Sustainability **2015**, *7*, 8855-8880; doi:10.3390/su7078855

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Article

Conservation Messages in Speech Bubbles–Evaluation of an Environmental Education Comic Distributed in Elementary Schools in Madagascar

Torsten Richter [1,†,*], Antje Rendigs [2,†] and Claudette Patricia Maminirina [3]

[1] Ecology and Environmental Education Group, Institute of Biology and Chemistry, University of Hildesheim, Marienburger Platz 22, 31141 Hildesheim, Germany

[2] Madagascar Wildlife Conservation–Deutschland, Postfach 6108, 30061 Hannover, Germany; E-Mail: antjerendigs@posteo.de

[3] Institut Supérieur de Technologie d'Ambositra, Ex-Bâtiment HODIMA, Ankorombe, Ambositra 306, Madagascar; E-Mail: claudette.maminirina@gmail.com

† These authors contributed equally to this work.

* Author to whom correspondence should be addressed; E-Mail: torsten.richter@uni-hildesheim.de; Tel.: +49-(0)-5121-883-40724; Fax: +49-(0)-5121-883-40701.

Academic Editor: Armin Lude

Received: 27 March 2015 / Accepted: 2 July 2015 / Published: 8 July 2015

Abstract: In this paper, we present the results of a survey of an environmental education program applied to a cohort of 542 students in six primary schools at Lake Alaotra, Madagascar. The educational materials used were a comic book and additional materials designed specifically for local conditions in rural Madagascar. The comic book conveyed mostly system knowledge and, to a lesser extent, action-related knowledge. The additional materials posed practical tasks to students and were meant to stimulate teamwork and group discussion of students. There was a control and two treatment groups. A questionnaire was applied to test students' environmental knowledge at three different points in time. The survey showed a significant increase in environmental knowledge of students receiving environmental education compared to controls. This effect significantly increased with additional education materials fostering peer-to-peer learning by students instead of when teacher-centred learning was provided. Students that used those materials also had the highest scores in tests one year after environmental education ended, thus indicating the usefulness of innovative and locally meaningful materials in environmental education.

Keywords: education for sustainable development; environmental education; program evaluation; nature conservation; Madagascar; Lake Alaotra; *Hapalemur alaotrensis*

1. Introduction

1.1. Madagascar, Lake Alaotra and Its Marshlands

Madagascar is still one of the poorest countries in the world with a per capita income of only US $431 and a population share of 81.3% below the income poverty line, despite receiving considerable funds from international donors for conservation and development issues over a long time period [1,2]. It is listed on the Human Development Index (HDI) ranked 155 out of 187 states, in the class "low human development", with an HDI value of 0.498 [2,3]. Pronounced income inequality between families is shown by a high GINI Index of 0.475 (ranked 26 out of all countries) [2,4]. The GINI Index is a measure to represent income distribution within a nation's residents and therefore also for income inequality. This translates to the education system. Children from well-off families attend privately funded quality schools, leaving the majority of school children to overcrowded and underfunded schools financed by the state [5,6]. Madagascar has a fast growing population of ~23 million with a growth rate of ~2.6% per year (ranked 25 out of 233 states), a birth rate of 3.3% (ranked 33 out of 233 states), a low median age of 18.72 years and a high mean adolescent birth rate of ~146 out of 1000 (women giving birth in the age range 15–19 years) for the last 25 years [2,7].

Madagascar also belongs to the group of the 11 countries most at risk of disaster-induced poverty over the next decades [8]. Furthermore, after the political coup overthrowing the legitimate President in 2009, the country was cut off from most international help it is dependent on, which further weakened the economic development [9].

The loss of biodiversity is one of the greatest challenges of global change [10]. Unsustainable land use, rapid population growth and progressive poverty have led to a dramatic decline in natural ecosystems. For Madagascar, forest degradation was reported to have reached up to 90% of its natural forests, leaving only 10%–15% in near natural conditions as early as the end of the 1980s [11]. This is particularly dramatic, since Madagascar has a unique flora and fauna, due to its long geographical isolation. Besides the well-known endemic lemur species of Madagascar, the island is also the habitat of at least 363 species of reptiles and 235 species of amphibians, out of which 92% of the reptile species and 100% of the amphibian species are endemic [12,13]. This makes Madagascar one of the five most valuable biodiversity hotspots in the world, biodiversity hotspots being defined as areas of outstanding biodiversity and endemism under severe threats to species conservation and survival [14,15]. Even if some progress has been made in the last decades, scientists have defined major conservation challenges within the next decade that are calling for immediate action. One crucial challenge is the involvement of rural populations in conservation efforts, alleviating poverty at the same time [16,17] while the country's biodiversity and people's livelihoods alike are increasingly threatened by population growth, overexploitation of natural resources and climate change [8,18].

For the two districts of Amparafaravola and Ambatondrazaka that expand around Lake Alaotra, the population has increased from some 110,000 people in the 1960s to nearly 550,000 in 2010 [19], and

still there is a marked population growth due to high birth rates and population influx from less favorable areas of Madagascar. The growing demand for arable land and a continuously declining productivity per unit [20] is leading to increased transformation of the remaining marshlands surrounding the lake, putting additional pressures on marshland biodiversity [17].

Rice cultivation and fishing are the main sources of income, supplemented by vegetable cultivation, zebu breeding and handicrafts [21,22]. One third of the country's rice output is harvested around Lake Alaotra [21]. However, local livelihoods are under severe pressure due to overuse of natural resources, uncontrolled fires in the marshes and erosion of the deforested hill sides around the lake leading to downhill sedimentation and siltation of agricultural lands and persevering loss of lake surface [20]. This loss of important ecosystem functions and services negatively affects the livelihoods of people [23]. Additionally, poor infrastructure is hindering trade of local products [22]. At the time this study was conducted (2010–2012), with the exception of diesel generators there was no electricity in the villages where the schools were located, nor was there tap water, television or a mobile network yet.

To summarize, given that Madagascar as a whole is prone to high disaster-risks, there are several severe hindrances for sustainable development. The overall situation of people and nature alike calls for immediate action to take place.

1.2. The Marshlands of Lake Alaotra

Like the forests, much of the wetlands in Madagascar have been severely altered or destroyed by humans. The conversion of natural vegetation into rice fields, mostly by "slash and burn" agriculture (Malagasy: "tavy") is the biggest problem [24–26]. The encroachment of invasive species is also increasingly leading to problems and to a displacement of the native flora and fauna, as can be observed at Lake Alaotra, Madagascar's biggest freshwater lake of ~20,000 ha surface area. Here, the water hyacinth (*Eichhornia crassipes*), originating from South America, even poses a threat to local livelihoods [22,27,28]. The largest wetland of Madagascar is to be found around Lake Alaotra (Figure 1). It covers an area of ~80,000 ha. Lake Alaotra is a very shallow water with an average depth of 1.0–1.5 m, reduced already to 20%–30% its original size due to sedimentation from deforested hillsides and agricultural irrigation [20,29]. Since French colonial times at the beginning of the 19th century, the French started to convert the marshes into rice fields to establish the "rice granary of Madagascar". Since then, more than 110,000 ha have been transformed into rice fields [30]. Those fields in 2004 produced ~300,000 tons of rice, a third of Madagascar's rice production, with the lake also yielding ~2500 tons of freshwater fish to the local value production [31].

The first in-depth inventory of the ecological state of Lake Alaotra and its adjacent marshes since the study of Pidgeon published in 1996 [32] has documented that the intense anthropogenic land use leads to an increasing degradation of natural lake and marsh habitats, altering the natural plant communities in favor of invasive plant species due to several interlinked causes [27]. Freshwater marshes are the natural vegetation surrounding the lake and are mainly dominated by reed (*Phragmites australis*) and papyrus (*Cyperus madagascariensis*). The rich flora and fauna includes a variety of locally endemic species such as the Alaotra gentle lemur (*Hapalemur alaotrensis*), the world's only primate living exclusively in wetlands, the Durrell mungo (*Salanoia durrelli*), which was only discovered in 2004 [33] and the Madagascar pochard (*Aythya innotata*). The future of *H. alaotrensis*, classified by the International

Union for Conservation of Nature (IUCN) as "critically endangered" [34], is highly uncertain given the continuously growing pressures on the marshland ecosystem, mainly in the form of marshland fires [35–37]. The last population estimations from 2005 reported numbers below 3000 individuals [38].

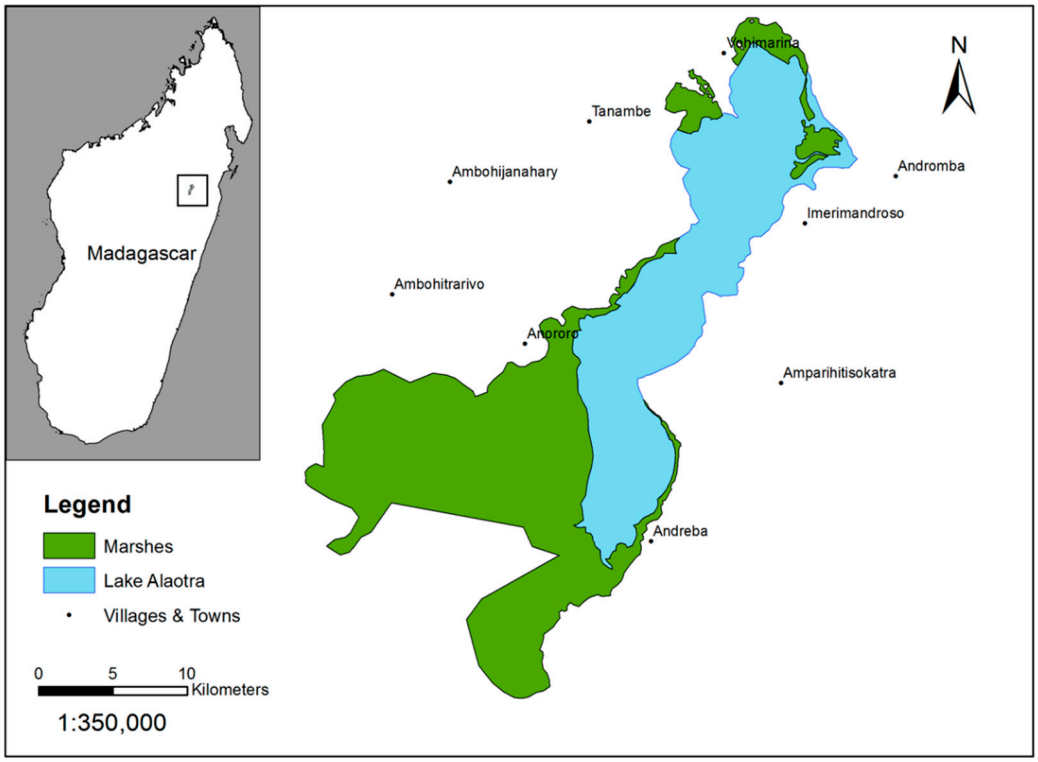

Figure 1. Map of project region Lake Alaotra and its location in Madagascar (modified after Durrell Wildlife Conservation Trust).

Several endemic species are already lost or nearly lost, such as the Alaotra grebe (*Tachybaptus rufolavatus*)—declared extinct in 2010—and the Madagascan pochard (*Aythya innotata*), gone from Lake Alaotra since the 1990s and rediscovered in a small population of ~20 individuals on a small lake in 2006 [39]. Due to its ecological peculiarity, its high biodiversity and the high proportion of locally endemic species, Lake Alaotra and its wetlands have had the status of a Ramsar site since 2003 [40].

1.3. Education and Environmental Education in Madagascar

Since the 1970s, both formal and informal environmental education [EE] have been recognized for their importance as a global approach for helping to enhance the environment [41–44]. Early theoretical texts on EE stressed the environmental and ecological perspective in educational approaches [45]. Lately, there has been a convergence of EE and education for sustainable development. Since the UNESCO proposal for the Global Action Program on Education for Sustainable Development [ESD] in 2013, the UNESCO applies the term ESD to all education activities aimed at fostering skills and competencies that help to make informed decisions on the environment and thereby improve the environment and human livelihoods alike "(...) irrespective of whether they themselves use the term ESD or—depending on their history, cultural context or specific priority areas—environmental education, sustainability education, global education, development education, or other" [46]. Pavlova [47] shows

how in different countries the international perspectives on and the traditional roles for EE led to divergent outcomes regarding this debate. Whereas some positions follow UNESCO's view and see EE as equal or being a part of ESD, others argue that there is indeed a broad overlap, but EE and ESD are both legitimate and necessary educational perspectives. Other authors emphasise the dangers of the inherent anthropocentric perspective of ESD and its call for economic development and argue to retain EE's ecocentric perspective and environmental ethics [48,49]. We follow the later perspective, thus calling our educational approach EE but stress the necessity to include also the issue of sustainable development within EE, at least when working within developing countries.

Even if the precise relationship between environmental knowledge, positive attitudes toward nature and ecofriendly behavior are still the topic of scientific debate, there is clear evidence that environmental knowledge plays a major role and there are different types of knowledge that should be addressed through EE [50–52]. Diagnostic environmental knowledge scales like the 2 factor Model of Environmental Values (2-MEV model) exist for some time for more or less industrialized countries and, more recently, for Latin America [53,54]. To our knowledge, such psychometric instruments are lacking for Africa and especially, for countries of a very low human development level so far.

Recent research demonstrated that effective EE programs should aim at converging system knowledge, action-related knowledge and effectiveness knowledge. Especially action-related and effectiveness knowledge proved to have a direct effect on conservation behavior of a sample from a European population, whereas system knowledge was more remote from influencing environmental behavior [50,55]. Nevertheless, due to the comparatively general low educational standards in Madagascar's rural primary schools, we mainly addressed system knowledge and, to a much lesser extent, action-related knowledge. Effectiveness knowledge was not part of our educational approach since it requires quite high cognitive skills considering different agendas and their outcomes. There are very limited courses of action to be balanced against each other by primary school students' in our research area anyway.

Environmental education and lessons on Madagascar's biodiversity and lemurs have only been integrated marginally in official school curricula so far, despite decades of lobbying by various non-governmental organizations (NGOs) and concerned scientists [6,56]. As a consequence, there is only limited and irregular environmental education and education on biodiversity in schools. Environmental education and teaching on the subject of biodiversity is still mainly carried out by foreign NGOs [23,57,58]. Most of the inhabitants of Madagascar are unaware of their unique nature and its progressive destruction. Only few Malagasy have seen a lemur in the wild [23], and most children are not informed about nature during their school education. Topics such as nature and environmental protection are usually not part of the school curriculum [59]. The Malagasy children are more likely to know lions and polar bears than their local wildlife. So most children in Western industrial countries know more about lemurs than the Malagasy children themselves. Consequently, as adults they have no interest in nature and conservation of biodiversity [59].

On average, a Malagasy child visits the public school system for only 5.17 years and most children do not even graduate from the five-grade primary schools, the primary school dropout rate being 59.3% [2]. Only 38% of all children start at least the first class of secondary school and only four out of 100 Malagasy people have access to higher education [2]. So targeting primary schools for environmental education ensures reaching out to the biggest portion of Malagasy children. Most

children start their working life already during or directly after primary school, hence the first five school years are the time span where it is feasible to teach them at least some basic knowledge on the environment, Malagasy biodiversity, ecosystem services and sustainable development. Even if the expected years of schooling increased to 10.3 years in 2013, an average of 5.17 realized years of schooling has remained the same since 2000. Though some progress to fight gender inequality has been made, fewer girls still visit schools than boys and malnutrition, frequent illness, need to work with families and poor hygiene are hindering successful schooling [2,60].

In addition, the teaching profession is also a poorly paid and therefore unattractive profession. Primary school teachers in rural areas have often insufficient vocational training. An increasing number of teachers are paid by local communities themselves because the state fails to pay the salaries. Teachers increasingly have to work in a second position or in subsistence farming to make ends meet [6,23]. On average, each teacher has to school 43 students [2]. For an in-depth description of the current school situation at Lake Alaotra with a focus on environmental education, see Reibelt *et al.*, 2014 [6].

At Lake Alaotra, environmental education is currently performed by Durrell Wildlife Conservation Trust (Durrell) and the organization, Madagascar Wildlife Conservation (MWC). The first steps in environmental education have already shown a positive effect. A study carried out by Durrell revealed a positive relationship between education and environmental awareness [21]. In the village Andreba, where MWC is supporting community-based projects in environmental education and ecotourism, both the poaching and the burning of marshes could be reduced to a minimum. This has a positive effect on the conservation status of *H. alaotrensis*. Guillera-Arroita *et al.* [35] found in census surveys of these lemurs that the population density in the area of the village Andreba is the largest compared to other villages around the lake. The frequency of sightings has more than doubled since the beginning of environmental education.

To quote Cowlishaw and Dunbar ([61] p. 331) "although there is little quantitative information available for determining either the impact of education and training programs on conservation or what determines their relative success or failure, there can be little doubt of their importance." Given the amount of effort invested in environmental education in developing countries, with few exceptions, there is a general lack of quality empirical studies on the outcomes and effectiveness of environmental education in general [62–64], the more so for Africa [65–71] and especially, Madagascar [6,23,58,72,73]. This may be a side effect of the current situation that almost all environmental education is provided by NGOs and undertaken by practitioners not trained in evaluation techniques, their donors normally financing only practical educational work and not time-consuming and costly scientific evaluation [74]. This also holds true for MWC, were the realization of this study was only made possible by a research grant of the European Association of Zoos and Aquaria (EAZA) Madagascar Campaign 2010.

At Lake Alaotra, environmental education is not equally well received in all schools. In some schools, there is a strong positive influence that goes so far that students are involved in practical tasks such as the restoration of the reed belt. However, other schools are much less motivated or have already dropped out of MWC's environmental education project. The reasons for the different acceptance of environmental education through schools are still unclear.

2. Experimental Section

The Malagasy primary schools have five grade levels due to the French tradition. We chose six schools according to the following criteria: schools had already participated successfully in MWC`s environmental education program and were located near Lake Alaotra, at least one trained teacher was still present at the school to teach in the intervention classes and there had to be two classes at each school in the third and/or fourth grades so that students would still be at their respective schools for the planned follow-up testing on lasting effects one year after the intervention. Participating schools were located in the villages Ambodivoara, Ambohimanga, Andilana-South, Andreba, Sahamamy and Vohimarina, belonging to the two Circonscriptions Scolaires (CISCO, which translates to the regional school authorities) of the Alaotra-Mangoro Region, Ambatondrazaka and Amparafaravola. We had a control class without environmental education and an intervention class per school to control for within-school differences. In the Alaotra region, the class teachers teach all school subjects in their classes, so there could be no bias due to other teacher's influence [6]. Since environmental education is not part of the Malagasy school curricula, students in control classes received instructions as usual. Given the fact that there were two intervention designs tested ("Comic Book" and "Comic Book Plus Additional Education Material", referred to as "Comic" and "Comic Plus"), we had six control classes and three intervention classes per test design with initially 542 students. We tested at three points in time: T0 before teaching started at the end of January 2011, T1 after the school term at the end of June 2011 and T2 one year after the intervention at the end of June 2012 using a questionnaire.

A previous version of this questionnaire was already used by MWC *et al.* for testing the effectiveness of environmental education for four years from 2006 onwards [23]. It served also as tool for a competition between the schools that were part of the environmental education program. The questions were first formulated by an international group of MWC members that were all trained scientists. The short questions addressed mostly basic factual knowledge derived directly from the comic episodes (e.g., food preferred by Bandros, legal status of lemurs) with some questions addressing conceptual knowledge about environmental relationships between two factors (for example that forests lessen soil erosion or that eroded soil leaking into the lake lessens rice field productivity). The questionnaire was translated from French to Malagasy by one of the authors having both languages as native tongues. Then, it was further adapted to the local Sihanaka idiom and culture by a Malagasy biologist born near Lake Alaotra. Since French differs vastly from Malagasy, which is part of the Austronesian language family due to the colonization history of Madagascar; these differences have to be taken into account when regarding translations back into English.

To prevent cheating during tests, the questionnaire was not known to the teachers in advance. A field worker handed out the questionnaire to students and questions were read aloud one after another. Students had the chance to ask questions to clear up any misunderstandings and teachers could comment also. So after use for four consecutive years in a competitive situation, we assumed that questions and answers were easily understandable for students. This assumption is corroborated by our findings that the percentage of correct answers given by students to factual knowledge questions shows no or minor variation between T0 and T1 within the control group (see results section and Tables S1 and S2 for more detail). The exceptions are two interlinked questions addressing the role of trees on the hill sides to prevent soil erosion and siltation of rice fields. Better results obtained at T1 in the control

group point in the direction that at least in some classes students' received some information about soil erosion. However, we did not exclude these questions from analysis because we had only a limited number of questions in the questionnaire, and this effect even worked against our hypothesis that providing EE has a measurable positive effect on students' performance.

The advanced questionnaire is a slightly shortened version consisting of 18 multiple-choice questions with three given answers, thereof one correct one. The maximum score therefore was 18. 14 questions asked for basic factual knowledge only that was provided within the comic episodes (for example: "What is the nourishment of Bandros? (a) insects; (b) litchis; (c) papyrus" or, "Where does the Bandro live? (a) in rice fields; (b) in the marshes; (c) in the forest"). 4 questions asked for conceptual knowledge (for example: "What can we do to help the animals in the marshes to survive? (a) we prepare them food; (b) planting additional reed and papyrus; (c) increase the rice fields"). Further questions addressed general knowledge about ecosystem functions, conservation, lemurs and protected areas. Two open questions ("What is the environment?"; "What would be your preferred job?") had to be answered in written form. The latter types of questions were analyzed, but not included in the overall score. The final task for students was to draw a picture of Lake Alaotra on a blank page. The whole questionnaire could be answered within a standard school hour, time being a major factor since school participation in the evaluation study was voluntary. The original questionnaire in French can be found in supplementary materials. The questionnaires were handed out in class while a field assistant of MWC was present so eventual comprehension problems by the students could be addressed and class teachers' couldn't intervene during the evaluation process. All answers were later translated from Malagasy to French by the one and the same Malagasy scientist who also entered all further data into Excel sheets. Those were then imported into the statistical program SPSS version 22.0 for further analysis.

2.1. Teacher Training

Teachers in the environmental education classes were trained by experts during workshops of three to five days prior to starting the environment education in class. Since these workshops initially took place some years before this study, the teachers of intervention classes got a refresher course in environmental education by MWC experts before the start of the term. Many topics were taught to teachers during the workshops (the environment and ecology; biodiversity of Madagascar, especially in the Alaotra region; threats and pressures on natural resources of the country; methods of how to use the comic book and transfer its environmental conservation messages to students). In addition, a visit to the marshes of Lake Alaotra was made at the end of the training so that teachers could observe the ecosystem of Lake Alaotra, which is the natural habitat of the local endemic lemur species that MWC seeks to protect against anthropogenic pressures, for themselves. Teachers in those classes that used the new additional materials got some further training on this subject.

2.2. Educational Material

2.2.1. Comic Book

A comic book in Malagasy language "AROVY FA HARENA" which translates to "protect, because it is richness", drawn by the Malagasy artist Andrianasolo Herizo "Ramafa", was used in

intervention classes. It was conceived by MWC in 2006 and 2007 and developed together with Malagasy conservation specialists, local teachers and students of the Alaotra region [75]. Introduced by the French colonists, comic books have a long-standing tradition in Madagascar for educational purposes. Malagasy artists even developed their unique artistic style, starting with a first local comic publication in 1961, until this tradition stopped for the time being with the coup of 2009, so comic books are a culturally appropriate medium for environmental education [76,77]. Compared to children growing up in industrialized countries, the children at Lake Alaotra have a very narrow living environment. This is due to the virtual absence of modern mass media. Very low individual motorization and limited means of public transportation limit their horizon of experience to the immediate vicinity of their village. In contrast to Western living environments offering vast amounts of ever-present written information, images, advertising and transportation, such written information, newspapers, books, libraries and advertising are virtually absent in the villages at Lake Alaotra. Thus, an oral tradition predominates and children are not familiar with large texts. Since successful education should take the living environment and previous knowledge base of learners into account, MWC opted for a comic with its unique possibility to combine pictures with short text messages. Thus, the familiar landscape of the children was reproduced in pictures throughout the episodes. The four main human characters were designed to offer identification and emotional bonding for learners as did the three animal characters with which the children in the comic interact. The animal characters are a Bandro called Malala (sweet), a kingfisher called Haja (respect) and a Meller's duck called Solofo (generation). Those three are natural experts for the marshes so to speak. The main human characters are two girls and two boys in the same age as the school children that get to know the animal characters in the first episode and experience some joint adventures subsequently. On 32 pages, MWC's comic book contains an introduction where characters' get to know each other and eight thematic episodes that address different aspects of the marshland related to nature conservation, ecosystem services and sustainable development in real-life situations and adequate language and complexity for primary school children. The episodes focus on respect for the natural heritage and the wildlife of the marshes, especially the endemic Alaotra Gentle Lemur or Bandro (*Hapalemur alaotrensis*). Further topics addressed are lemurs as pets or bush meat, the importance of an intact marsh for wildlife and people alike, threats to the marshes by agricultural overexploitation, fires and deforestation with their negative impact on rice cultivation and fisheries. Possible solutions for sustainable resource management like planting trees and ecotourism are addressed. Students should learn that lemurs are unique to Madagascar (and Bandros to Lake Alaotra) by providing an outside perspective given by visiting scientists and ecotourists in two comic episodes.

Within Bloom's Revised Taxonomy, most knowledge addressed was in the Knowledge Dimension of "Factual Knowledge" and some "Conceptual Knowledge". Higher dimensions were not addressed. The expected Cognitive Process Dimension was 1.0 "Remember" and the lower ranges of 2.0 "Understand" up to 2.4 "Summarizing" with some episodes addressing 3.0 "Apply" [78,79]. For example, students were supposed to understand that intact reed beds are essential for humans (as raw materials) and wildlife (as shelter and nourishment) alike (first thematic episode) and that reed beds are the natural habitat for fish spawn, thereby providing food for piscivore birds and humans (third episode). Two episodes differ from this simple scheme by broaching the issues of liberating Bandros kept as pets and planting trees as a long-term solution for improving degraded environments. Within

Monroe's *et al.* framework for environmental education strategies [80], this would fall within the category "Convey Information". As stated above, following Frick *et al.*, most of this knowledge falls within the category of "system knowledge" and only some into "action-related knowledge" [50]. The episodes are meant to be read together in class, followed by a conversation lead by the class teacher.

2.2.2. Additional Educational Materials

Three among the six primary schools were chosen to use the additional materials (Ambohimanga, Andreba and Sahamamy). The additional materials are meant to stimulate further learning in a less formal and more innovative pedagogical setting than the comic book. In addition to the reading of the comic episodes in class with its traditional student–teacher interaction, the students get three illustrations of different typical marsh and lake habitats devoid of wildlife and a page printed with various local animals. One prominent species that does not live in Madagascar, a Gorilla, is mixed in. The material was designed by the French artist Emmanuelle Tanaïs Aupest after extensive consultations with the Malagasy team of MWC.

The students work in small groups and are encouraged to cut out the animals, discuss their specific habitat types, to glue them on the appropriate part of the illustrations and to identify the non-native species. An accompanying quiz requires the deduction from short animal descriptions to the correct animal images. These materials focus on creating an interactive learning environment without a prominent role for the teacher, fostering peer-to-peer learning, handiwork, group discussions and joint decision making instead. In contrast to the comic, materials are spent during class and have to be provided anew every class. Since materials are provided in an unarranged manner and students are encouraged to break materials down into their constituent parts (animal species), discuss their different ways of life, rearrange them according to their relatedness in regard of habitat requirements and place them correctly within three different habitat types, the Cognitive Process Dimension 4.0 "Apply" according to Bloom's Revised Taxonomy is addressed. Inline with Monroe *et al.* (2007), these materials are meant to "Build Understanding" [80]. The main environmental knowledge category addressed remains "system knowledge" as with the comic book [50].

A comic book costs ~1€ each and can be used by consecutive classes over a prolonged period. The additional educational materials cost ~0.90€ per student. This comparatively high price is a consequence of the necessity to provide schools with scissors, glue, colored pencils and other materials in addition to copies of the illustrations. Testing comic book classes against those with additional materials therefore had an inherent economic component, testing the effectiveness of different education approaches and a possible justification of the increased financing necessary to provide schools with those single-use materials.

3. Results and Discussion

3.1. Results

A total of 1284 students answered the questionnaires (T0 = 542; T1 = 518, T2 = 224). The questionnaires were answered by 602 girls (47.7%) and 660 boys (52.3%). This ratio varied only very slightly over time. Only in the classes at Andreba and Vohimarina were more girls than boys in the sample. On average, students were 10.34 ± 1.904 SD years old with mean age increasing as could be

expected with time intervals between tests (T0 = 10.02 ± 2.014 SD; T1 = 10.36 ± 1.861 SD; T2 = 11.06 ± 1.490 SD). The sample had an age range from 6 to 21 years. This broad range can be explained because alphabetization of younger adults also takes place in local primary schools. Girls (mean age: 10.01 ± 1.830 SD) were significantly younger than boys (mean age: 10.64 ± 1.898 SD; Two-tailed *t*-test for unpaired groups, $p = 0.000$).

Experience of nature: 73.5% of students stated that they had never been in a primeval forest (forêt vierge), as opposed to 26.5% that said they had been ($n = 1243$). According to the results, 70.3% of the students never went to a nature reserve with their school class, whereas 29.7% said that they had visited one ($n = 1243$).

Three questions examined student's familiarity with lemurs. Only 23.6% answered they had seen a lemur, 64.8% had never seen a lemur and 11.7% were not sure if they ever had seen one ($n = 1269$). Of those who stated to have seen a lemur, only 80 students answered that they had seen one under natural conditions (representing 6.3% of the basic population). 231 (18.2%) students had seen lemurs in books only, 88 (6.9%) in a zoo and 49 (3.9%) in captivity. For the majority of students, lemurs are only to be found at Lake Alaotra (61.9%), followed by Africa (30.3%) and only 7.8% answered correctly that lemurs are restricted to Madagascar ($n = 1279$). Most students knew that lemurs are protected by law (59.2%), but 22.5% said they are not protected and 18.3% were unsure ($n = 1266$; see Table S3 for more details).

Looking at the time series, it stands out that the highest percentage gave the right answer to the lemur's natural habitat ("Madagascar") at T0. In both intervention groups, the proportion of correct answers dropped markedly to only 3.7%, reflecting the misconception that lemurs are only found at Lake Alaotra (77.2% and 68.9%). Knowledge that lemurs are protected by law was stable in the Control group between T0 and T1 (63.3% and 62.9% respectively) whereas it increased in the Comic group (40.0% and 59.4% respectively) and increased markedly in the Comic Plus group (26.7% and 81.3% respectively).

Ten multiple-choice questions examined student's knowledge of local biotopes (marshes, hills, forests), their ecosystem services and their wildlife (Table S2). Within these questions, two addressed conceptual knowledge. Even if the percentage of correct answers increased between T0 and T1 in both intervention groups, there were marked differences. Knowledge of the most familiar biotope, the marsh, was relatively high even at T0 and increased to at least 77.0% (Comic group) or 88.0% (Comic Plus group). Percentage of correct answers remained below this level for animals like birds (60.3% Comic group and 63.0% Comic Plus) or fish (25.8% Comic group and 56.3% Comic Plus) at T1. Interestingly, correct and incorrect answers regarding a custom forbidden by law (Should we burn the marshes?) were nearly evenly distributed at T0 within both intervention groups. People can profit in the short term by burning the protected marsh belt by harvesting fish buried in the mud during the dry season or by converting burnt marsh into rice fields, but in the long run, this custom is very detrimental for human resource use and protected wildlife alike. Correct answers to the burning of marshes at T1 were higher in the Comic Plus group (82.2%) compared to the Comic group (72.1%). Correct answers to the two questions addressing conceptual knowledge (the connection between deforested hillsides, soil erosion and rice field productivity) started from a lower level and increased mostly only to an intermediate level at T1 (Comic group T0 52.9% and 25.0%; T1 63.7% and 40.4%; Comic Plus T0 52.4% and 22.1%; T1 82.8% and 61.5%, respectively).

Six multiple-choice questions examined student's familiarity with the local lemur species, the Bandro (*H. alaotrensis*). One can conclude here that students in general know this species well, the lowest percentage of correct answers being 86.5% with the exception of the question "What is unique about the Bandro?" (Answer "Being endemic to the marshes of Lake Alaotro") that one-quarter of students answered incorrectly (Table S1).

Since we had to deal with fluctuations within groups due to the specific primary school situation in rural Madagascar mentioned in detail in the Introduction section, we tested for differences between groups (Control, Comic, Comic Plus) at each survey period rather than for change over time which requires stability in group composition and tracking of individuals over time. The three survey periods were before the intervention (T0), after five months of environmental education for intervention groups at the end of term (T1) and one year after T1 (T2).

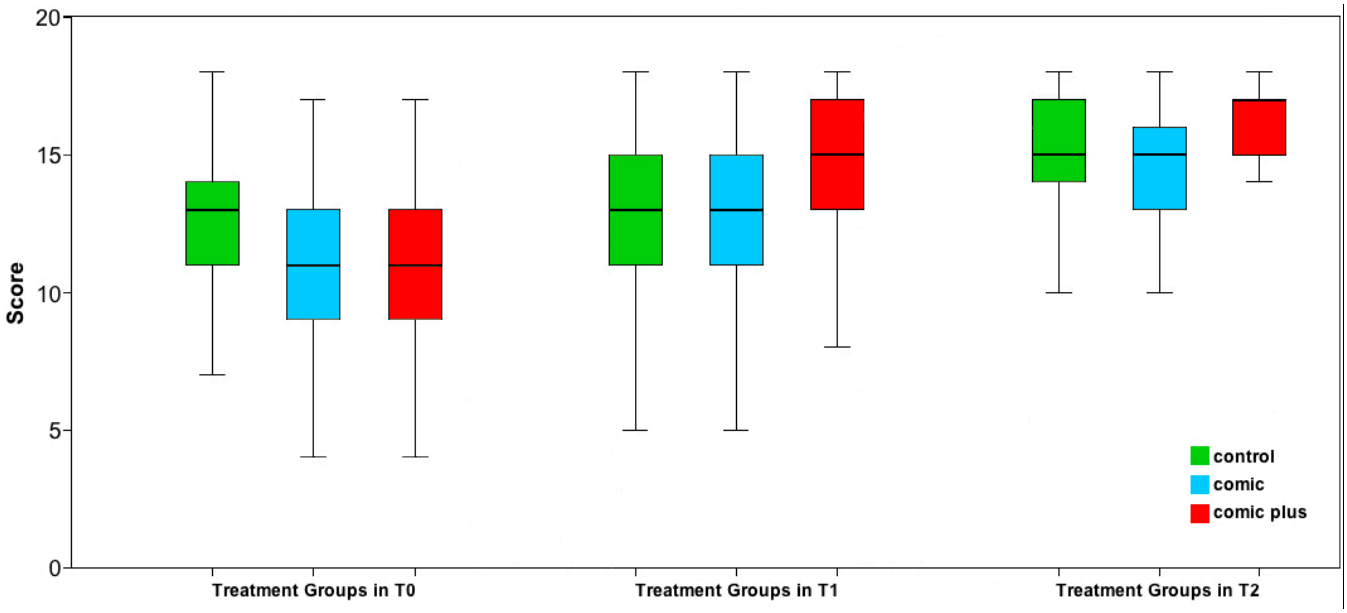

Figure 2. Student's scores for different treatment groups at the three survey times T0, T1 and T2.

At T0, there was a significant difference between mean scores (number of correct answers to 18 multiple-choice questions in the questionnaire) between groups (ANOVA, Table 1; Figure 2). *Post hoc* tests (Bonferroni) showed that the Control Group had a significantly higher score than both intervention groups that did not differ from another. In search of an explanation, we found out that students in the Control Group were significantly older by about a year (mean age 10.52 years for Control; Comic 9.54, Comic Plus 9.58; ANOVA with *post hoc* tests, Bonferroni, $p = 0.000$, level of significance set at 0.05) than students in the intervention groups. Thus, the Control Group had, on average, one more year of schooling. Boys were also slightly overrepresented in the Control Group (53.8% in Control compared to 52.3% in the basic population). Overall, boys had a significantly higher test score (13.08) than girls (12.60), what may have contributed to the observed result (*t*-test, two-tailed for independent groups, $p = 0.004$).

Table 1. Analysis of the variance of students' scores between and within treatment groups at the three survey times T0, T1 and T2.

ANOVA T0: Score					
Source	**Sum of squares**	**df**	**Mean square**	**F**	**Sig.**
Between	434.206	2	217.103	29.418	0.000
Within	3970.341	538	7.380		
Total	4404.547	540			
ANOVA T1: Score					
Source	**Sum of squares**	**df**	**Mean square**	**F**	**Sig.**
Between	335,619	2	167.809	22.843	0.000
Within	3783.310	515	7.346		
Total	4118.929	517			
ANOVA T2: Score					
Source	**Sum of squares**	**df**	**Mean square**	**F**	**Sig.**
Between	52.765	2	26.382	766	0.001
Within	865.698	222	3900		
Total	918.462	224			

At T1, there was a significant difference between mean scores (number of correct answers in the questionnaire) between groups (ANOVA, Table 1, Figure 2). *Post hoc* tests (Bonferroni) showed that the Comic Plus Group had a significantly higher score than both other groups after five months with environmental education in class (ANOVA with *post hoc* tests, Bonferroni, $p = 0.000$, level of significance set at 0.05). Control and Comic Groups did not differ from each other, so the Comic Group had made up for the difference at T0 within five months.

The mean score increased significantly differently between the three treatment groups from T0 to T1 (Figure 3; Friedman two way ANOVA on ranks, $p = 0.000$; level of significance set at 0.05) with the Comic Plus Group performing best, followed by the Comic Group, whereas the mean score of the Control increased only slightly overall and even decreased in two of six schools.

The survey period T2 posed several problems. In the aftermath of the political coup in 2009, which led to a budgetary breakdown since most international donors withdrew from the not-internationally-acknowledged government, the payment of school teachers lagged dramatically behind and nationwide strikes by teachers followed this development. Thus, after a prolonged period of strikes, less than half of the students than usual attended class when tests took place. The school in Sahamamy had already shut down before the official end of the term when the field research team visited at the arranged date. Thus, only 224 students in eight classes (four Control, two Comic, two Comic Plus) took the tests for long-term effects one year after the end of the environmental education intervention.

At T2, there was a significant difference between mean scores (number of correct answers in the questionnaire) between groups (ANOVA, Table 1, Figure 2). *Post hoc* tests (ANOVA with *Post hoc* tests, Bonferroni, $p = 0.001$, level of significance set at 0.05) showed that the Comic Plus Group had a significantly higher score than the Comic Group. Control and Comic Group did not differ from each other, as did the Control and Comic Plus Group.

At T2, all eight remaining classes had higher scores than at the survey time T1, including the four Control classes (Figure 3, Table 2). This is contradictory to expectations, since normally the measurable

effects of any given educational intervention decline over time. A further visit by our field research team to the schools to look for possible explanations revealed that school teachers in general used the comic books that stayed with the schools after the intervention ended in all classes—including the controls—due to a lack of school books. Interviews revealed that the teachers thought that the experiment was over when the environmental education ended in intervention classes in summer 2011 and used the comic books in a range of school subjects such as reading, geography and the Malagasy language afterwards.

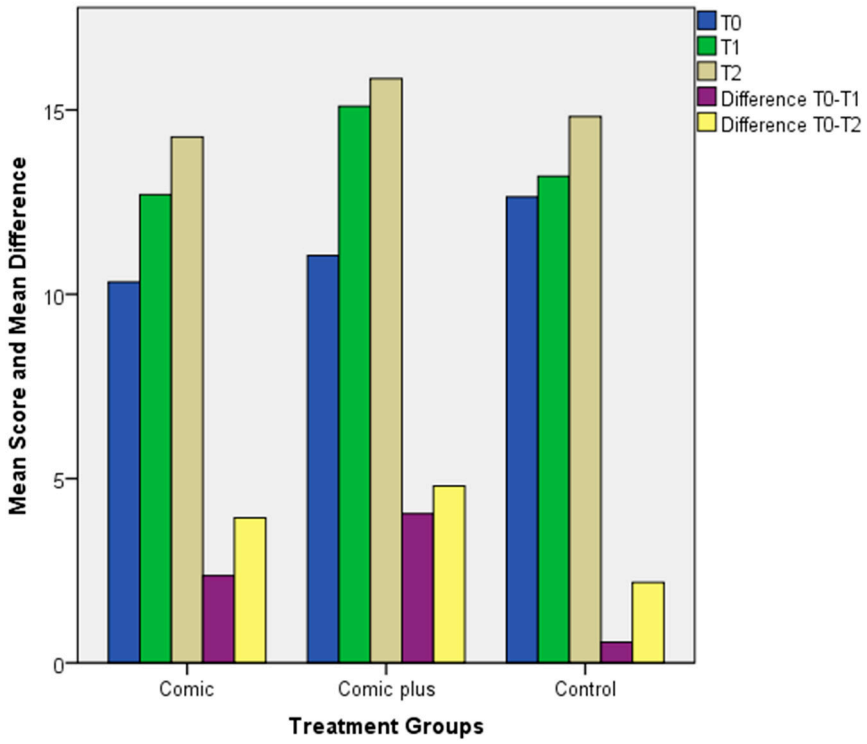

Figure 3. Mean score and mean difference between measurements for treatment groups at the three survey times T0, T1 and T2.

Table 2. Mean score of students and standard deviation for each treatment group at the three survey times T0, T1 and T2 (n given in brackets).

Survey time	Control	Comic	Comic Plus
T0 (542)	12.42 ± 2.592 (253)	10.76 ± 2.831 (139)	10.51 ± 2.813 (149)
T1 (518)	12.80 ± 2.895 (247)	13.03 ± 2.664 (136)	14.70 ± 2.388 (135)
T2 (224)	15.06 ± 1.866 (108)	14.39 ± 2.121 (79)	15.79 ± 1.961 (38)

3.1.1. Open Questions

The questionnaire contained two open questions. The first one addressed students' understanding of the environment (Figure 4). The mostly short and not overly complex answers were subsumed into broader categories. Since there were no discernible trends over time, all answers were pooled together. The three largest out of thirteen categories contained 50% of all answers. Students mentioned plants, trees and forests as often as nature or everything that surrounds us, everything that lives. From very

similar answers in several classes, it was clear that they memorized definitions given to them by teachers. A typical answer in the form of an enumeration was "the entity of earth, water, air, house, school, road, factory, lessons in class, living things". It was common that answers contained terms belonging to the natural and human environment alike. In contrast, 4.9% of all answers referred only to the human environment of the village. The third largest category contains all answers that mentioned air, clean air and (stopping) air pollution. (Clean) water and personal cleanliness and hygiene such as keeping the household and village unsoiled were also often given as definition of the environment by students. Taken together, the three categories stand for more than 25% of all answers. The marshes and their wildlife were mentioned by 4.7% of students. Lake Alaotra itself was never mentioned as part of the environment.

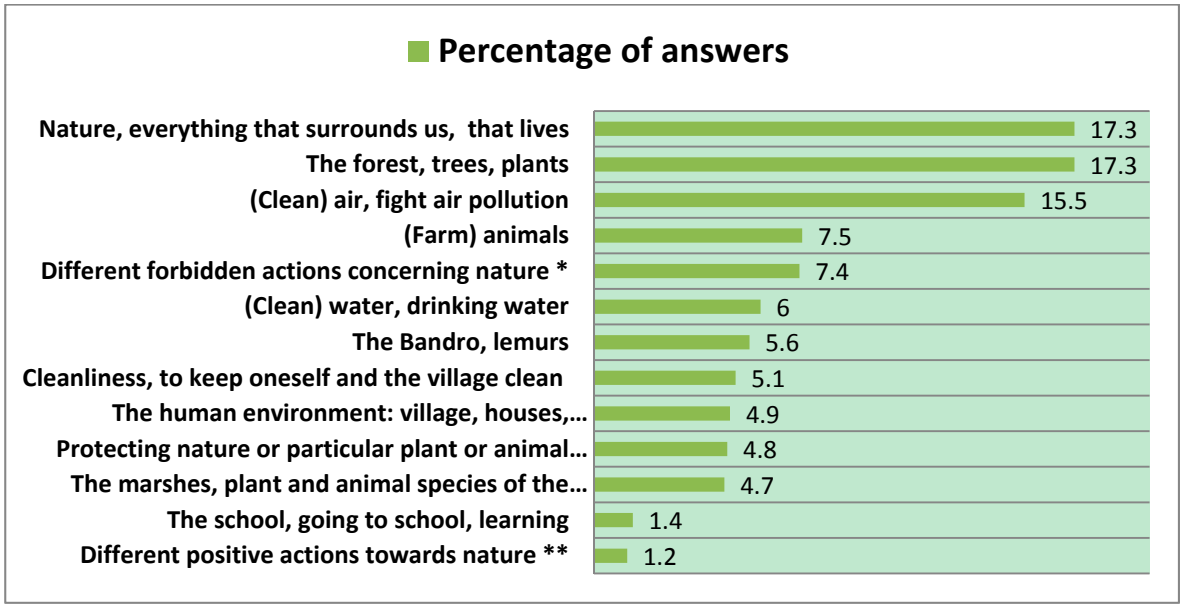

Figure 4. Students' answers to the open question "What is the environment?" given as a percentage of all answers. Only categories containing more than 20 answers are included. * such as: do not burn, do not cut bamboo, do not destroy plants, do not kill living species, do not kill the Bandro; ** such as: we plant trees, grow papyrus and bamboos.

According to the results, 7.4% mentioned forbidden actions towards nature or specific species ("do not burn the marshes or the forests, do not kill animals, do not kill Bandros, do not cut trees"), fewer (4.8%) mentioned protective attitudes ("protect the marshes or forests, protect the trees, the soils, the Bandro"), even fewer (1.2%) mentioned positive actions to be taken ("plant trees, plant reeds"). Very few of these answers were put into context or further elaborated on.

3.1.2. Career Aspirations

The second open question addressed the topic of future job perspectives (Table 3). Throughout all tests, "teacher" was clearly the most popular profession, followed with considerable distance by "doctor". The predominant professions held by students' parents, farming and fishing, started with 15.2% and 5.5% respectively at T0, constantly lost attractiveness over time and ended with 7.3% and 2.3% at T2. Becoming a policeman or soldier held growing attractiveness over time mostly for boys,

whereas girls frequently considered becoming nuns. Only a few students thought of a career in nature conservation. This choice also was clearly influenced by the factor "school"—with very few exceptions the students came from the school in Ambodivoara and were evenly distributed between the control and the comic book intervention class. It seems, therefore, that environmental education has no measurable influence on career aspirations for primary school students.

Table 3. Career aspiration of students (only answers >4% or environmental related answers are shown).

	T0 (*n* = 489)			T1 (*n* = 485)			T2 (*n* = 219)			Percentage of all answers		
Career aspiration	**Girls**	**Boys**	**All**	**Girls**	**Boys**	**All**	**Girls**	**Boys**	**All**	**T0**	**T1**	**T2**
Teacher	95	79	174	105	59	164	60	32	92	35.7	33.8	42.0
Doctor	41	37	78	40	33	73	17	23	40	16.0	15.1	18.3
Rice/Vegetable Farmer	29	45	74	12	25	37	7	9	16	15.2	7.6	7.3
Nun/Priest	20	7	27	49	10	59	9	4	13	5.5	12.2	5.9
Fisher	2	25	27	2	16	18	1	4	5	5.5	3.7	2.3
Help the parents	16	5	21	4	-	4	3	-	3	4.3	0.8	1.4
Policeman/Soldier	1	16	17	10	63	73	3	26	29	3.5	15.1	13.3
Protector of marshes	1	4	5	4	10	14	4	3	7	1.0	2.9	3.2

3.2. Discussion

Environmental education has proven to be a valuable tool in fostering pro-environmental knowledge, attitudes and behavior, even if its present practice and theoretical paradigms have to be advanced in an increasingly transdisciplinary manner that integrates different disciplines, NGOs, local stakeholders, sociocultural background and development issues [81,82]. Accordingly, providing successful environmental education should be addressed more and more as one of the so-called "wicked" problems withstanding easy solutions due to their complex and interdependent nature [82]. The notions to further include an African perspective in conservation policy to protect biodiversity [83] and to strengthen local languages, local needs and cultural context in providing basic education for sustainable development is expressed in the current debate [6,84].

Results of this research project clearly show that providing adequate EE within rural Malagasy public primary schools can significantly increase student's knowledge of the environment, compared to a control group without EE. Combining new hands-on teaching materials with the comic book used by the MWC in EE for nearly a decade by now further increased student's environmental knowledge significantly. In general, overall knowledge of students of the most familiar biotope, the marshes and the local lemur species was quite good and increased markedly towards T1. Factual knowledge of less familiar biotopes (forests, hills) and less familiar animal species (birds and fish) began at a lower level and stayed below those levels reached in the familiar realm of students. Students had clearly more difficulties with factual knowledge addressing abstract facts like the legal status of lemurs than with applied factual knowledge like lemur habitat, lemur food or human use of marshes. Students also had difficulties with conceptual knowledge addressing ecological interactions and possible side effects for people. It should be noted that in the aforementioned categories, learning outcomes of the group using the additional materials were clearly better than those of students using only the comic book so peer-to-

peer learning in smaller groups had a positive effect not only on overall knowledge acquisition, but also on the acquisition of more complex, interconnected and abstract forms of knowledge. The study, therefore, adds to the so-far-small body of empirical evaluation studies carried out under the challenging conditions of developing countries compared to evaluation studies in Western countries [50,52,55,66,68]. Providing environmental education for students proves to have a measurable and lasting positive effects [85].

Even if environmental knowledge itself does not lead automatically to positive attitudes towards nature and nature conservation, it is seen as a necessary prerequisite for developing positive attitudes. Positive attitudes themselves are not sufficient to foster environmental friendly behavior but are seen correspondingly as a necessary prerequisite [86]. Therefore, transmitting environmental knowledge can be seen as an in itself insufficient, but indispensable first step towards environmental friendly behavior. However, the overarching objective remains to change people's behavior towards the environment [87].

Malagasy teachers, especially in rural communities, often lack proper vocational training and have to teach all school subjects in class. In addition, classes often consist of more than 50 and up to 100 students so ex-cathedra teaching is often used by teachers in this situation [6]. The comic book can easily be used for this traditional teaching style in class. In combination with modern teaching materials that envisage no dominant role for teachers but strengthen students' interactions instead by fostering group discussions, joint decision making and collective manipulation of materials (cutting-out of animals and inserting them into their proper natural habitats), significantly better results are obtained. Thus, even if those materials are used up during learning experiences and pose increased costs for the NGOs providing them, those additional costs seem justified in the light of better learning outcomes. Nonetheless, the effectiveness of such additional materials should always be subject to proper evaluation within given education programs before providing them on a greater scale. Students that used those materials were also clearly ahead of the other groups when tested for the long-term impact one year after environmental education took place. Thus, long-term effects are in favor of the extra investment in those materials, too. EE programs containing outdoor activities or outdoor adventure education have repeatedly proven to have strong and had lasting long-term impacts on participants [65,88] but are even more costly to provide and difficult to be conducted under challenging conditions like those at Lake Alaotra.

Kuhar *et al.* [68] also found evidence for long-term knowledge retention of their environmental education program in Uganda. They observed some trends towards a continued performance increase over time they attributed to follow-up instructions in class, older students transferring knowledge to siblings, friends and family and a sort of institutional learning of schools and teachers that were involved in EE programs for many years. Since their evaluation design lacked control groups, the evidence remains convincing but circumstantial.

An unwelcome side effect of poverty is that most schools in rural Madagascar lack modern school books and teaching materials. School books sometimes even date back to colonial times or are provided for by France or other Western countries. Nevertheless, they are used due to lack of alternatives [6]. A striking effect of this practice can be seen by the frequent mentioning of (clean) air and air pollution (15.5%) when students were asked for their understanding of the environment. The air at Lake Alaotra is not polluted, nor did the local population have any means to significantly pollute

the air, even if wished for, since factories are virtually absent and individual motorized transportation is rare in the area. In a different study, similar answers were obtained by teachers at Lake Alaotra that frequently mentioned air pollution as being an environmental problem in the area [6]. Korhonen and Lappalainen [58] found similar answers by students for the equally rural Ranomafana region of Madagascar, far away from our study area. These findings can only be explained by the frequent use of textbooks designed for a totally different context and audience. The frequent mistaking of environmental problems caused by Western lifestyles in the foreign textbooks is then made locally meaningful by teachers and students alike by mentioning lack of sanitation or poor personal hygiene and garbage disposal as a prominent source of air pollution.

Teaching practices in front of large classes often rely on memorization of lessons taught. In addition to providing sayings to be memorized by students, these often are phrased in a negative way as prohibitions and lack context or explanatory powers to make them meaningful to students (examples mentioned by students include answers as "do not kill animals", "do not cut trees" or "do not burn the marshes"; 7.4% of students mentioned forbidden actions concerning nature or specific species). Fewer students (4.7%) mentioned rules phrased in a positive way ("protect the marshes" or "protect the Bandro"), equally lacking explanatory content as to why those rules should be applied or obeyed. Only 21 answers (1.2%) out of 1670 answers were concerned with positive actions that could be taken to improve the environment or help conservation of habitats or species. In Uganda, Kuhar *et al.* [68] equally found bare prohibitive rules to dominate when students were asked to name possible solutions for environmental problems. Rules, independent of positive or negative phrasing, that lack any explanation for the expected behaviour and local meaningfulness seem unlikely to be obeyed and translated into behaviour. Only very few answers of students gave an explanation for the desirable behaviour ("to protect the marshes and the forests because they retain the soil"). Education materials therefore should be written in a way that rules are made sufficiently understandable to students and give positive examples resulting from their application for local livelihoods and nature conservation.

A task of our educational intervention totally failed, which was to enhance students understanding of lemurs being the core natural heritage of Madagascar. Instead of increasing knowledge that lemurs are endemic and emblematic to Madagascar, in the end, very few students understood this fact. We see this as a side effect that the comic book was set in the familiar surroundings of students and assigned a dominant role to the local lemur species, the Bandro. Most students never saw a lemur for themselves and the only diurnal lemur at Lake Alaotra is the Bandro anyway. Thus, by intending to teach them that their familiar lemur species is of superior importance, attracting foreign scientists and tourists alike, they obviously lost the greater perspective of Madagascar. Anyway, students had clearly problems understanding concepts beyond their limited daily experience as mentioned above. In a revised version of the comic book, an episode introducing other emblematic lemur species and a map of Madagascar showing their habitats should be included to eliminate this misconception.

Misunderstanding the importance of lemurs for global conservation issues, tourism and Madagascar's natural heritage lies at the core of insufficient conservation efforts by Malagasy people and the national government. This misunderstanding has been reported, for example, by Ratsimbazafy [59]. His notion that most Malagasy people have never seen lemurs is emphasized by our findings that only 6.3% of students living in rural conditions said they had ever seen a lemur in the wild.

Clearly, EE also did not lead to more complex explanations of the environment or influence the career aspirations of students towards nature conservation. Interestingly, in the equally rural Ranomafana region of Madagascar, environmental careers were popular among primary and second school students. This was attributed to their familiarity with staff and guides of the nearby Ranomafana National Park [58]. The authors of this study reported a clear preference of school children for the well-educated professions of teachers and doctors. With only one exception out of 18 schools, students had a disregard for becoming farmers like their parents and in general aspired to careers requiring more education. The latter findings are congruent to our results where teachers and doctors were in high regard and traditional professions of parents like farming or fishing were unpopular and even lost attractiveness over time for students.

The Alaotra Gentle Lemur (*Hapalemur alaotrensis*) has been in the center of conservation efforts for decades by Durrell. Conservation activities include a wide array of actions taken, such as participatory ecological monitoring of the marshes combined with an inter-village competition and fighting further burning and conversion of marshes into rice fields [21]. In addition to those activities that are undertaken in the whole region, a small nature reserve, the Parc Bandro, has been established near the village of Andreba. MWC operates a community camp near the village that supplies accommodation for scientists and tourists and arranges canoe tours with trained local guides into the marshes to see the endemic lemur. This secures some additional income for villagers living mostly under threat of livelihood security and is, therefore, an example of successful valorisation of their natural heritage [22,25]. The primary school in Andreba has also been continuously involved in MWC's EE program since 2006. Monitoring of *H. alaotrensis* showed that encounter rates were three times higher in Andreba compared to other sites the species is known to occur. Groups of lemurs tended to be larger and the animals displayed a clearly less fearful behaviour [35]. Even if it is impossible to distinguish which measures contributed in which amount to this success, it seems obvious that EE is a vital part of it.

4. Conclusions

In addition to providing suitable materials, adequate teacher training has to be implemented in programs. Traditionally, EE is insufficiently addressed during teacher training and not, or only marginally, included in the current Malagasy school curriculum, with the result that teachers frequently feel uncomfortable teaching this subject [6,58]. This has been reported from other education research in African developing countries as well [68]. Thus, it is necessary to strengthen teacher's environmental knowledge and required teaching skills and self-efficacy in regard to education materials. The best possible solution seems to be that NGOs from the start onwards include local teachers, school authorities and conservation practitioners into designing environmental education programs. At first, this may seem more laborious, but taking this road is the only way to ensure that in the end local meaningful, culturally appropriate materials that do not force a foreign perspective on people are developed. The omission of the African perspective by intervening conservationists from Western countries can be seen in the obvious failure of a lot of conservation projects [83]. Only such participatory developed materials stand a chance to be used frequently by teachers in schools and to convey their conservation message to students even when external program funding may have stopped. If materials are designed using the local native language, their effectiveness is further increased [84].

In Madagascar, the switch from Malagasy to French as teaching language (the latter being forced upon students and teachers alike in superior grades of primary school) has been identified as a hindrance for successful learning [6].

An unexpected benefit of providing EE materials to schools was revealed by follow-up testing of students one year after the project ended. Contrary to our expectations, environmental knowledge had increased in all ten remaining school classes, even markedly within the five remaining control classes without formal EE. Follow-up interviews with teachers revealed that the comic books had been used in all classes in a range of school subjects due to lack of appropriate school books in general. Thus, the environmental knowledge of students did increase without formal EE taking place. This possibility was further explored in a joint Master's thesis with the Ecole Normale Superieure in Antananarivo (the capital of Madagascar). This thesis examined the potential of MWC's comic book to be used in a range of mandatory school subjects, giving further advice on appropriate use in terms of official school curricula content and teaching methods in primary schools [89]. Thus, by providing schools in developing countries with teaching materials that have suitable content for an array of diverse school subjects as geography, language acquisition or even mathematics and take the state's official school curricula for those subjects into account, in effect, EE could happen in the classroom without EE having to take place officially. This solution could offer a shortcut to the common and frustrating dilemma that, despite long lasting lobbying processes by NGOs and official bodies such as UNESCO for EE and ESD, those subjects are so far absent or insufficiently integrated into the official school curricula of most developing countries.

Acknowledgments

We would like to thank three anonymous reviewers whose reviews and advice on missing literature helped greatly to improve the quality of the manuscript. We thank the school authorities (CISCO and ZAP) of the districts of Ambatondrazaka and Amparafaravola, as well as school directors and teachers in the Alaotra region for their open-minded support for implementing environmental education and enabling the evaluation process. A special thanks goes to Rindrahatsarana Ramanankirahina for her reliable and dedicated translation of the questionnaires and data entering, to Marine Joly and Lena Reibelt for their thoughts, encouragement and helpful support and to Ramafa for the artistic realization of the comic and Emmanuelle Tanaïs Aupest for the artistic realization of teaching materials. Furthermore, we thank Fidimalala Ralainasolo for his assistance with logistics and distribution of the materials on-site. Thanks also to Nils Benit for help with statistics, Irene Leser for valuable ideas on handling of qualitative data and Anke Meisert for helping out with redrawing figures. Richard Kotter provided additional ideas and greatly helped to improve the language of the manuscript. Last but not least, we would like to mention all the students who pursued environmental education with lots of enthusiasm and curiosity.

This project would have been impossible without the financial support of the Hahnemühle FineArt Paper GmbH and the European Association of Zoos and Aquaria (EAZA).

Author Contributions

Torsten Richter planned the scientific evaluation of the environmental education and did all analysis of qualitative and quantitative data. Antje Rendigs and Claudette Patricia Maminirina co-developed the comic book and the first version of the questionnaire. Antje Rendigs co-developed the additional education materials and coordinated the field work during the evaluation period. Claudette Patricia Maminirina did most field work at Lake Alaotra and did the translation of the questionnaire into Malagasy.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Horning, N.R. Strong support for weak performance: Donor competition in Madagascar. *Afr. Affairs* **2008**, *107*, 405–431.
2. UNDP Human Development Report 2014: Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience. Available online: http://hdr.undp.org/en (accessed on 25 February 2015).
3. International Monetary Fund. World Economic Outlook Database, April 2008. Available online: www.imf.org (accessed on 12 February 2015).
4. UNDP Human Development Report 2014: Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience–Explanatory note on the 2014 HDR composite inidices–Madagascar. Available online: http://hdr.undp.org/en (accessed on 25 February 2015).
5. Glick, P.; Sahn, D.E. The demand for primary schooling in Madagascar: Price, quality, and the choice between public and private providers. *J. Dev. Econ.* **2006**, *79*, 118–145.
6. Reibelt, L.M.; Richter, T.; Waeber, P.O.; Rakotoarimanana, S.H.N.H.; Jasmin Mantilla-Contreras, J. Environmental education in its infancy at Lake Alaotra, Madagascar. *Madag. Conserv. Dev.* **2014**, *9*, 71–82.
7. CIA World Fact Book 2015, Available online: https://www.cia.gov/library/publications/the-world-factbook/ (accessed on 13 March 2015).
8. Shepherd, A.; Mitchell, T.; Lewis, K.; Lenhardt, A.; Jones, L.; Scott; L.; Muir-Wood, R. *The Geography of Poverty*, *Disasters and Climate Extremes in 2030*; ODI: London, UK, 2013.
9. Randrianja, S. (Ed.) *Madagascar*, *le coup d'État de mars 2009*; Éditions Karthala: Paris, France, 2012.
10. Stokstad, E. Despite progress, biodiversity declines. *Science* **2010**, *329*, 1272–1273.
11. Green, G.; Sussman, R. Deforestation history of the eastern rain forests of Madagascar from satellite images. *Science* **1990**, *248*, 212–215.
12. Glaw, F.; Vences, M. *A Field Guide to the Amphibians and Reptiles of Madagascar*, 3rd ed.; Vences & Glaw: Cologne, Germany, 2007.
13. Vieites, D.R.; Wollenberg, K.C.; Andreone, F.; Köhler, J.; Glaw, F.; Vences, M. Vast underestimation of Madagascar's biodiversity evidenced by an integrative amphibian inventory. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 8267–8272.

14. Mittermeier R.A.; Gil, P.R.; Pilgrim, J. *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*; Conservation International: Arlington, VA, USA, 2005.
15. Myers, N.; Mittermeier, R.A.; Mittermeier, C.G.; da Fonseca, G.A.B.; Kent, J. Biodiversity hotspots for conservation priorities. *Nature* **2000**, *403*, 853–858.
16. Rakotomanana, H.; Jenkins, R.K.B.; Ratsimbazafy, J. Conservation challenges for Madagascar in the next decade. In *Conservation Biology–Voices from the Tropics*; Sodhi, N.S., Gibson, L., Raven, P.H., Eds.; Wiley-Blackwell: Hoboken, NJ, USA, 2013; pp. 33–39.
17. Rendigs, A.; Reibelt, L.M.; Ralainasolo, F.B.; Ratsimbazafy, J.H.; Waeber, P.O. Ten years into the marshes–Hapalemur alaotrensis conservation, one step forward and two steps back? *Madag. Conserv. Dev.* **2015**, *10*, 13–20.
18. Hannah, L.; Dave, R.; Lowry, P.P.; Andelman, S.; Andrianarisata, M.; Andriamaro, L.; Cameron, A.; Hijmans, R.; Kremen, C.; Mackinnon, J.; *et al*. Climate change adaptation for conservation in Madagascar. *Biol. Lett.* **2008**, *4*, 590–594.
19. Institut National de la Statistique. 2012. Available online: http://www.instat.mg/index.php?option=com_content&view=article&id=33&Itemid=56 (accessed on 18 January 2014).
20. Bakoarinininiaina, L.N.; Kusky, T.; Raharimahefa, T. Disappearing Lake Alaotra: Monitoring catastrophic erosion, waterway silting, and land degradation hazards in Madagascar using Landsat imagery. *J. Afr. Earth Sci.* **2006**, *44*, 241–252.
21. Andrianandrasana, H.T.; Randriamahefasoa, J.; Durbin, J.; Lewis, R.E.; Ratsimbazafy, J.H. Participatory ecological monitoring of the Alaotra wetlands in Madagascar. *Biodivers. Conserv.* **2005**, *14*, 2757–2774.
22. Rakotoarisoa, T.; Waeber, P.O.; Richter, T.; Mantilla-Contreras, J. Water hyacinth (Eichhornia crassipes), opportunity or threat for the Alaotra wetlands and livelihood? *Madag. Conserv. Dev.* **2015**, in press.
23. Dolins, F.L.; Jolly, A.; Rasamimanana, H.; Ratsimbazafy, J.; Feistner, A.T.; Ravoavy, F. Conservation education in Madagascar: Three case studies in the biologically diverse island-continent. *Am. J. Primatol.* **2010**, *72*, 391–406.
24. Copsey, J.A.; Jones, J.P.G.; Andrianandrasana, H.; Rajaonarison, L.H.; Fa, J.E. Burning to fish: Local explanations for wetland burning in Lac Alaotra, Madagascar. *Oryx* **2009**, *43*, 403–406.
25. Copsey, J.A.; Rajaonarison, L.H.; Ranriamihamina, R.; Rakotoniaina, L.J. Voices from the marsh: Livelihood concerns of fishers and rice cultivators in the Alaotra wetland. *Madag. Conserv. Dev.* **2009**, *4*, 25–30.
26. Ranarijoana, H.L.T. Concept de Modéle Ecologique pour la Zone Humide Alaotra. *Madag. Conserv. Dev.* **2007**, *2*, 35–42.
27. Lammers, P.; Richter, T.; Waeber, P.O.; Mantilla-Contreras, J. Lake Alaotra wetlands: Ecological status quo in one of Madagascar's most important rice and fish production regions. *Madag. Conserv. Dev*. **2015**, in press.
28. Villamagna, A.M.; Murphy, B.R. Ecological and socio-economic impacts of invasive water hyacinth (Eichhornia crassipes): A review. *Freshw. Biol.* **2010**, *55*, 282–298.
29. Ferry, L.; Mietton, M.; Robison, L.; Erismann, L. Le lac Alaotra a Madagascar-Passe, Present et Futur. *Z Geomorphol.* **2009**, *53*, 299–318.

30. Penot, E.; Benz, H.; Bar, M. Utilisation d'indicateurs économiques pertinents pour l'évaluation des systèmes de production agricoles en termes de résilience, vulnérabilité et durabilité: Le cas de la région du lac Alaotra à Madagascar. *Èthique et écon.* **2014**, *11*, 44–60.
31. Plan Régional de Développement. Région Alaotra-Mangoro, Province Autonome de Toamasina. **2005**, unpublished work.
32. Pidgeon, M. *An Ecological Survey of Lake Alaotra and Selected Wetlands of Central and Eastern Madagascar in Analyzing the Demise of Madagascar Pochard Aythya Innotata*; WWF/Missouri Botanical Garden: Antananarivo, Madagascar, 1996.
33. Durbin, J.; Funk, S.M.; Hawkins, F.; Hills D.M.; Jenkins P.D.; Moncrieff, C.B.; Ralainasolo, F.B. Investigations into the status of a new taxon of Salanoia (Mammalia: Carnivora: Eupleridae) from the marshes of Lac Alaotra, Madagascar. *Syst. Biodivers.* **2010**, *8*, 341–355.
34. The IUCN Red List of Threatened Species. Aythya Innotata. Available online: http://www.iucnredlist.org/details/9676/0 (accessed on 18 January 2014).
35. Guillera-Arroita, G.; Lahoz-Monfort, J.J.; Milner-Gulland, E.J.; Young, R.P.; Nicholson, N. Monitoring and conservation of the Critically Endangered Alaotran gentle lemur Hapalemur alaotrensis. *Madag. Conserv. Dev.* **2010**, *5*, 103–109.
36. Guillera-Arroita, G.; Lahoz-Monfort, J.J.; Milner-Gulland, E.J.; Young, R.P.; Nicholson, E. Using occupancy as a state variable for monitoring the Critically Endangered Alaotran gentle lemur Hapalemur alaotrensis. *Endanger. Spec. Res.* **2010**, *11*, 157–166.
37. Ratsimbazafy, J.H.; Ralainasolo, F.B.; Rendigs, A.; Mantilla-Contreras, J.; Andrianandrasana, H.; Mandimbihasina, A.R.; Nievergelt, C.M.; Lewis, R.; Waeber, P.O. Gone in a puff of smoke? Hapalemur alaotrensis at great risk of extinction. *Lemur News* **2013**, *17*, 14–18.
38. Ralainasolo, F.B.; Waeber, P.O.; Ratsimbazafy, J.; Durbin, J.; Lewis, R. The Alaotra gentle lemur: Population estimation and subsequent implications. *Madag. Conserv. Dev.* **2006**, *1*, 9–10.
39. The IUCN Red List of Threatened Species. Version 2014.3. Available online: http://www.iucnredlist.org/details/22680380/0 (accessed on 13 March 2015).
40. Ramsar Convention Secretariat. *The Ramsar Convention Manual: A Guide to the Convention on Wetlands (Ramsar, Iran, 1971)*, 6th ed.; Ramsar Convention Secretariat: Gland, Switzerland, 2013.
41. Hart, E. Identification of key characteristics of environmental education. *J. Environ. Educ.* **1981**, *13*, 12–16.
42. Palmer, J.A. *Environmental Education in the 21st Century: Theory, Practice Progress and Promise*; Routledge: London, UK, 2003.
43. UNESCO. *Trends in Environmental Education*; UNESCO: Paris, France, 1977.
44. UNESCO. *Final Report: Intergovernmental Conference on Environmental Education*; UNESCO: Paris, France, 1978.
45. Orr, D.W. *Earth in Mind*; Island Press: Washington, DC, USA, 1994.
46. UNESCO. *Proposal for a Global Action Programme on Education for Sustainable Development as Follow-Up to the United Nations Decade of Education for Sustainable Development (DESD) after 2014*; UNESCO: Paris, France, 2013.

47. Pavlova, M.B. Environmental education and/or education for sustainable development: What role for technology education? In *PATT 25*, *CRIPT 8–Perspectives on Learning in Design & Technology Education*; Stables, K., Benson, C., de Vries, M., Eds.; Goldsmiths University of London: London, UK, 2011; pp. 333–339.
48. Kopnina, H. Revisiting Education for Sustainable Development (ESD): Examining Anthropogenic Bias Through the Transition of Environmental Education to ESD. *Sustain. Dev*. **2011**, *22*, 73–83.
49. Kopnina, H. Education for sustainable development (ESD): The turn away from "environment" in environmental education? *Environ. Educ. Res.* **2012**, *18*, 699–717.
50. Frick, J.; Kaiser, F.G.; Wilson, M. Environmental knowledge and conservation behavior: Exploring prevalence and structure in a representative sample. *Pers. Indiv. Differ*. **2004**, *37*, 1597–1613.
51. Kaiser, F.G.; Fuhrer, U. Ecological behavior's dependency on different forms of knowledge. *Appl. Psychol.-Int. Rev.* **2003**, *52*, 598–613.
52. Roczen, N.; Kaiser, F.G.; Bogner, F.X.; Wilson, M. A Competence Model for Environmental Education. *Environ. Behav.* **2014**, *46*, 972–992.
53. Bogner, F.X.; Wiseman, M. Adolescents' attitudes towards nature and environment: Quantifying the 2-MEV model. *Environmentalist* **2006**, *26*, 247–254.
54. Geiger, S.M.; Otto, S.; Diaz-Marin, J.S. A diagnostic Environmental Knowledge Scale for Latin America. *Psyecol. Biling. J. Environ. Psychol.* **2014**, *5*, 1–36.
55. Liefländer, A.K.; Bogner, F.X.; Kibbe, A.; Kaiser, F.G. Evaluating Environmental Knowledge Dimension Convergence to Asses Educational Programme Effectiveness. *Int. J. Sci. Educ.* **2015**, *37*, 684–702.
56. Jolly, A. Challenges of Environmental Education in Madagascar. In Proceedings of the Conference Environmental Education in Madagascar, University of Sussex, Brighton, UK, 27–28 January 2012.
57. Patel, E.R.; Marshall, J.J.; Parathian, H. Silky sifaka (*Propithecus candidus*) conservation education in northeastern Madagascar. *Lab. Primate Newsl.* **2005**, *44*, 8–11.
58. Korhonen, K.; Lappalainen, A. Examining the environmental awareness of children and adolescents in the Ranomafana region, Madagascar. *Environ. Educ. Res.* **2004**, *10*, 195–216.
59. Ratsimbazafy, J.H. Lemurs as the most appropriate and best didactic tool for teaching. *Lemur News* **2003**, *8*, 19–21.
60. Brown, C. UNICEF initiatives in Madagascar. In Proceedings of the conference Environmental Education in Madagascar, University of Sussex, Brighton, UK, 27–28 January 2012.
61. Cowlishaw, G.; Dunbar, R. *Primate Conservation Biology*; University of Chicago Press: Chicago, IL, USA, 2000.
62. Ferraro, P.J.; Pattanayak, S.K. Money for Nothing? A Call for Empirical Evaluation of Biodiversity Conservation Investments. *PLoS Biol.* **2006**, *4*, 482–488.
63. Carleton-Hug, A.; Hug, J.W. Challenges and opportunities for evaluating environmental education programs. *Eval. Program Plan.* **2010**, *33*, 159–164.
64. Stern, M.J.; Powell, R.B.; Hill, D. Environmental education program evaluation in the new millenium: What do we measure and what have we learned? *Environ. Educ. Res.* **2014**, *20*, 581–611.

65. Ajiboye, J.O.; Olatundun, S.A. Impact of Some Environmental Education Outdoor Activities on Nigerian Primary Schools Pupils' Environmental Knowledge. *Appl. Environ. Educ. Commun.* **2010**, *9*, 149–158.
66. Bettinger, T.L.; Kuhar, C.W.; Lehnhardt, K.; Cox, D.; Cress, D. Discovering the Unexpected: Lessons Learned From Evaluating Conservation Education Programs in Africa. *Am. J. Primatol.* **2010**, *72*, 445–449.
67. Krief, S.; Nambogwe, H.; Mankoto, S.; Krief, J.-M. Malles pédagogiques itinérantes «les grands singes et leur habitat«: Parcours et premières évaluations de l'impact du projet en Ouganda et au Gabon. Available online: http://primatologie.revues.org/383 (accessed on 24 February 2015).
68. Kuhar, C.W.; Bettinger, T.L.; Lehnhardt, K.; Tracy, O.; Cox, D. Evaluating for Long-Term Impact of an Environmental Education Program at the Kalinzu Forest Reserve, Uganda. *Am. J. Primatol.* **2010**, *72*, 407–413.
69. Kuhar, C.W.; Bettinger, T.L.; Lehnhardt, K.; Cartwright, B.; Cress, D. Education Program Evaluation at Multiple Primate Sanctuaries in Equatorial Africa. *Int. J. Primatol.* **2012**, *33*, 208–217.
70. Johnson-Pynn, J.S.; Johnson, L.R. Successes and Challenges in East African Conservation Education. *J. Environ. Educ.* **2005**, *36*, 25–39.
71. Borchers, C.; Boesch, C.; Riedel, J.; Guilahoux, H.; Outtara, D.; Randler, C. Environmental Education in Côte d'Ivoire/West Africa: Extra-Curricular Primary School Teaching Shows Positive Impact on Environmental Knowledge and Attitudes. *Int. J. Sci. Educ.* **2014**, *4*, 240–259
72. Keane, A.; Ramarolahy, A.A.; Jones, J.P.G.; Milner-Gulland, E.J. Evidence for the effects of environmental engagement and education on knowledge of wildlife laws in Madagascar. *Conserv. Lett.* **2011**, *4*, 55–63.
73. Ormsby, A. Development of Environmental Education Programs for Protected Areas in Madagascar. *Appl. Environ. Educ. Commun.* **2007**, *6*, 223–232.
74. Jacobson, S.K. Conservation education programs: Evaluate and improve them. *Environ. Conserv.* **1987**, *14*, 201–205.
75. Maminirina, C.P.; Girod, P.; Waeber, P.O. Comic strips as environmental educative tools for the Alaotra Region. *Madag. Conserv. Dev.* **2006**, *1*, 11–14.
76. Cassiau-Haurie, C. La Bande Dessinée dans l'océan indien. Festival de bande dessinée de l'Île Maurice: Îles en bulles, 2006. Available online: http://eprints.aidenligne-francais-universite.auf.org/339/1/Iles_en_bulles.pdf (accessed on 18 February 2015).
77. Ravelontsalama, N. Représentations et fonctions de la bande dessinée à Madagascar. *Études Océan indien* **2008**, *40–41*, 256–268.
78. Anderson, L.W.; Krathwohl, D.R. (Ed.) *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*; Longman: New York, NY, USA, 2001.
79. Krathwohl, D.R. A Revision of Bloom's Taxonomy: An Overview. *Theory Pract.* **2002**, *41*, 212–218.
80. Monroe, M.C.; Andrews, E.; Biedenweg, K. A Framework for Environmental Education Strategies. *Appl. Environ. Educ. Commun.* **2007**, *6*, 205–216.
81. Krasny, M.E.; Dillon, J. (Eds.) *Trading Zones in Environmental Education*; Peter Lang: New York, NY, USA 2013.

82. Stevenson, R.B.; Brody, M.; Dillon, J.; Wals, A.E.J. (Eds.) *International Handbook of Research on Environmental Education*; Routledge: New York, NY, USA; London, UK, 2013.
83. Abrams, R.W.; Anwana, E.D.; Ormsby, A.; Dovie, D.B.K.; Ajagbe, A.; Abrams, A. Integrating Top-Down with Bottom-Up Conservation Policy in Africa. *Conserv. Biol.* **2009**, *23*, 799–804.
84. Babaci-Wilhite, Z. Local Languages of Instruction as a Right in Education for Sustainable Development in Africa. *Sustainability* **2013**, *5*, 1994–2017.
85. Rakotomamonjy, S.N.; Jones, J.P.G.; Razafimanahaka, J.H.; Ramamonjisoa, B.; Williams, S.J. The effects of environmental education on children's and parents' knowledge and attitudes towards lemurs in rural Madagascar. *Anim. Conserv*. **2015**, *18*, 157–166.
86. Heberlein, T.A. *Navigating Environmental Attitudes*; Oxford University Press: Oxford, UK, 2012.
87. Schultz, P.W. Conservation Means Behavior. *Conserv. Biol.* **2011**, *25*, 1080–1083.
88. Liddicoat, K.; Krasny, M.E. Research on the Long-Term Impacts of Environmental Education. In *International Handbook of Research on Environmental Education*; Stevenson, R.B., Brody, M., Dillon, J., Wals, A.E.J., Eds.; Routledge: New York, NY, USA; London, UK, 2013; pp. 289–297.
89. Rafidimanana Rajosera, M. Integration de la Bande Dessinée Arovy fa harena en tant qu'Outil Pédagogique au Niveau des E.P.P. d'Ambatondrazaka et d'Amparafaravola. Master's Thesis, Ėcole Normale Superieure, Antananarivo, Madagascar, 2013.

© 2015 by the authors; licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/4.0/).