Oxford handbook of human motivation (pp. 167–187). New York: Oxford University Press, 2012.

Richardson, D., & Birge, B.: Teaching physiology by combined passive (pedagogical) and active (andragogical) methods. Am J Physiol, 268: S66–S74, 1995.

Rogers, D.L., Martin, R.E. & Kousaleos, S.: Encouraging science through playful discovery, Day Care and Early Educ J, 16, 20-23pp, https://doi.org/10.1007/BF01620353, 1988.

Rozek, C., Hyde, J., Svoboda, R., Hulleman, C., & Harackiewicz, J.: Gender differences in the effects of a utility-value intervention to help parents motivate adolescents in mathematics and science. Journal of Educational Psychology, 107(1), 195–206. http://dx.doi.org/10.1037/a0036981, 2015.

Sarama, J., Lange, A. A., Clements, D. H., & Wolfe, C. : The impacts of an early mathematics curriculum on oral language and literacy. Early Childhood Research Quarterly, 27(3), 489–502, 2012.

Savelsbergh, E., Prins, G., Rietbergen, C., Fechner, S., Vaessen, B., Draijer, J., et al.: Effects of innovative science and mathematics teaching on student attitudes and achievement: A meta-analytic study. Educational Research Review, 19, 158–172, http://dx.doi.org/10.1016/j.edurev.2016.07.003., 2016.

https://doi.org/10.5194/gc-2019-7
Preprint. Discussion started: 3 July 2019

Sheldrake, R. : Students' intentions towards studying science at upper-secondary school: The differential effects of under-confidence and over-confidence. International Journal of Science Education, 38(8), 1256–1277. http://dx.doi.org/10.1080/09500693.2016.1186854 , 2016.

Sheldrake, R., Mujtaba, T., Reiss, M.J.: Science teaching and students' attitudes and aspirations: The importance of conveying the applications and relevance of science. International Journal of Educational Research (85), 167-183, 2017.

Souza, P.V.S., Morais, L.P., Girardi, D.: Spies: An educational game. Phys. Educ. 53 (2018) 045012 (4pp), 2018.

Smith, K.A., Sheppard, S. D., Johnson, D.W., Johnson, R.T.: Pedagogies of Engagement: Classroom-Based Practices. Journal of Engineering Education, https://doi.org/10.1002/j.2168-9830.2005.tb00831.x , 2005.

Steinberg, S.: The benefits of video games. Retrieved from http:// abcnews.go.com/blogs/technology/2011/12/the-benefits-of-video- games/, 2011.

Van Os, A., Soulsby, R., Kierkegaard, J.: The future role of experimental methods in European. The future role of experimental methods in European hydraulic research: towards a balanced methodology. Journal of Hydraulic Research. Pages 341-356. https://doi.org/10.1080/00221686.2004.9641203 , 2010.

Wilkinson, I.A.G., Fung, I.Y.Y.: Small-group composition and peer effect. International Journal of Education Research, 37 425-447, 2002.

Windschitl, M., Thompson, J., & Braaten, M.: Ambitious science teaching. Cambridge, MA: Harvard Education Press, 2018.

Zaslow, M., Tout, K., Halle, T., Whittaker, J. E., & Lavelle, B.: Emerging research on early childhood professional development. In S. B. Neuman & M. L. Kamil (Eds.), Preparing teachers for the early childhood classroom: Proven models and key principles (pp. 19–47). Baltimore: Brookes Publishing, 2010.

Zyda, M.: From visual simulation to virtual reality to games. Computer, IEEE Computer Society, 2005.