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Converging science and literature cultures: learning physics via *The Little Prince* novella*

A Godínez-Sandí[1,2], D Fallas-Padilla[1,2], S España-Tapia[3], A Zúñiga-Villegas[4], Milena Castro[5,6] and O A Herrera-Sancho[1,2,7,8]

[1] Escuela de Física, Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica
[2] Centro de Investigación en Ciencia e Ingeniería de Materiales, Universidad de Costa Rica, 2060 San Pedro, San Jose, Costa Rica
[3] Escuela de Ingeniería Mecánica, Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica
[4] Escuela de Ingeniería Civil, Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica
[5] Escuela de Estadística, Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica
[6] Centro de Investigación en Matemática Pura y Aplicada, Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica
[7] Centro de Investigación en Ciencias Atómicas Nucleares y Moleculares, Universidad de Costa Rica, San José 2060, Costa Rica
[8] Author to whom any correspondence should be addressed.

E-mail: oscar.herrerasancho@ucr.ac.cr

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Abstract
Primary level education follows a pedagogy model where literature and science have been historically separated. Natural children processes are disrupted, as learning based on play curiosity is completely transformed by a chalkboard model. Specific experimental realizations can link thinking processes based on science to study problems contextualized by literature. Converging the essences of these two cultures has the potential to enhance the education experience, dramatically. This paper proposes a new didactic strategy using experimental demonstrations based on *The Little Prince* story, providing a journey through different philosophical questions about nature and Universe laws. Therefore, the story is used as a scientific metaphor applied to a teaching-learning situation. A workshop was implemented to a group of 26 students attending sixth grade (mean age = 12 years old), from two primary schools located in Heredia, Costa Rica. In order to evaluate the sessions' performance, Pearson's χ^2 test for independence was used to contrast association within a set of variables related to perception of learning processes and emerging interest in science. Overall 77% of the students perceived an increased interest in science, despite gender characteristics. Curiously, a gender association was observed related to the preferences

* Grown-ups never understand anything by themselves and it is tiresome for children to be continually explaining things to them *Saint-Exupéry, 1943* [1].

girls and boys have for specific experimental demonstrations. Additionally, 92% of the students perceived learning of scientific concepts after the sessions delivered. Our research establishes a new didactic strategy with the potential to break historical pedagogical patterns and could pave the way into integration of contrasting disciplines.

1. Introduction

Pedagogical models used in the majority of educational centres divide knowledge into different categories, which are taught separately using a compartmentalized and a linear structure. As Saint-Exupéry states, adults have difficulty understanding children, not only given their perception of the world, but also the way knowledge is disaggregated. A few decades ago, the English physicist Snow conceived the concept 'The two cultures', to approach the specific case between science and literature [2]. Therefore, we propose a breakthrough of this linear paradigm demonstrating concepts of fundamental physics as a result of experimental realizations, based on *The Little Prince* novella. This new didactic strategy juxtaposes these cultures with the curiosity of little-prince-children and grown-ups, undertaking experiments to learn how nature behaves.

Worldwide education performs science and Spanish language classes as two different and completely separate topics, providing evidence of 'The two cultures' theory [3]. Students often consider literature analysis as an unattractive or cumbersome activity and it is not necessarily enjoyable, even though this is where they spend most of their reading time [4]. The main goal of literature classes is to provide a sound understanding of the novels assigned during each school calendar year [5, 6]. Therefore our ambition is to allow students to go further and relate the novel's contents to subjects found in other academic areas. The approach of science classes in primary school is to follow a specific textbook, and it is extremely rare to let children read science literature such as science fiction, scientific divulgation, or to carry out some experiments related to the concepts learnt. Because of these limitations, students often feel frustrated and overwhelmed in science classes [7].

To address the transdisciplinary disconnection, experimental scientific realizations are designed to go beyond the simplistic text comprehension and literary analysis exercises. Moreover, relating literature passages with hands-on experiments, let students have a different attitude towards science, allowing them read beyond the literary topics. Prior research confirms that educating children with technology has a positive effect on their learning process [8–10].

Didactic strategies used in physics and literature classes are specific for each domain and do not provide key links between the different subjects. For example, Mazur has proposed a peer instruction methodology to teach physics engaging students by elaborating the concepts to be explained to other classmates [11]. Literature, on the other hand, has been historically taught from a passive reader perspective, analyzing grammatical structures and psychosocial factors involved in the stories [5, 6]. Furthermore, literature classes lack experiential environments favoring a more emotional learning. Consequently, to converge these two cultures a historical and philosophical background is needed for science education [12], where literature can be key in offering a rich context to be studied. Given the task of this merge, *The Little Prince* story was selected along with specific experimental realizations to build up an appropriate and unique environment. In addition to the design of a new didactic strategy connecting science and literature, we expect to observe an emergence of interest in science as a positive effect on the motivation of each student. Therefore, it is important to take into account characteristics of the students to allow equity in learning, like gender differences according to the preferences on the type of experimental demonstrations. Furthermore, relation between science and literature has been applied to different situations [13–17].

To promote a transdisciplinary approach of education in Costa Rica, a workshop was developed for primary level students of the Escuela Manuel del Pilar and the Escuela San Lorenzo, located in Heredia. Sixth grade students were involved in different activities related to *The Little Prince* short novel, where text understanding skills and scientific concepts were presented and explained through experimental demonstrations and observations.

2. Materials and methods

As an introduction to the didactic strategy, the plot of *The Little Prince* can be found at https://littleprinceplot.wordpress.com/

2.1. A Little Prince didactic strategy to teach science in primary school

To obtain a didactic strategy script, two contents of the cultures need to be selected: concepts of fundamental physics for the science culture and a specific novel to represent the literature culture. A learning process can be developed from the convergence of these two contents, usually delivered in separate classes. The opportunity that this strategy offers is given by the possibility of creating an experiential journey despite the culture a teacher can be more familiar with. The starting point of the design process can be provided by a literature teacher departing from a story that becomes real in class, or as a science teacher that needs to contextualize theoretical concepts demonstrated as experimental realizations.

In order to select stories to teach science concepts, different characteristics can be considered: (1) visual elements (2) an appropriate vocabulary for the age of the students (3) simplicity of the story (4) a main character similar to the students learning position (5) short length (6) fiction stories (7) clear definition of the changes of the development of the story (8) considering the historical characteristics when the story was written, and finally, (9) texts of the educational official program for primary education can be a source of novels and science concepts to merge either in science or literature classes. Ideally, science and literature teachers can get together to discuss the selection in both cultures (the novel and scientific concepts).

Once the contents are selected different materials have to be prepared: (1) the biography of the author and the historical context of the literature piece when it was written, (2) selection of stories and chapters according to the novel, (3) visual presentations about key elements of the story that integrate the scientific concepts, (4) a list of initial questions to start a discussion within students, and (5) preparation of the materials for the experimental realizations.

The workshop consisted of four different sessions planned to last approximately 1 h and 20 min, where text understanding skills and scientific concepts were discussed with students. The structure of the workshop is shown in figure 1. Selected experimental realizations were performed to relate different phenomena represented in the story. An introductory explanation of the author's context while writing the story was used to start the sessions to specify relevant general knowledge about the novella. To cover the whole story during the workshop, three sections were carefully chosen: the meeting of The Little Prince with the Aviator (chapters 1–9), The Little Prince traveling to different asteroids (chapters 10–15), and finally, The Little Prince's and the Aviator's experiences in the desert (chapters 16–27). It is worth mentioning that a complete presentation, of 30–40 min, was prepared at the beginning of all sessions, including videos and images used as supporting material. Specific questions were asked to generate an integral discussion about scientific concepts represented in the story.

In the first session, a short introduction of the workshop was presented. The first 20 min of the session were used to present the workshop structure and chapter distribution for each session. Then, icebreaker activities were introduced during the following hour to become more familiar with the students. The aim of the exercise was to get to know names, ages and hobbies. Chapters 1–9 of the novella were assigned to students to be read by the following session.

In the second session, light phenomena was related with passages of the story and light properties were explored through different experiments. Chapters previously assigned were reviewed and discussed using question generation in subgroups of four to six students, where they had 3 min to debate and write an answer to be shared with the rest of the group. After 30 min of

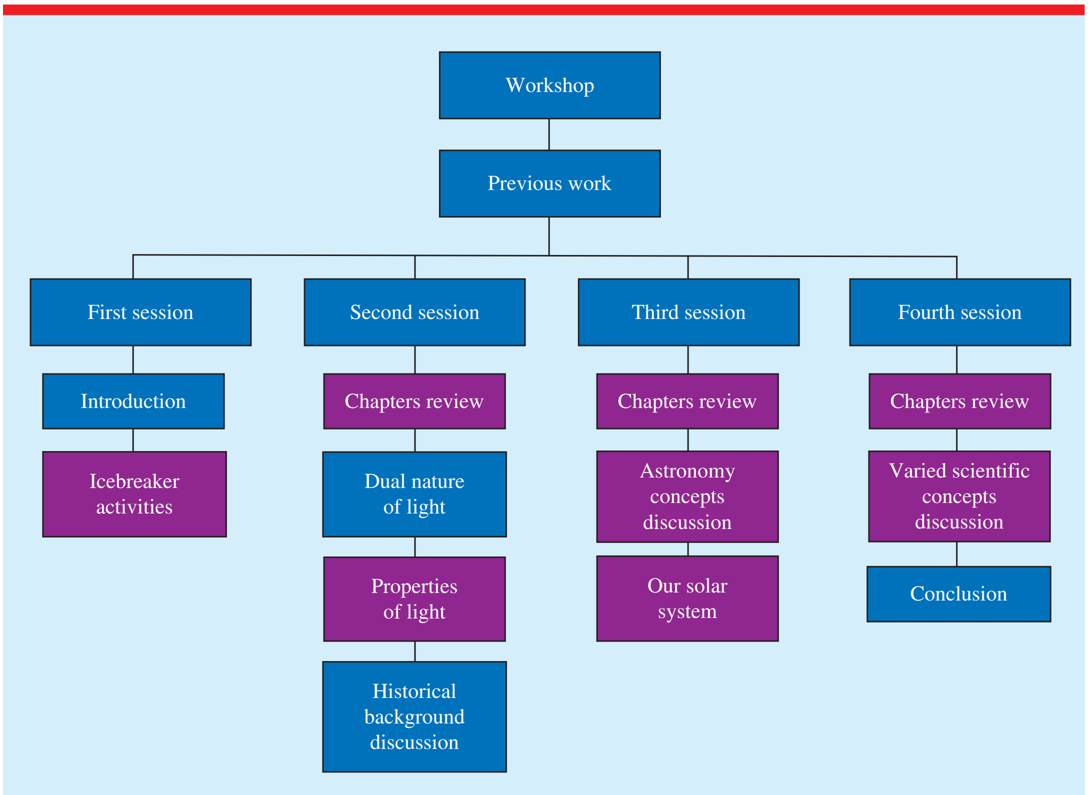

Figure 1. Flow diagram of the structure of the workshop. Blue boxes show leading activities of instructors and purple boxes show activities were students lead their learning routes.

discussion, students were invited to participate in the performance of two experimental realizations, see table 1. Specific instructions were provided to allow students to observe, take notes and manipulate the different elements of the demonstration. In addition, a historical context and a biographical review of the author was introduced to portray the background of the novel. Also we reviewed the author's enthusiasm for aviation and his zeal for literature and poetry [1]. According to Botelho and Kabakow, a discussion about the historical background of a novel provides students an association of story events with the author's life and society's specific context, in which it was written [18]. This, potentially allows a didactic strategy to break the divergence between science and literature, and therefore, the story becomes more significant for students. At the end of the session, chapters 10–15 were assigned to be read at home in preparation for the next session.

In the third session, the journey of the Little Prince to different asteroids was summarized. Topics represented in these chapters were introduced as scientific concepts, rather than performing experimental realizations. A collection of pictures and drawings of the celestial bodies were shared with students: meteorites, asteroids, stars, planets, planetary orbits, atmospheres, galaxies and constellations among others. Before the introduction of each concept we used question generation, to initiate a discussion from their previous ideas about the pictures and build up from there the different concepts. To close this session, a planet was assigned to each subgroup and the learning activity was based on the preparation of a brief presentation, they had to select one or two presenters and had 15 min for a short dissertation to the rest of the group. This activity was called 'Our solar system', see table 2. For the final session, chapters 16–27 were assigned to be read at home for the following part of the workshop.

During the fourth and final session, the story takes the reader back to Earth. Emphasis was placed on topics such as domestication of animals;

Table 1. Didactic script of the second session.

Activity	Time (min)	Description
Chapters revision	30	The students were organised in subgroups of 4–6. Passages of the chapters were discussed and reading comprehension questions were asked to the groups of students
Experimental realizations	30	'Dual nature of light' and 'Properties of light' realizations were performed
Historical context	20	Historical context and a biographical review of the author was presented by the instructors

Table 2. Didactic script of the third session.

Activity	Time (min)	Description
Chapter revision	30	The students were arranged in groups of 4–6. Passages of the chapters were discussed and reading comprehension questions were asked to the groups of students
Astronomy debate	20	Based on these chapters' theme, several astronomy concepts were introduced to the students
'Our solar system' collaborative student presentation	30	A different planet or satellite was assigned to each group of students. They had to prepare a list of characteristics of the specific celestial body (with help of the instructors) and then present it to the rest of the class

and consequently the scientific concept of artificial selection was delivered. This session focused on the implication of snake bites, hence questions such as: how does the venom of snakes work? and how are antidotes manufactured? were discussed. Students learnt about the Clodomiro Picado Institute, located in Dulce Nombre, Vázquez de Coronado, San José, Costa Rica, which is a pioneering institution of the scientific-technological research related to snakes and the development of antivenoms. This institute is considered one of the most important scientific research centres of Costa Rica and Latin America [19]. After a deep discussion, a part of the session was dedicated to outline conclusions as a result of the scientific method experienced by the students. This discussion was guided by instructors, however students were motivated to place their own perspectives of the learning process. See table 3 for the didactic script of the session.

The specific experimental demonstrations are detailed as follows:

2.1.1. Dual nature of light. For a long time there was a discussion among scientists about the behavior of light. There were questions about the interpretation of light as an electromagnetic wave or a particle until the famous Young's interference experimental realization [20]. One of the most popular passages in *The Little Prince* is the misinterpretation of the drawing made by the character of the Aviator, see figure 2 [1]. This figure shows light behaving as an electromagnetic wave and a particle. If light is interpreted as a particle, the Aviator would observe a hat, and if light is considered as a wave, surprisingly the Aviator would see the boa constrictor swallowing an elephant.

To demonstrate the wave character of light interference, diffraction phenomena was introduced generating water waves into a water container using sticks with polystyrene balls attached, see figure 3(a). The goal was to create waves from the interference patterns on the water. In order to explore the behavior of light as a particle, we produced a visual experiment of a colliding ball of polystyrene against the wall. This mainly demonstrated particle behavior of light when it interacted with large obstacles.

After discussing the dual behavior of light using a visual tool, an experiment was conducted where light interacted with a small obstacle to illustrate the wave property of light. This experimental visualization consisted of a monochromatic light interaction with one hair as a small obstacle. For this experiment we only needed one laser (wavelengh $\lambda = 650$ nm), one paper sheet and one hair. We placed the hair in front of the laser, the paper sheet worked as a detector screen

Table 3. Didactic script of the fourth session.

Activity	Time (min)	Description
Chapters revision	30	The students were arranged in groups of 4–6. Passages of the chapters were discussed and reading comprehension questions were asked to the groups of students
Science discussion	40	Based on these chapters' theme, different scientific concepts were introduced to the students
Outlining conclusions of the workshop	10	A summary of the workshop was presented by the instructors. The students had a space to express their opinion about the workshop

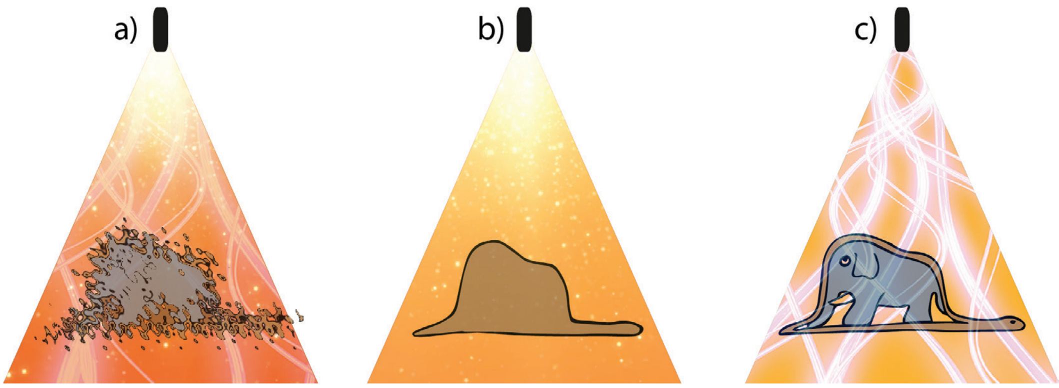

Figure 2. Artistic visualization of: (a) dual behavior of light as a particle and a wave, makes the diffused drawing a superposition of these two possible outcomes after measurement. (b) If light is considered as a particle, it makes the diffused drawing turn to one of the two possibilities specified in (a), therefore a hat is observed by a grown-up [1]. (c) If light is interpreted as a wave, it makes the diffused drawing to show the other possible outcome, a boa constrictor swallowing an elephant is identified by little-prince-children [1]. Reproduced with permission from Felipe Molina Gutiérrez.

in front of the laser and the hair in between. Once the laser was turned on, an interference pattern was observed due to the interaction of light with a small obstacle, see figure 3(b). With this simple experiment, students learnt how light behaves unexpectedly when interacting with small objects, therefore a comparison was made with the water container experiment. We could even quantify the hair size by applying the following equation: $d \approx \frac{\lambda D}{y}$, where D is the distance between the screen and the hair, y is the separation between two maximums, λ is the monochromatic light wavelength, and d is the hair width.

2.1.2. Properties of light. An experimental visualization was selected to show light properties of reflection and absorption, by interacting different laser beams with distinctly colored gummy bears. Here we took the opportunity to introduce the concept of white light. There are detailed studies stating students, in general, have issues in understanding color phenomena given the lack of familiarity with the white light concept [21]. Therefore, this extremely simple but very enriching experiment was chosen for the workshop.

If we strike the gummy bear with a laser beam of the same color, gummy bears shine with the same color, due to the reflection property of light. They will not shine if we strike the gummy bear with a laser beam of a different color, due to the absorption property of light; see figure 3(c). In this case, it will look as if we were pointing a laser beam to a massive opaque object, like a wall. At last, it is well known that every gummy bear is going to shine with the color that they are when we make them interact with white light. This simple and rather silly experiment allowed us, in a great way, to get students attention, and in the meantime introduce important properties of monochromatic and white light.

2.2. Methodology

A workshop was developed for primary level students attending Escuela Manuel del Pilar and Escuela San Lorenzo, located in Heredia, Costa

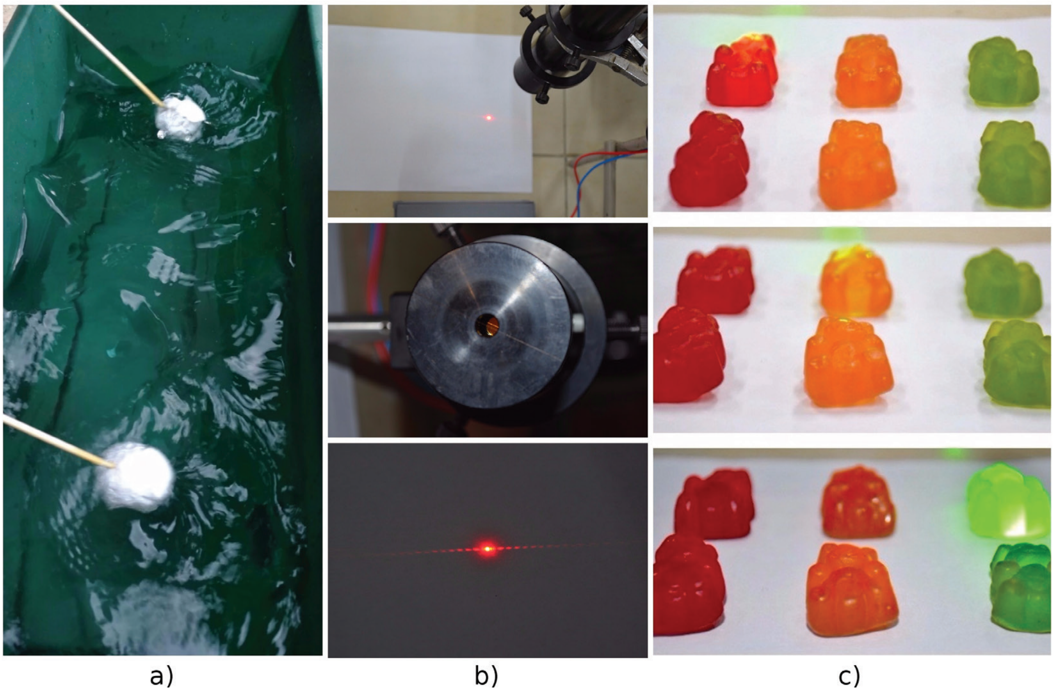

Figure 3. (a) Sticks with polystyrene balls were used to generate wave patterns in a water container. (b) Double slit experiment was reconfigured situating a hair in front of a turned on laser beam to show an interference pattern. (c) Gummy bears were illuminated with a green laser beam to illustrate properties of absorption and reflection of light. Red and orange ones absorb light and do not shine, the green ones reflect light and laser light can be observed.

Rica. In order to evaluate the workshop performance a survey was implemented after the four sessions were delivered and the school year was finished. Given the breakthrough of the classical approach, the aim of the evaluation was focused on the quantification of the observable effect related to the motivational attitudes of the students, after delivering the workshop. In order to assess the effectiveness of the didactic strategy a construct of *Interest in Science* was appropriate for the type of didactic strategy designed. This construct can be operationalized with different variable levels: (a) enjoyment (measured with variables 3, 6 and 7), (b) personal value of science (using variables 4 and 8), (c) science-related activities (variables 5, 7 and 8), (d) future-oriented motivation to learn science (variable 5) and (e) expectations for a scientific career at age 30 (not included) [22], for a total of 8 variables specified in table 4. Therefore, the assessment consisted of measuring students' perception related to their learning achievements and emerging interest in science. Variables were also intended to offer information related to the domain interest in science and subject interest, as Krapp defined, these two levels of information can provide information on whether students are interested in the content of the domain that is being taught or the interest students showed in the strategy developed to teach that domain [22].

2.3. Statistical analysis

The analysis of the results was conducted in R environment (free statistical software). Descriptive statistics were calculated to evaluate each variable and Pearson's χ^2 test for independence of categorical variables was applied. Null hypothesis was assumed that variables have no association. Yate's correction was used for binomially distributed variables [23, 24]. The probability of undertaking type I error for hypothesis testing (α level) was set at 0.010, as the risk is not considerable for this assessment.

Table 4. Questions asked to the participants and definition of variables.

Question	Variable	Scale
1. Gender		
2. Age		
3. What was the experimental realization that you preferred the most from *The Little Prince* workshop?	Experimental realization preference	laser–hair experiment, gummy bear experiment, Water container experiment
4. Did you think of relating *The Little Prince* or other stories reviewed during school year with experimental realizations?	Perception of innovation	Yes or No
5. Did the presentation wake up any interest in basic sciences?	Emerging interest in science	Yes or No
6. Which was your preferred topic discussed during the sessions?	Content preferences	experiments, astronomy, literature, other
7. Would you have preferred to approach literature only? Or did you enjoy the scientific demonstrations of the story passages?	Preference between different approaches	literature or experiments
8. Were you able to learn concepts related to light properties and astronomy during the workshop?	Perception of learning scientific concepts	Yes or No

3. Results and discussion

The four sessions designed were implemented between September and November 2017, with a total of 26 students (35% were girls). Experimental demonstrations impacted 58% of the students as they expressed that experimental realizations was their preferred content of the workshop, see question 6 in table 4. Providing a fundamental piece of evidence related with the need of converging the two cultures (science and literature), at an early stage of the education process. The use of experimental visualizations offers a dramatic change in cognition, hence the way students think about science is a turnover from chalkboards and textbooks to observation and exploration analysis. Consequently, primary level students become young scientists, starting a new educational-momentum-wave with the potential to impact society.

An important feature of the workshop was to consider the emerging interest in science, see question 5 in table 4 and figure 4. When students were consulted about it, 77% affirmed that the presentation 'woke up' their interest. This outlines the aim of the workshop to be achieved with the majority of students. Additionally, we explored if there was any association by gender, applying Pearson's χ^2 test for independence, see section 2.

Students were asked about which was their experimental realization preference during workshop, see question 3 in table 4. Figure 5 shows the experimental demonstrations' frequency preference distributed by gender, where over 80% showed that the gummy bears' realization was the student's favorite, suggesting visual and colorful realizations are key in examining scientific concepts. Likewise, the fact that students are usually in contact with gummy bears, opens a scenario in which they could replicate the experiment at home, this might account for the high percentage of preference. Two different types of objects were integrated in the same workshop, one that is very familiar for them, sweets represented by gummy bears and laser beams which are hardly used as a teaching tool in primary level education. This context brings together two levels of knowledge: knitting new scientific concepts from previous known objects and introducing unknown objects.

The other two realizations had a similar percentage of preference within each other, but differences by gender are observed, see figure 5. From the total of students, 12% of them preferred the laser–hair experimental realization, and all of them were boys. On the other hand, 8% of the total of students chose the water container experimental realization as their favorite and all were girls'. Regarding the dual interpretation of light (particle and wave), two complementary experimental realizations were specifically

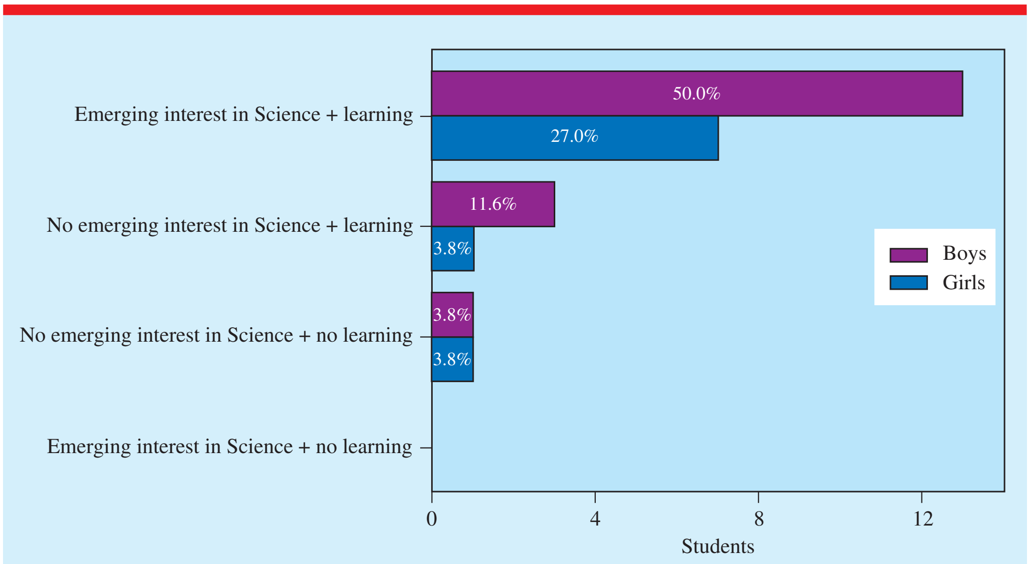

Figure 4. Distribution of student answers for emerging interest in science according to their perception of learning scientific concepts, by gender, after the workshop. These categories are created after merging variables represented in question 5 and 8, see table 4. Blue bars correspond to girls and purple bars correspond to boys. Relative frequencies are shown inside bars.

incorporated to be able to explain different scientific concepts, and take advantage of visual phenomena, see section 2. In the case of the formation of waves, the water container experiment was used. To represent interference patterns, the laser–hair experiment was demonstrated. These two experiments (representing light as a wave) were more difficult to explain to primary level students than the gummy bears experiment. The gummy bears experiment represents the absorption and emission properties of light (light as a particle).

When analyzing the association between gender and preference for a specific experiment (figure 5), significant evidence was observed (p-value $= 0.067$). This is interesting because it is one of only two significant relations between gender and any other variables that were studied. It also evidenced that there were certain experiments more appealing for boys, such as the laser–hair experiment, and other ones captured the girls' attention more easily, such as the water container experiment. These gender differences were expected as known socialization patterns are distinct for boys and girls, resulting in a preference for a more abstract experiment within boys and a preference for a more concrete visualization among girls [25]. The desired scenario for any of these workshops will include experiments which are equally attractive to boys and girls, such as the case of the gummy bears experiment, the most popular overall among students. These results could be influenced by the small sample size involved ($n = 26$), it would be interesting to replicate the workshop in other educational centres, to obtain a bigger sample size and assess the continuity of the pattern. We devised a new version of the workshop integrating experiments and didactic features to be equally attractive for boys and girls, and offer it to a larger group of students.

In regards to the proposed relation between literature and science, evaluated as the perception of innovation, see question 4 in table 4, the majority of students (77%) never considered to associate these two cultures. Within the participating girls (35% of the overall students) 22% agreed with this merge, and within the participating boys (65% of overall students) 23% acknowledged the relation. No association was observed between gender and perception of innovation. This low perception of the relation between literature and science showed a sort of expected resistance about a new way of working in class. Therefore, this new didactic strategy proposed in our workshop, could be applied to the overall pedagogy model delivered by the actual educational system.

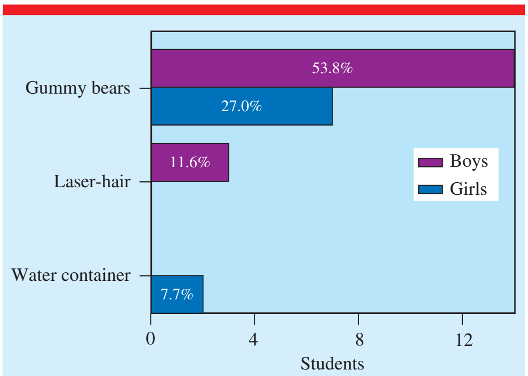

Figure 5. Preference frequency of different experimental realizations distributed by gender, see question 3 in table 4. Blue bars correspond to girls and purple bars correspond to boys. Relative frequencies are shown in bars.

Finally, regarding the preference between different approaches (see question 7 in table 4), we asked students if they preferred to limit the novel review to a literary analysis representing the classical approach, or if they preferred to merge the two cultures, using experiments to represent a story. Overwhelmingly, 100% of the students answered positively to the preference of using experimental demonstrations to discuss and learn about art, literature, physics, astronomy and science in general. Despite the fact that the perception of innovation was very low, students considered it is fruitful to develop a pedagogy model based on knitting little-prince-children's curiosity, different experimental visualizations and stories that provide a context to contrast questions about nature.

4. Conclusions

This piece of research establishes a dramatic change in cognition, hence students way of thinking about science is a turnover from chalkboard and textbooks to observation and exploration analysis. Consequently, primary level students become young scientist, starting a new educational-momentum-wave with the potential to impact society, in art, literature, physics, astronomy and science in general.

Our workshop was devised to offer experimental visualizations to be inclusive for girls and boys.The gummy bears demonstration has proven to be successful in providing a gender equality experiment. On the other hand, laser–hair and water container experiments pave the way to identify features needed to make these realizations equally attractive for boys and girls.

This new proposed didactic strategy promotes a breakthrough of the pedagogical classical approach, juxtaposing the background of the two cultures of literature and science with the curiosity of little-prince-children and grown-ups, undertaking experiments to learn how nature behaves. Students perceived this ensemble as an enlightening learning process, that increased their interest in science and their overall general knowledge. We envision a new workshop dimension by simulating the decision making process involved in the social development of scientific revolutions, using for example games theory prisoner's dilemma.

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Alejandro Godínez-Sandí is a graduate student at the University of Bonn, Germany. His research interests are in ultra-cold atoms and quatum computing. He is also interested in teaching strategies for the introduction of science concepts at an early stage of the education programs.

Diego Fallas-Padilla graduated with a degree in physics at the University of Costa Rica, 2018. He has worked as a high school teacher of physics, chemistry and maths. His research interests include condensed matter physics, biophysics, science materials and computational physics.

Sebastián España-Tapia is student of mechanical engineering at the University of Costa Rica. His fields of interest are thermodynamics, hydraulics and vibration analysis.

Andrea Zúñiga-Villegas is currently studying civil engineering at the University of Costa Rica. Her research interests focus on optimal structure design.

Milena Castro is a statistics professor at the University of Costa Rica. She completed her PhD thesis in biostatistics at the University of Leicester, UK, in 2013. Her research interests cover health technology assessment, health economics, meta-analysis and complex modelling. She currently works developing science didactic strategies using statistics for diverse teaching scenarios.

Óscar Andrey Herrera-Sancho is a physics professor at the University of Costa Rica. In 2012 he completed his Doctor Rerum Naturalium at the Leibniz Universität Hannover, Germany, in quantum optics. His research interests are quantum biology, quantum metrology, surface science, complex systems, and physics education.