ESEB Outreach fund - **Evolving Evolutionary Ideas**

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Summary:
Funding from ESEB will allow the development of teaching kits for use in Portuguese elementary schools, where evolutionary concepts are currently not taught. Funding will be used to develop and build 20 kits and to pay for travel expenses of visits with the kits to schools during the school year. The kits will include flower seeds to demonstrate genetic drift, buttons and plastic pearls with different colours to demonstrate natural selection, cards with images of different organisms to demonstrate how taxonomy relates with evolution, small mirrors and genealogical trees to demonstrate the heritability of characters.
Funding: 2000 euros

Description of the activity and major outcomes:
Although the project was initially designed to be developed at three distinct elementary schools, the hierarchical re-organisation that took place in Portuguese educational system in the beginning of the present school year delayed the beginning of the present project and made impossible to test these activities in one of the schools initially programmed. Accordingly, the activities financed by ESEB funds took place at two Portuguese elementary schools, one in the city of Porto ('Porto School') and other in the district of Mangualde ('Mangualde School').
Porto School was chosen in order to be representative of an urban school as it is located in the centre of Porto which is the second largest and most important Portuguese city. In this school we tested the activities at four distinct classes, one from each grade. Students aged from 5 (1st grade) to 10 (4th grade) years old. Mangualde School was chosen in order to be representative of a school from the interior part of the country which is markedly more rural and with a more conservative, religious society. In this school we tested the activities at three distinct classes: one from the first grade, one from the second grade and one from the third grade. Students aged from 5 (1st grade) to 8 (3rd grade) years old. No teacher from the fourth grade allowed us to test the activities in their classes. The medium class size was 22 students.
We visited both schools for 13 times: one first time to meet with the teachers, 4 times to do the first activity, 2 times for each other activity and 2 times for evaluation of activities (after the activities about natural selection and genetic drift). For each activity we spent half a day (3 hours) with the students. All visits had to be previously book with the teachers, according to their availability and the school calendar. The first visit was done in November and the last one in the beginning of April (the week prior to the Easter vacations' break).

The activities

In each of the classes we tested four distinct activities, developed to allow children to understand that species diversity and species features resulted from a long evolutionary process and to understand the role of evolutionary mechanisms like natural selection and genetic drift on the evolution and divergence of species/populations.

1. Intraspecific diversity and heredity

The first activity was designed to make students notice the existence of hereditary intra-specific diversity and to make them understand some basic hereditary principles. Two visits to each class were necessary to accomplish these goals.

In the first visit we asked the students to identify features that showed diversity within human species. The students were able to identify several features that show diversity within humans. We then make them notice that for some of these features (like skin colour and height) the phenotypes showed a continuous distribution while others (like the presence/absence of a cleft chin) displayed a discrete distribution. We then asked the students to make a draw from themselves that depicted all the features that were identified by them as showing intraspecific diversity.

During the second visit we explored a human genealogical tree in order to make them notice that: *i*) the features of a child are inherited from their parents; *ii*) each child always receives two information for the same feature: one from the mother and one from the father; *iii*) that the inheritance of a given phenotypic character was independent from the inheritance of another character; *iv*) that some information behaves like dominant and some like recessive. Some students brought pictures of their close relative and thus the information of their own genealogical trees was also used to demonstrate these mechanisms. A mother-son-possible fathers' "trio" was used to further explore the concepts thought in both visits and to test the efficacy of the activity.

2. Natural selection and the importance of intraspecific diversity

The second activity was designed to make students understand how the genetic composition of a species may change due to natural selection and how this mechanism affects intraspecific diversity and may cause species/populations divergence. In order to do this we began the activity by telling the story of the "butterflies from the yellow forest": a species of butterflies with wing colour diversity (represented by flattened plastic beads of 5 colours) inhabited a forest with a great diversity of plants (represented by the box filled with colourful plastic pearls) and were preyed by birds (represented by the students); one day a yellow ink factory was constructed near that forest and released a yellow dust that covered the plants (represented by a box filled with yellow plastic pearls). The question was: what is going to happen to the butterflies? We first allowed the students to prey butterflies in the diverse habitat and the non-preyed butterflies were able to reproduce so that they could understand how the game worked. Each student then drew the predicted results on the yellow forest and

only after that they were allowed to prey on this habitat and observe the evolution of the preyed species.

Before this activity only a small fraction of the students were able to correctly predict the expected results. At the end of the game the students were able to understand that the butterflies' population evolved through time and became adapted to the new environment. They also understood that this evolution and adaptation was due to the fact that the yellow butterflies were much less preyed in the new habitat, surviving more and having more descents. The yellow butterflies were then placed in a different habitat (represented by the box filled with green plastic pearls) to help students understand that human activities impact on intraspecific diversity and that genetic diversity is important to species' survival rates. To evaluate whether the students were able to apply the concept in a new context we visited each class once more and ask the students to predict what would happen to an insular population of birds with distinct flights abilities after the introduction of cats. The vast majority of the students were able to correctly predict the expected result and to explain it as the outcome of differential survival and reproduction of the distinct types of bird.

3. Genetic drift and the impacts of human activities on genetic diversity

The third activity was designed to make students understand how the genetic composition of a species may change due to random factors and how genetic drift may affect intraspecific diversity and cause species/populations divergence. In order to achieve this goal we asked the students to predict the impact of a construction of a road (represented by the black cloth strip) on a population of butterflies (represented by the wood butterflies with colour diversity) initially distributed on the previously continuous habitat (represented by the green cloth). After drawing their predictions, students played the game. They randomly distributed the butterflies (six butterflies per each of the five distinct colours) on the continuous habitat and then divided this habitat in two patches of different sizes. Random survival and reproduction (represented by the blind choice of individuals from an opaque bag) was simulated several times for each of the two recently separated populations and all the results were registered.

After this activity, the students were able to understand that the two populations evolved through time becoming different from each other and from the initial population only due to random factors. They also noticed that both populations lost genetic diversity, and that the extent of the diversity loss was negatively correlated with the size of the population. Finally the students were also able to understand that human activities that cause habitat fragmentation and that decrease populations' sizes deeply impact the intraspecific diversity of the species. This activity was evaluated by asking students to predict levels of intraspecific diversity in two new recently occupied habitats, one larger and with more individuals and one smaller and with fewer individuals.

4. Systematics

This fourth activity was developed so that students could understand that the diversity of species that we nowadays observe results from a long process of evolution and that their features reflect their evolutionary history. In order to achieve these goals, photos from several

animal and plant species were presented to the students and they were asked to form groups of two species that were more similar to each other than to any other species. The rationale for forming each group were discussed with the entire class and registered. The students were then asked to make groups of the previously formed groups using the same grouping criteria. This procedure was repeated until all the species were joined in a single group. This hierarchical grouping was represented as an evolutionary tree and the students were then asked about the reason for the hierarchical distribution of species similarities. The students immediately compared the evolutionary tree drawn to the genealogical trees they drawn in the first activity and this comparison allowed them to understand that the species similarities depended on the time passed since they shared their last common ancestral. The evolution and divergence of species through time and the role of genetic drift and natural selection on this process was then explained and discussed with the students.

Main results and outcomes

1- Development of the activities and their public divulgation

The visits to elementary school allowed us to develop the activities in order to be used in classrooms, in articulation with the Portuguese official educational program, by allowing us to identify and correct major problems, to identify possible applications and test their results and outcomes. This experience has been used to write a guidebook where these activities are described and that will soon be made free available to the public in Portuguese and English in the blog "O Jogo da Evolução/Playing Evolution" (http://playingevolution.blogspot.com/). This guidebook will also include pedagogic suggestions to explore the reported activities in other contexts and with students from all levels of scholarship.

2- Construction of 20 kits for performing the activities

The material necessary to perform the activities was produced taking into account the experience from the elementary schools visits. The kits were constructed so that the price per kit was minimised and the number of their possible users maximised.

Apart from the guidebook, each kit includes:

1- First activity: 2 mirrors, 1 genealogic tree, 1 mother-son-three possible fathers' "trio".

2- Second activity: 1 plastic box full of plastic pearls of distinct colours, 1 plastic box full of yellow plastic pearls, 1 plastic box full of green plastic pearls, 15 flatten plastic beads of each five distinct colours.

3- Third activity: 1 green cloth of 40x40cm; 1 strip of black cloth, 2 opaque cloth bags, 15 wood butterflies of each five distinct colours.

4- Fourth activity: a set of cards with photos of 44 animal and plant species.

Twenty of these kits were made with the attributed funds. Seven of these kits will be offered to the elementary schools visited (one per classroom). The remaining 13 kits will be offered to schools (from elementary to high schools) and other entities interested in performing these activities to kids and/or general public.

3- Science communication

A blog (http://playingevolution.blogspot.com/) was created to divulge these and other activities that may be developed in the future by our team to students and general public and to inform about important events and internet sites related to evolution. We are still updating it the results from our visits. The Portuguese and English version of the guidebook will be made freely available in the blog. Benefiting from another outreach fund, from the Society for the Study of Evolution (SSE), we were also able to develop new ways to explore evolutionary concepts directly linked to biodiversity and to further invest in advertising and sporadic collaborations with others schools. We merge these activities in an outreach activity named "The butterflies from the yellow forest/As borboletas da floresta amarela", that is also the blog label for all posts related to ESEB and SSE' funded activities. This blog is also part of the CIBIO research group "Population Genetics, Hybridization and Speciation – PopGen" website (http://popgencibio.org/outreach/).

4- Application of these activities in other contexts

Given the excellent results obtained with elementary school students, two of the proposed activities (natural selection and genetic drift) were made available to the general public at "Darwin's Evolution" exhibition that is now taking place in Porto (see site http://expodarwin.up.pt/en/). These activities have been applied by the exhibition monitors to groups of organised visits (most of them composed by students from different grades) with great success. As people play an active role in these activities and evolution happens as a result of their actions it is much easier to understand how these two evolutionary mechanisms affect genetic diversity, their consequences and properties and how they may cause species/populations divergence. Some of the teachers that attended these sessions with their students reported that these activities greatly facilitated the understanding of these evolutionary mechanisms by their students and showed interest in using these activities in their own classes.

The activities here reported were also used with to two groups of children (one with children with ages between 6 and 10 years old and the other with children with 11 and 12 years old) that spent a week of their school vacations in the "Darwin's Evolution" exhibition.

Description of expenses:

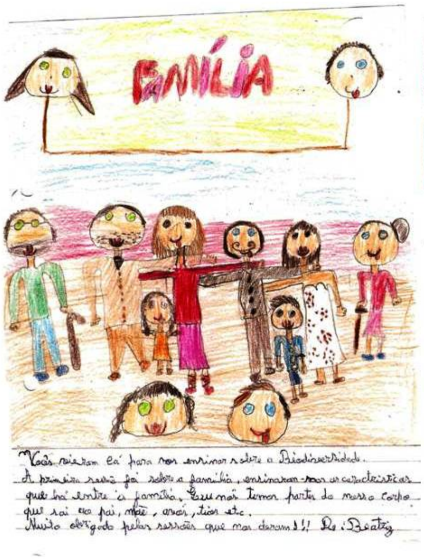
Description	Amount (in euros)	Justification
Traveling between Porto and Mangualde	863,20 + 83,50 (lunches) Total=946,70	Costs were calculated based on half the value of price/Km attributed to CIBIO researchers (i.e. 0,20 euros/Km = 60 euros) plus highway toll (3,20 euros each way). Using the car was the best option as there are no direct transport between Porto and Mangualde and by car was the only way to work with the 3 classes in only two days (going by bus -24 euros per person- would forced us to go to Mangualde 3

		times for each activity -6 for the first- and thus expend more money in the end). Lunches refer to the last 3 activities, as the meeting and the evaluations were done only during the afternoon and the school offered us lunch in the first visits.
Stationary and kits	34,65	Expenses with papers and printers to produce the complementary documents (intraspecific diversity and heredity) for the activities and the evaluation forms and to be used by the students to make predictions and write the results. CDs will be used to give each teacher a collection of the photographs taken during our visits.
Kits	415,93	Plastic pearls (natural selection), fabrics (drift) and cards (systematics) for some activities.
Graphic design	600	Joana Monteiro (http://joanamonteiro-work.blogspot.com/2005/06/cv-2007.html) is responsible to produce the final design and printing of the guidebook, the genealogical tree and trio and the animal and plants' cards.
TOTAL = 1997,28 euros		

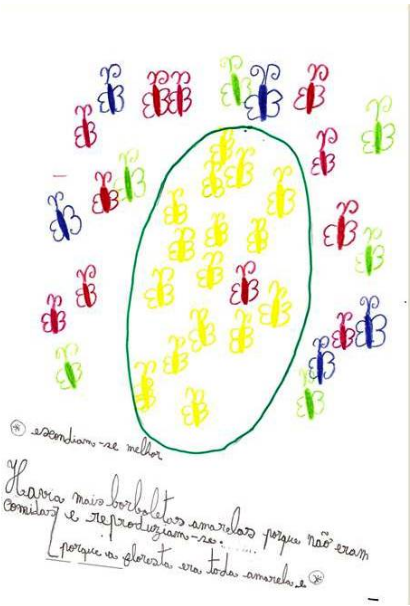
Some images taken during the visits, scans from some of the works done by the students as part of the activities and the components of each kit:

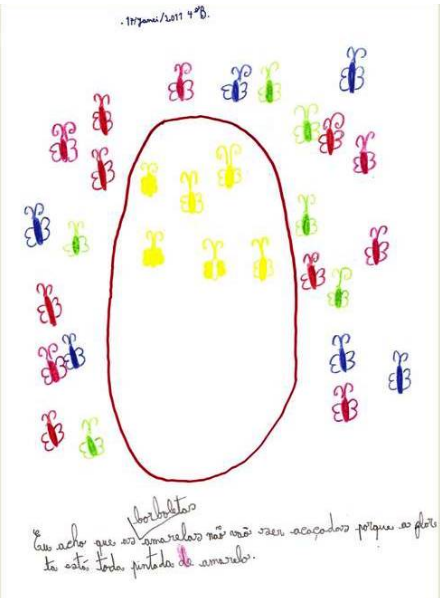

GIOTTO
Porto, 17 de Janeiro de 2011

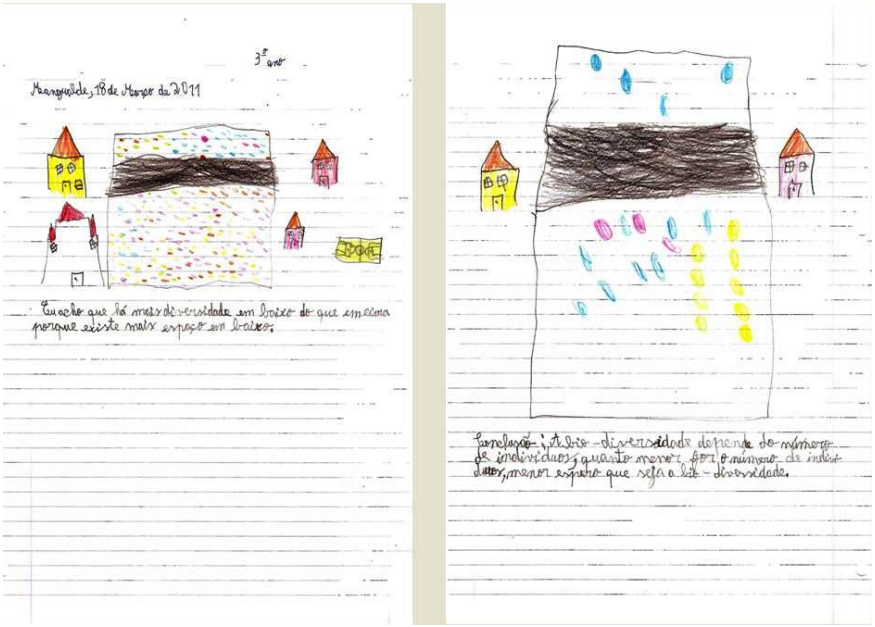

EVOLUÇÃO


FAMÍLIA
Vocês vieram cá para nos ensinar sobre a Biodiversidade.
A primeira sessão foi sobre a família, ensinaram-nos as caracteristicas que há entre a família. Eu não temos partes do nosso corpo que sai ao pai, mãe, avós, tios etc.
Muito obrigado pelas sessões que nos deram!! De: Beatriz


Tatiana


escondiam-se melhor
Havia mais borboletas amarelas porque não eram comidas e reproduziam-se.
porque a floresta era toda amarela e


Eu acho que as borboletas amarelas não vão ser caçadas porque a floresta está toda pintada de amarelo.



Vairão, 29 April 2011

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