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Animal Navigation in the Classroom: Lessons From a Pilot Experience

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In response to a direct request from science teachers, researchers initiated a pilot experience on animal orientation and navigation, which was delivered to 61 13-year-old students in Florence, Italy. The aim was to explain the approach to ethology and to link animal navigation with geography, focusing on species crossing the Italian territory. Together with the theoretical workshop, an experiment held in the classroom allowed the students to make and test their own hypotheses through an hands-on approach. A questionnaire was submitted before and after the experience to test the effectiveness of the whole activity, and highlight issues relevant to the improvement of school science program. Results indicate an uptake of the concepts and the sharing individual knowledge among the classroom, leading to an overall knowledge increase regarding the species mentioned. This experience indicates that the issue of animal orientation and navigation and helps knowledge integration. The engaging nature of this topic makes it ideal for promoting biological conservation, by focusing attention on species behavior and the habitats where such behavior is displayed. The author found direct collaboration between researchers and teachers to be an effective aid to the formation of the next generation of scientists.

INTRODUCTION

The report on Science Education in Europe by Osborne and Dillon (2008) addressed many broad suggestions, among them the following:

Recommendation 1: "The primary goal of science education across the EU should be to educate students both about the major explanations of the material world that science offers and about the way science works. . . . "

Recommendation 2: "More attempts at innovative curricula and ways of organizing the teaching of science that address the issue of low student motivation are required. . . ."

Recommendation 4: "EU countries should ensure that: Teachers of science of the highest quality are provided for students in primary and lower secondary school.

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The emphasis in science education before 14 should be on engaging students with science and scientific phenomena. Evidence suggests that this is best achieved through opportunities for extended investigative "hands-on" experimentation and not through a stress on the acquisition of canonical concepts."

Although this pilot experience cannot fulfill such broad goals, its strength lies in originating from a direct request from secondary school science teachers to researchers in animal orientation and navigation. The teachers were looking for an integration of different sectors of the school program, while researchers were seeking how to involve young people in Ethology studies. The activity was thus set up first in order to raise awareness of the scientific approach to a phenomenon, then to use science to integrate different knowledge sectors. Animal behavior, and namely orientation and navigation, was selected as a suitable topic to raise interest and enhance students' ability to link information coming from different sectors of the school program (e.g., geography and mathematics are different school subjects, orientation and navigation require the integration of these skills). The timing (last year of the middle Italian school, i.e., 13-year-old students) was considered appropriate to define one's interest in science and the willingness to develop a scientific career (Maltese & Tai, 2009). Compared with family and TV, we found school to be the most likely context where the dynamics and processes involved in scientific topics are learnt (Fanini & Fahd, 2009). All activities were therefore carried out in the classroom.

The goals of the present article were to estimate the effectiveness of the activity carried out in the classroom, and to estimate the suitability of animal orientation and navigation as topic to enhance the interface between researchers, teachers and students.

METHOD

After a meeting with the teachers, two workshops of 3 hr each were planned to be carried out by the researchers in the classrooms, with one week between them. Three classrooms of 24, 22, and 20 students participated to the pilot experience.

To illustrate to the students the challenges presented by the study of animal orientation and navigation, we focused on specific topics, namely: the first meeting included the information about animal orientation, and an hands-on orientation experiment in the classroom. The results of the experiment were discussed in the classroom within this first meeting. The second meeting included the information about animal navigation, migrations, homing and human tools for navigation.

Students were given a brief overview of navigation systems in living beings (Bingman & Cheng, 2005). The information was related to the tools that researchers used to gather the data (e.g., the Emlen funnel to study the direction of passerines during the migratory period, and the different systems to study navigation: ringing, nets, radar, radio-tracking, observations), and how they derived current theories. Last, we restricted the focus to animal migrations occurring in Italy, and when and where it was possible to observe them. We explained homing behavior, together with some examples of homing experiments and some model species, from the "classical" pigeon (*Columba livia*) to the "unexpected" limpet (*Patella caerulea*). Eventual questions raised by students, or requests of clarification by the teacher were taken into account when preparing the second meeting.

The Classroom Experiment

Orientation experiments were carried out on the supralittoral amphipod *Talitrus saltator*, common name sandhopper (Fig. 1a). Sandhoppers, when removed from their daily shelter, try to reach a safe zone (on a beach represented by the wet sand stripe) to burrow. The direction is expected to be chosen by using a sun compass mechanism (more details in Scapini, 2002). For the orientation

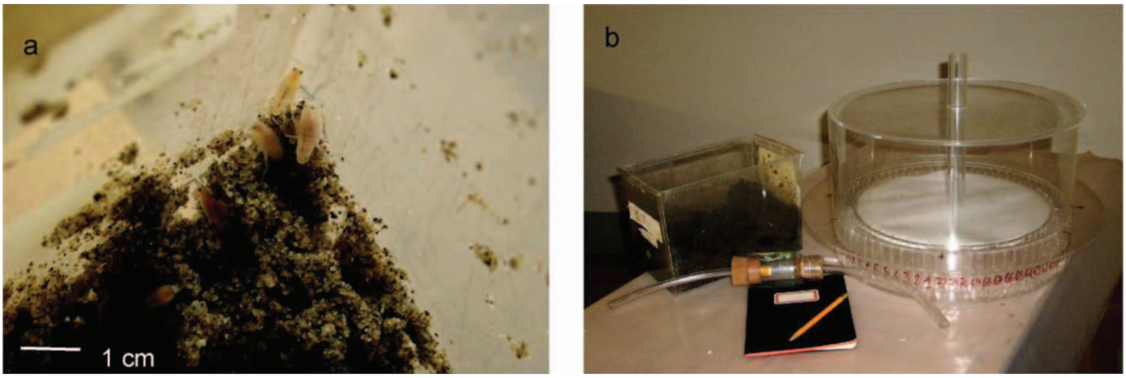

Fig. 1. a) Sandhoppers (*Talitrus saltator*) tested in the experiments carried out in the classroom; b) Experimental device used for the experiment: entomological aspirator to keep sandhoppers from the bucket, arena to test their orientation, external stimuli supplied (here, a light source), sketchbook to write down what happens (including eventual disturbances occurred, new questions raised, etc.). (Color figure available online.)

experiments, sandhoppers were introduced in an experimental arena, released and then collected from the 72 pitfall traps at the arena's rim, each trap subtending a sector of five degrees (Fig. 1b). Trap number 1 was oriented toward the North using a magnetic compass, so the direction taken by the sandhoppers was calculated according to the number of the trap in which they were caught. Last, directions chosen by sandhoppers were displayed around a circumference on the blackboard and discussed in the classroom. It was stressed that the strength of an experiment is in the curiosity of the researcher and in the ideas, and not in the cost or the novelty of the tools used. The students had to discuss and actively choose the stimula to be displayed around the arena, such as a light source (phototaxis) or a dark pattern (scototaxis), and this had to be related with the hypothesis to be tested. It was pointed out that we were using exactly the same instruments used by the researchers during their work, and that this experiment was new, so none of us knew the results in advance.

It was explained that no animal lives in a vacuum, but gathers information from environment, in order to be able to deal with it. Consequently, researchers have to link all the available information to unravel the animal behavior, and in most of the cases this information comes from diverse disciplines and frameworks. That is why *measuring* behavior is a tricky issue: it can appear difficult to those dealing with it for the first time, and an eventual oversimplification may lead to misinterpretation of the results (Milinski, 1997). To explain step by step the setup of the experiment in the classroom we used therefore the guide-book by Martin and Bateson (1993), thought for biology students. The achievements in the classroom were checked with respect to these same points.

Two experimental devices were used per classroom, so that students, acting in small groups, were able to fully participate to the experience, manipulating the instruments and the animals under the control of researchers and teachers. In the experiment, it was made clear that we were providing new data. The students were aware of making something new, and that they were consequently expected to discuss the results from the experiment, not by repeating data but interpreting results. The hands-on experience was therefore related to the discovery of new things, consistently to what called by Charpak (2001).

Questionnaire on Animal Orientation and Navigation

We submitted a questionnaire before the first meeting and at the end of the second meeting (questionnaire in Appendix A). The questionnaire was anonymous to avoid students feeling judged and included five closed questions (Q1, Q2, Q3, Q5, Q6) and an open one (Q4). The option "I don't know" was presented to avoid false answers. Questionnaires filled before and after the experience were paired with the help of the teacher, using the students' handwriting from the open question. Ethology is not included in the national school program, so the information available to students at the time of the experience was likely to be raised from books, television, and other sources external to the school, related to personal interests.

The answers to the questions presented in the questionnaire were indirectly mentioned during the two workshops. Also, in the second workshop, the results from the students' answers to the question (Q4) about migratory species were presented as an histogram and discussed in the classroom. We used the Global Positioning System (GPS) as topic to introduce a brief history of human navigation, the use of systems internal and external systems of references, and how they are also used by animals.

We estimated the information flow related to the topics mentioned as follows: variation in correct answers and decrease of "I don't know" answers (*n*s and percentages) and variation in number of species mentioned by the same student (*t*-test on paired data) between the questionnaire submitted before and after the meetings. Differences in taxonomic precision when mentioning a migratory species in the questionnaire were also reported. The involvement of students in the activities was estimated by collecting direct feedback during the experience, such as proposals of hypotheses and proposal of discussion topics, and checking the number of inactive students.

RESULTS

Classroom Experiment

The main achievements with respect to the approach to the measurement of behavior (Table 1) were noticed after the active participation of all students to the activities in the classroom. The students were able to relate the tools used with the hypothesis to be tested, such

Table 1
Comparison of the Steps Indicated by the Guidebook "Measuring Behaviour" (Martin & Bateson 1993) With the Steps of the Experiment Held in the Classroom

Hypotheses formulation	The tools used were related to hypotheses to be tested, about different orientation mechanisms: orientation of sandhoppers towards a light source (positive phototaxis); orientation following a slope (negative geotaxis); orientation towards a dark pattern (positive scotoaxis); orientation toward their "sea" (sun compass mechanism); disordered escape in all directions (no orientation).Once divided in groups, each group selected one hypothesis to be tested.
Make preliminary observations	After a first series of sandhoppers' releases in the device, the students proposed some improvements for the experiment: cutting the dark pattern in an irregular shape to simulate the wrack; testing the sandhoppers' attraction by the blue color by testing the effects of the blue screen of the projector vs. a blue jacket of a student.
Practice the recording methods & collect the data	We stressed the need of an experimental protocol and sketchbook to collect the data with a practical example: there were relevant differences between what students remembered about the direction chosen by sandhoppers and the direction effectively recorded during the experiment.
Analyze the data	At the end of the discussion about the orientation angles chosen by the sandhoppers, all students agreed on the fact that sandhoppers oriented mainly towards any light source: the lamp, the window, or the projector screen. Without a light source, sandhoppers headed mainly towards their sea, ignoring the pattern eventually placed. Just a couple of them followed the slope, so geotaxis is less important to them than other cues.

Table 2
Results of the Questionnaire Submitted Before and After the Workshops

	Questionnaire before			Questionnaire after		
	Correct answer	Wrong answer	Don't know	Correct answer	Wrong answer	Don't know
Why do animals move?	97.0	3.0	0.0	93.3	6.7	0.0
What do you need to orient?	60.6	39.4	0.0	80.0	18.3	1.7
What do you need to navigate?	86.4	13.6	0.0	96.7	3.3	0.0
What does it mean "homing"?	32.0	46.8	21.2	91.7	6.6	1.7
What is a Global Positioning System (GPS)?	75.8	16.6	6.6	85.0	10.0	5.0

Note. Answers are reported in percentage. Percentages were calculated on the basis of the 61 valid questionnaires.

as a light source to test the phototaxis, understand the importance of using the right tools, and the possibility of refining them after preliminary observations; last, they were able to analyze the results and rate the relevance of different stimuli to the sandhoppers' orientation.

The Questionnaire

A total of 66 students were involved in the experience; among them, 61 were present at both workshops. The results of the questionnaires were analyzed based on the 61 (38 females and 23 males) valid records (Table 2).

The percentage of correct answers in the questionnaire submitted before the experience was higher than 60.0% for all questions, with the exception of Q5, on homing behavior, which also had the highest rate of "I don't know" answers. In the questionnaire after the experience, all questions marked a score equal or higher than 80.0% correct answers. An increase in correct answers was recorded for all the questions but the first one. Before the experience, Q1 reached the highest score (97.0%), but decreased to 93.3% after that. The option "I don't know" was selected by the students only for Q5 and Q6, about homing and GPS, respectively. It is worth mentioning that the English word *homing*, was used when talking about animal behavior; despite the students knowing the English word *home*, its behavioral meaning was less intuitive than for English native speakers.

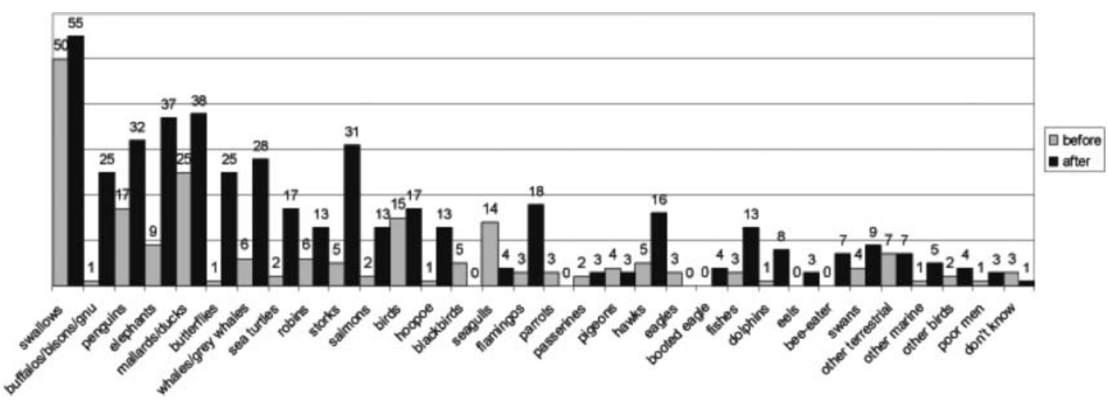

Fig. 2. Animals mentioned, before (white bars) and after (gray bars) the workshops. The animals mentioned are reported in the attempt of maintaining as possible their original meaning in the common language used by children. Also categories were presented as mentioned, i.e. including low definition (such as "birds" or "fishes") and high definition (such as "bee-eater" and "honey buzzard"). Similar categories were merged, such as "buffalos/bison" and "mallards/ducks"; the category "others" indicate all those species mentioned less than two times on the total amount of questionnaires. Frequencies are reported as numbers on the top of the bars.

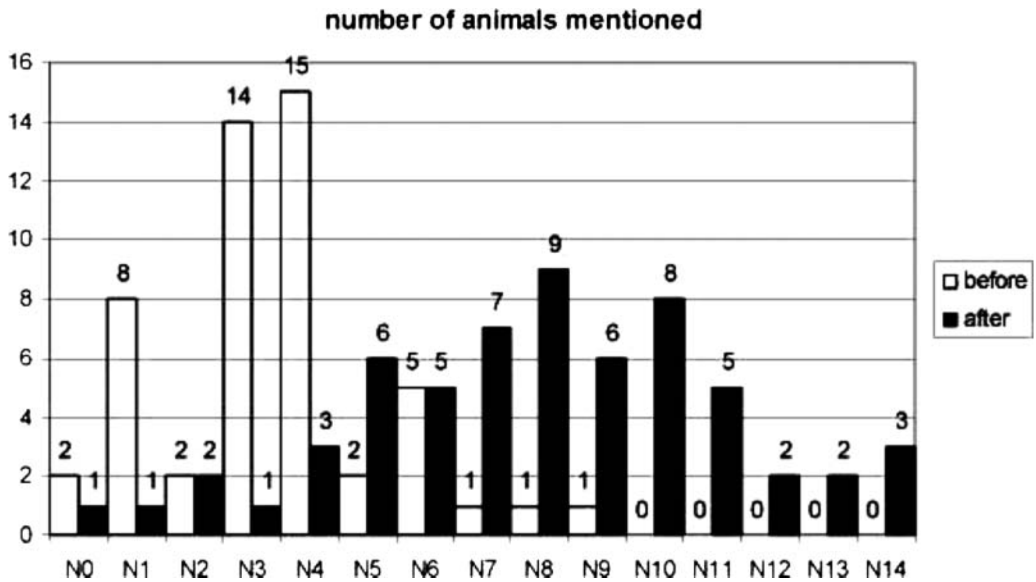

Fig. 3. Number (N ranging from 0 to X before and from 0 to X after) of species mentioned by each student, before (white bars) and after (gray bars) the workshops. The number significantly increased significantly after the experience.

Before the meetings, in Q4 just a few animals were mentioned (Figure 2), but and a low frequency of wrong answers (e.g. blackbird *Turdus merula*) was recorded. Different taxonomic precision was recorded among answers in both the questionnaire before and after the experience (Figure 2). After the workshops, an increase in number and detail of the mentioned species was recorded, including both species mentioned by researchers and by students during the experience. We also recorded an increasing taxonomic precision in species mentioned (including the use of "some" before mentioning a category, e.g. "some fishes" indicating at least the willingness to reach higher precision). The number of animals mentioned (Figure 3) varied significantly after the experience (t-test on paired data, $p < .01$, $df = 60$, with mean values shifting from 3.36 ± 1.82 to 7.90 ± 3.19 animals mentioned in the questionnaire before and after the workshops, respectively). Ants and pigeons were indicated in few cases as migratory species, probably after being mentioned to explain the homing behavior. In one case, the student described the migratory routes beside the species name. A blank answer to Q4 was infrequent, both before and after the workshops.

The Discussion in the Classroom: Sharing Information

Each classroom revealed its own profile, shaped by single students' knowledge background; however, common characteristics can be highlighted. In all cases, the existence of terrestrial migrants, suggested by a minority of students, was mentioned by all of them later on, after the discussion. The swallows (*Hirundo rustica*) were in all cases (before and after questionnaire, in all classrooms) the most frequently mentioned species. Some species appeared to be particularly attractive: the picture of a bee-eater (not mentioned in the questionnaire before, then mentioned 7 times after the experience, Figure 3) was presented, showing Italy as goal for their summer migration. This picture raised questions about the feeding strategy and the details about nesting places, which were further discussed. The hoopoe (*Upupa epops*) was mentioned by a single student, while most of them didn't even know the animal. A picture of an hoopoe was thus shown, and the peculiarity of flight were explained. In the questionnaire after the experience, 13 students mentioned the hoopoe. Also the flamingos (*Phoenicopterus* sspp.) were found to be an attractive species for the students, as most of them have seen flamingos during holidays in Italy or North African and their flight peculiarity raised questions that were explained. The flamingos increased from 3 mentions in the questionnaire before to 18 mentions in the questionnaire after. Many more species than those mentioned during the discussion and in the theoretical lesson appeared in the second questionnaire, indicating curiosity about other species (e.g. tuna fishes, dolphins), and connections with information coming from the personal experience. Last, in two classrooms the connection between migrants' behavior and migrant people was established by students and discussed, under the overall framework that living beings move to reach the conditions suitable to their survival.

DISCUSSION

The experience of direct collaboration between teachers and researchers established a link between people working in contact with the students, and researchers mentoring the students (at a later stage of their career) and met its goals. However, the experience came from a direct teachers' request. This confirms again that students' interest is likely related to science teachers' interests (Osborne, Ratcliffe, Collins, Millar, & Duschl, 2003), and teachers' attitude is still expected to play a major role in the integration of learning, including the inquiry-based and scientific approach (Morin, 2005).

The inquiry-based approach was found here to be effective in connecting research and teaching (Healey, 2005), and the topic was found suitable not only for the school, but also a way of developing links between research and the public. This is consistent with the indications of the reports on education (Osborne & Dillon, 2008), but could also aid researchers in ecology aiming at a broader audience and at social involvement of science (Stanica & Thomas, 2010).

The individual knowledge background likely played a role in the answers to the questionnaire: during the discussion, students declared to have seen swallows coming back to their nest, or knowing from TV about the migration of gray whales. Other information sources are available for some species: the fact that swallows coming back during spring is part of the popular knowledge, and a delayed return or a decrease in swallows is often presented stressing the media as an example of the effects of human impact and climate change on migratory birds. Swallows were mentioned with the highest frequency in the questionnaire before ($n = 50$) and after ($n = 55$). With respect to human navigation, GPS belongs nowadays to everyday life and most of the students have heard about it, even if they are not driving a car. Consequently, most students found readily acknowledged the connection between hi-tech devices and animal navigation, given that they both share the goal of a proper navigation.

The visualization of their own responses on migratory animals as frequency histograms raised an high attention in the students. This facilitated the sharing of individual knowledge through the discussion (the discussion took around one third of the second workshop, and no students were inactive during the discussion) in the classroom. The emotional approach aptly enhanced their participation, and no students were inactive during the discussion. Such participation was also the probable cause of the increase in the number of the species mentioned. Students referred to their own experiences: some of them had seen the movie "March of the penguins" (directed by Luc Jacquet, 2005), while the book King Solomon's Ring (Lorenz, 1989 Italian edition) was recommended by the teacher for the previous Summer vacations. These two previous experiences likely determined the high frequency of answers mentioning penguins ($n = 17$) and mallards ($n = 25$) in the questionnaire submitted before the workshops. In the case of storks and flamingos, some students had seen them during a vacation and took the occasion of the discussion in the classroom to tell about it, thus improving their retention of the information.

The involvement of the simplest categories of affective domain, such as receiving phenomena, and responding to phenomena (as illustrated by Krathwohl, Bloom, & Masia, 1973) presumably strengthened the links between the scientific information presented and the affective domain (Iozzi, 1989).

Indications to Go Beyond This Experience

Although this is a pilot study, some indications can be derived about the potential of animal orientation and navigation as topic to establish fruitful links between researchers in animal navigation and the wide public.

The examples of single species resulted particularly attractive for the students, and references to previous information received in the classroom (bee-eaters, storks, flamingos) were magnified in the questionnaire after the experience. The storytelling is currently used to communicate complex concepts and solve a range of issues, among them environmental conflicts (Zellmer, 2006) or health promotion (Hartling et al., 2010). Telling a story is also confirmed in the case of this experience as an effective way to communicate both qualitative and quantitative scientific data, and anchor them to the affective domain.

The involvement of affective domain can also enhance a positive attitude towards a species and its habitat. It is noteworthy that many organizations and agencies are using flagship species to promote their conservation campaigns; a further step was to connect such species to the cultural and local contexts (Bowen-Jones & Entwistle, 2002). The fascinating behavior of a species can enhance the public attention and represents a suitable topic for establishing links between researchers, wide public and environmental agencies.

Students' ability to make connections among zoology, migratory routes, and geophysical features highlighted the potential of this kind of experience for connecting between different study subjects. It is interesting to note that the connections with "migrants" was raised by the students in two of three classrooms involved, movements across space, despite being related to social rather than natural phenomena. In the long term, this ability could be a valuable tool to deal with the increasing demand of interdisciplinary approaches in ecology (Öberg, 2011).

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APPENDIX A

Test Submitted Before and After Workshops
The correct answer appears in bold.
Q1. Why do animals move?

a. **To satisfy their primary needs (which are those things needed to maintain themselves alive)**
b. Because they have fins, paws or wings
c. To burn calories
d. Because they cannot stay always in the same place
e. I don't know

Q2. What do you need to orient?

a. To know all my possibilities and then choose the right one
b. To know where the food is
c. **To know the own position and to know where you want to go**
d. To have magnetite in the brain
e. I don't know

Q3. What do you need to navigate?

a. An engine or at least a paddle
b. **To know the own position, to know where do you want to go, and have a reference system to maintain your direction to the goal**
c. The ability of going straight without taking a rest
d. The willingness to discover new things
e. I don't know

Q4. List the migratory animals you know (please, try to be as detailed as possible)

Q5. What does "homing" mean?

a. Looking for a new home
b. **Going back home**

c. Fighting for the territory
d. Leaving home
e. I don’t know

Q6. What is a Global Positioning System (GPS)?

a. A system to record our movements and keep them in a databank
b. An alternative way to the telephone to communicate at wide distance
c. A tool for the car
d. **A system of satellites around the Earth, telling us our position**
e. I don’t know