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Teaching Species Identification – A Prerequisite for Learning Biodiversity and Understanding Ecology

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Animal and plant species identification is often emphasized as a basic prerequisite for an understanding of ecology and training identification skills seems a worthwhile task in biology education. Such identification tasks could be embedded into hands-on, group-based and self-determined learning: a) Teaching and learning should make use of a small selection of species (6-8) and b) these species should be embedded into learning about their natural and life history; c) different materials could be used for identification, i.e. stuffed taxidermies, plastic models or pictures. However, pictures seem only a second choice; d) ideally, pupils use identification books or dichotomous keys for their identification task to foster their methodological skills and to promote lifelong learning by enabling them to make use of such books and keys; e) if the preference is on identification keys rather than on illustrated material, pupils should be trained previously to cope better with the extrinsic load put on them by the difficult material; f) outdoor field trips and excursions should be employed only after a proper preparation in the classroom.

Keywords: Books, Ecology Teaching, Identification Materials, Methods, Species Identification

INTRODUCTION

Why species identification?

Children have serious problems with classifying animals (e.g. Bell, 1981) and they often incorrectly classify vertebrates as invertebrates (e.g. Braund, 1998) or birds as non-bird species (Trowbridge and Mintzes, 1988, Prokop et al., 2007). Although these facts are well-known there is a limited source of research that investigates children's abilities to identify living organisms. Albeit there are a few reports from plant species identification (Bebbington, 2005), reports from vertebrate species identification are scarce.

Species identification may be viewed as an antique way of teaching and learning in biology education. Modern times have turned to syllabi stuffed with general biology, aspects of genetics, ecology and evolution. However, for a clearer understanding of these aspects of the living world mostly, if not always, examples from species were used, e.g. when illustrating allopatric divergence of populations (speciation processes) during the glaciation of the Pleistocene, very often the European Crow species (Carrion Crow Corvus corone and Hooded Crow Corvus cornix) were invoked. Also, to illustrate material flow and functioning of ecosystems, this approach needs discrete species to make the facts more understandable.

Biodiversity has become a challenging educational topic, enforced by the conference of Rio in 1992 (van Weelie and Wals 2002; Gaston and Spicer 2004). Today, the value – even in currency – and the general importance of biodiversity is unquestioned (Gaston and Spicer 2004). Most people throughout the world value and appreciate biodiversity. However, biodiversity is a rather 'ill-defined' and complex construct at least in

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terms of educational circumstances (van Weelie and Wals 2002). Such complex and abstract constructs usually have to be transformed into smaller entities to aid learning and understanding especially in school students, and of course, also in the general public. The most common entity used by conservation groups are species (van Weelie and Wals 2002). Especially spectacular species, such as the Ivory-billed Woodpecker (Campephilus principalis, Dalton 2005) or dolphins (Barney et al. 2005) were used as a venue in environmental education and conservation.

Therefore, basic knowledge about animal or plant species, their identification and life history has been targeted as a fundamental aspect for learning and understanding in biodiversity (Lindemann-Mathies 2002; Randler and Bogner 2002; Gaston and Spicer 2004; Randler et al. 2005) as well as in the framework of ecological questions (Leather & Helden 2005). Such a fundamental view of biodiversity is shared by both, educational instructors and practitioners as well as by conservation biologists. Many conservation agencies and NGOs make use of flagship species to raise money, again, emphasising the value of species (Czeck et al. 1998; Dalton 2005).

Animals are fascinating for children and adolescents, e.g. in Norway animal-related activities received high scores, such as bird feeding (74%), or watching hare, fox and moose (63%). Watching TV programmes received an almost similar proportion compared to learning about animals in schools (Bjerke et al. 2001), suggesting that schooling might not be the main source of animal knowledge. Further, engagement in animal-related activities decreased parallel to age (Bjerke et al. 2001) suggesting that species knowledge may also decrease. There are few studies aiming at assessing knowledge about vertebrates and identification skills in pupils (overview: Randler and Bogner 2002), mostly complaining about the low species knowledge in general. Further, many educational practitioners and conservationists claim – often without sustain – a significant decrease of species knowledge in today's children and adolescents. As there are not many studies in this respect, such a claim may belong to the 'folklore' of environmental education (Hendee 1972).

Here, I will focus on different methods in teaching and learning about species. The primary focus is on vertebrate species, although insects, spiders and other invertebrates should receive a similar treatment at school.

What are the basic concepts of pupils in species identity?

Generally, many pupils have concepts and ideas about animal species and they are able to identify them on a higher taxonomic level such as genus, family or order. For example, nearly 100% of all pupils are able to identify a Mallard (Anas platyrhynchos) as a member of the family ducks (Anatidae), but only a small number of pupils can label the species correctly as Mallard (Randler, 2003, 2006). Teaching and learning, therefore, should make use of such prior concepts and embed them into the lessons, hence, a refinement of the concept duck into a more detailed description (diving ducks versus dabbling ducks), and two examples (Mallard and Tufted Duck Aythya fuligula) would result in a better learning because it focuses on the refinement itself and makes use of the prior concept. Figure 1 depicts some examples of prior concepts.

Why is species identification so difficult?

Some practitioners and teachers compare identification of species with the learning of new words of a new language. However, it seems that learning species names is much more difficult and complex than acquiring new words for a given language. Names of species can be grouped into different clusters:

Some names contain information about the visual appearance of the species; assume, for example, a Black-Headed Gull (Larus ridibundus). Even if you have never seen one, you will have a vivid impression how the bird might look like.

Other names may contain information about the song or behaviour of the species which will not usually aid the identification, e.g. the Chiffchaff's (Phylloscopus

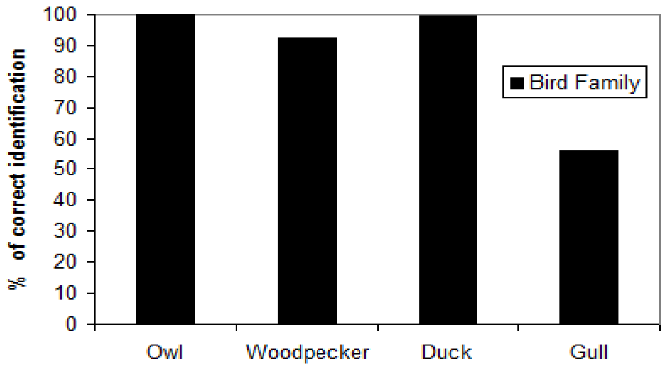

Figure 1. Percentage of pupils that are able to identify the respective bird family correctly as owl, woodpecker, duck and gull.

collybita) song sounds "chiff-chaff" and its name contains information about vocal characteristics but could not be used to learn species by its appearance.

A third cluster contains names that refer to an association, such as the Monk Vulture (Aegypius monachus), a vulture with an appearance as a monk.

The last group of species names contains names that are not motivated with regard to appearance or do not provide any association. Such names are often names that refer to a person, e.g. Naumann's Thrush (Turdus naumannii) and it is difficult to imagine mentally the appearance of it.

To test these different clusters of species names and their influence on learning and retention, Randler & Metz (2005) applied a research design with University students. A total of 15 species were selected, and the selection consisted of five triplets. Each triplet contained three species that shared the genus or family name and differed in the species name. One of the species contained a name that referred to its appearance, e.g. the Blue Tit (Parus caeruleus) has a blue head, the Coal Tit (Parus ater) has a black face (similar to coal, an association), and the Willow Tit (Parus montanus) prefers willow/birch habitats. The name of the latter species does not aid its identification. Five such groups were presented to the students.

Randler & Metz (2005) presented these species (as a photo and a capital containing the name of each species) in a computer-aided presentation to 100 students, in different orders of randomisation, and the students were asked trying to remember as much species as possible. After 80 minutes, the procedure was repeated in a different order and the students had to write down the names. In between were two lessons **of** German grammar or of educational psychology. Results are depicted in Figure 2.

As expected, names without any visual aid were retained less often than names with visual aid. Interestingly, names that evoked an association were retained better than names with a reference to its appearance. This means that during teaching species identification, the names of the species should be explained to aid learning and understanding. It further shows that retention of species names is difficult itself which again emphasise that pupils (and even students) should not be treated with too large lists.

How many species should be taught?

A first survey based on an expert rating organized as delphi-study (Mayer 1991) found a large amount of species that should be taught during secondary schools: nearly 250 species were identified. Of course, this is far too much for teaching even when this list was based on a covering of the complete secondary level. Teaching and learning should make use of a small selection of species and should emphasize methodological aspects, such as hands-on, group based learning using original objects. Randler & Bogner (2002) chose 14 different bird species centering on the ecosystem lake and found low retention rates after six to eight weeks. These authors further tested different methods of teaching (see below). As one result, these authors concluded that six to eight species are considered sufficient for an identification task (Randler & Bogner 2006). These species should be embedded into learning about their natural history and their key life history traits. This seems crucial to learning and understanding since teaching species names in a way that simply appears as some kind of labeling is detrimental.

Which educational methods should be used?

In their study mentioned above, Randler & Bogner (2002) used 14 bird species and applied two different educational methods. First, one group received a hands-on, learner-centered environment and pupils could look

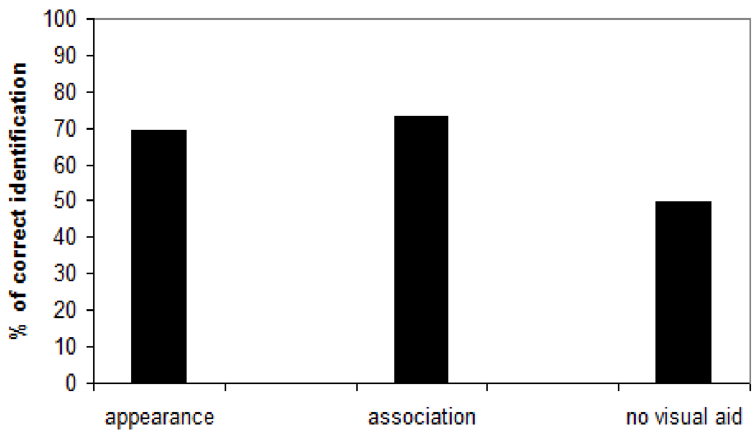

Figure 2. Percentage of correct identification (retention) of bird species names according to three different groups of names. A) Name with regard to the visual appearance, B) name with an association, and C) name with no visual aid for identification.

at stuffed taxidermic specimens. The other group served as a control and received a teacher-centered demonstration using a slide presentation dealing with exactly the same species. Knowledge was tested previous to teaching, immediately thereafter and with a delay of 6-8 weeks. Approx. 250 pupils participated in this treatment-control-study (see Figure 3).

Interestingly, both treatments did not differ in their effectiveness and overall retention was not very high. Therefore, Randler & Bogner (2002) concluded that the number of species in these two lessons might have been to high, and, as consequence reduced the number of species from 14 down to six (albeit for one educational lesson).

Then, they repeated their treatment in other biology classes with approx. 500 pupils. The treatments were carried out in two different school stratifications. [The German school system separates pupils at the end of the 4th grade into three stratifications, according to their cognitive abilities: lowest stratification = Hauptschule, medium stratification = Realschule and highest stratification = Gymnasium]. The results are presented in Figure 4.

In both stratifications, pupils in the taxidermic treatment received significantly higher achievement scores in the retention test. This suggest that hands-on group based work is significantly better than a teacher-centered presentation. However, retention as measured in percent (Figure 4) was high in both treatments, again suggesting that a reduction in the number of species to be learnt improves retention.

Educational implications from these studies emphasize: i) a reduction in species number is a useful way to improve learning, and ii) "modern" instructional approaches lead to a higher retention rate.

Materials used for identification tasks

Having demonstrated that such hands-on, group-based and learner-centered work retains a sufficient amount of knowledge in the retention test, we now turn towards some more details, namely materials used for identification. Many syllabi emphasize (or even request) the use of a dichotomous identification for species identification as a scientific method. At the University (tertiary) level, these identification keys are usually used during courses in botany and zoology. Dichotomous keys are usually based on a decision between two alternatives, followed by another pair of alternatives unless the final species name (or other taxonomic level, such as genus or family) is reached. These keys have been developed for different topics, e.g. human biology (Bavis et al. 2000), plant identification (Ohkawa 2000), fruits, nuts and cones of trees (Collins 1991), timber (Thomas 1991) and amphibians (Randler 2006). If coloured keys or books were used for identification,

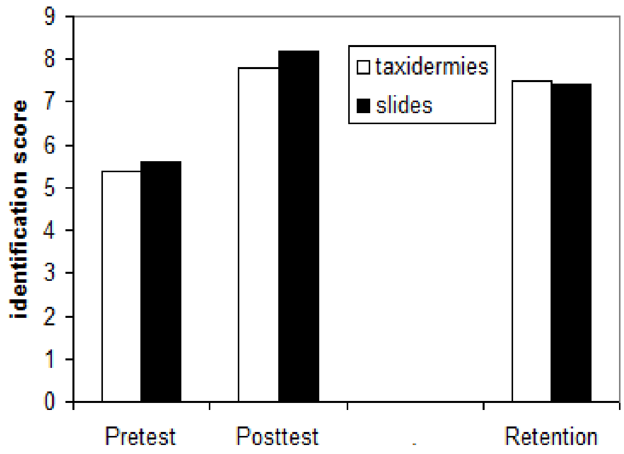

Figure 3. Changes in knowledge about bird species using two different treatments.

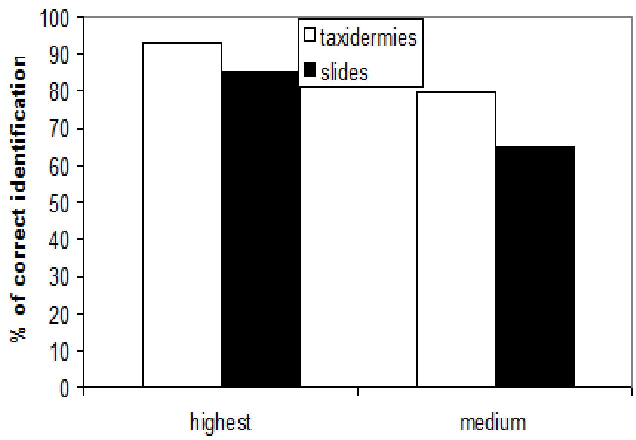

Figure 4. Retention rates (in percent) of two different treatments (taxidermies vs. slides) and in two different school stratifications.

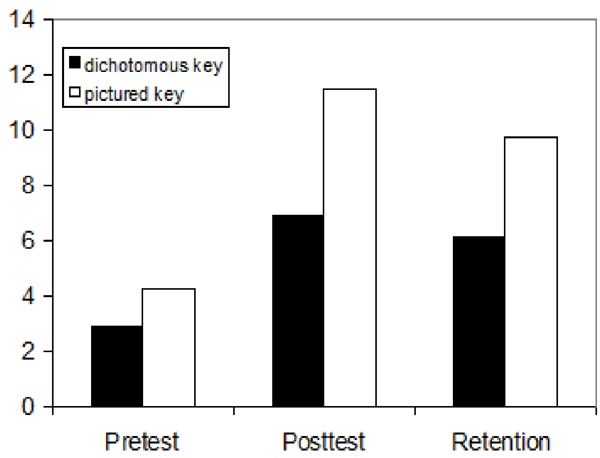

Figure 5. Differences between two identification materials over time (Mean scores are presented).

pupils often focus on the pictures alone. The benefit of dichotomous keys is a closer and more detailed look at the objects or models. Further, in comparison to books, such keys are scientifically more precise and foster the understanding of scientific terms.

To examine this question, a research design was applied to contrast both methods. The educational program was based on signs and tracks of animals. These signs were presented in the **class as** original materials. The tracks contained objects such as owl pellet, insect galls from different trees, feathers, tracks, feeding passageways of insects in the bark of trees, or feeding remains at spruce cones. The identification keys were similar in structure and in the number of solutions they offer, but they differed in the presentation of the way which leads to a correct identification: The illustrated key contained pictures of the respective tracks and signs, while the dichotomous key started with a decision between two alternatives. All other variables were kept constant (e.g. we used the same original objects and the same teacher and the same number of alternatives).

Achievement scores of both groups are depicted in Figure 5. As prior knowledge differed, we applied a multivariate general linear model (GLM) using pre-test as covariate, and gender and treatment as fixed factors. As expected, pre-test showed a significant influence. Further, treatment, received significance. In detail, pupils performed better in both posttest and retention when using a picture-based identification key and boys scored better than girls in the posttest.

Further, some emotional questions were used to gain insight into other dimensions than cognitive ones. Emotional variables derived from the inventory proposed by Laukenmann et al. (2003) and Gläser-Zikuda et al. (2005) were used. We measured these constructs based on four different dimensions: interest, well-being, boredom and difficulty of the questions based on a five-point Likert-scale (1 = lowest expression, 5 = highest). Each dimension was tested with one question immediately after the lesson.

There were significant differences with regard to the emotional variables: Pupils of the illustrated key perceived a significant higher well-being and tended to be less bored (Figure 6). No differences existed between both identification keys in interest and both groups experienced similar difficulty in their task, suggesting that cognitive results are not based on differences in the difficulties of the instructional materials.

The results presented here are interesting because they support the use of illustrated identification materials for teaching and learning biodiversity. In contrast to the views of many practitioners, language based keys indeed seem inferior compared to picture-based keys.

Therefore, to cope with these results, we used another line of research to improve the usage of dichotomous keys. Now, we used a language-based dichotomous key that was supported by a few black-and-white illustrations which aid the final identification of the respective species. The benefit of this key is that it can be copied and pupils can take them home for their personal use.

Two different identification materials were compared with each other. The identification key was obtained from Schroedel-Verlag (Schrodel, Braunschweig, Germany) and was explicitly made for the use in a school setting (biology lessons, 5th and 6th graders). It contains a DIN A 3 page in black-and-white that can be easily copied and given to the pupils. The key has a dichotomous structure where there is always a decision between two alternatives, e.g. whether the pupil of the eye is vertical or horizontal. When you have gone through all alternatives the final species' name is reached and there is a black-and-white illustration to further support the identification.

The identification book (Amphibien und Reptilien erkennen und schützen, amphibians and reptiles; total pages: 159; Blab & Vogel 1996) was also obtained from a commercial producer. This book depicts a total of 19 reptile species on 37 pages. The book provides various photographs and sketches in colour and verbal information about identification, behaviour, natural history and ecology.

Pupils worked together in groups of 2 - 4 pupils and each group received either an identification book or the dichotomous key. The plastic models were presented in a kind of workstations (Schaal & Bogner 2005). Pupils then moved from one desk to another, looked at the models and identified them. After pupils had finished their work, results were discussed and corrected in the classroom.

Pupils did not differ in their prior knowledge (Figure 7). Immediately after the educational treatment there were no significant differences between both treatment groups, and also after a delay of four weeks. This suggests that both educational materials are equivalent in their effectiveness and that both may be used to achieve a sustained learning and retention (Figure 7).

Model specimens, identification tools (either books or keys), hands-on instruction and group-based learning approaches provide successful learning environments for secondary school pupils. This was proved in some earlier studies (Randler & Bogner 2006, Randler & Knape 2007).

In this study, we used these previous results and focused on the identification material itself. Both treatment groups significantly improved their species identification knowledge about reptiles and we further suggest that such methodological teaching sequences should be embedded into everyday school practice. Further, we emphasize that the number of species that should be taught during such lessons should not be exceedingly high – approximately six different species seem sufficient for 5th and 6th graders.

With regard to our identification materials, we found no significant difference between both approaches, suggesting that either the identification book as well as the black-and-white key were equally suitable for this identification task. The advantages of the key are clearly its low costs, i.e. it can be copied and each pupil may retain the key and may use it further in out-of-school settings. Further, this key trains pupils to look critically at verbally explicated differences and to scrutinise the models in detail. However, the identification book also has its advantages. The book consists of many pages and, therefore, pupils must thoroughly go through it to find the correct identification. Further, such books also provide a wealth of information about the respective species' ecology and behaviour.

Addressing the age-old question about outdoor ecology

Outdoor ecology and field trips have been acknowledged in many publications (see Rickinson et al. 2004). When teaching biodiversity, many practitioners prefer settings with an outdoor ecological education over classroom instructions (Barker et al., 2002, Killermann 1998, Lock 1998, Tilling 2004). However, such educational lessons often deal with rather immobile taxonomic groups such as plants or invertebrates (Killermann 1998) because amphibians (or mammals, birds) are sometimes difficult to observe under natural conditions. Conservation actions, such as preserving migrating frogs or toads should be useful settings for teaching and learning about species.

Further, outdoor education could be enhanced by previous learning within the classroom to properly prepare the students for forthcoming issues and task in nature and to prevent students from a cognitive load and from novelty effects (Falk 1983, Sweller et al. 1998). Such a cognitive load (or novelty) may arise when students are confronted simultaneously with different environmental conditions. In terms of amphibian conservation actions this might mean i) species that are new to students and previously unknown, ii) different settings compared to the rather familiar classroom setting (weather conditions; night time), and iii) different learning environments, such as working in groups and doing hands-on activities or encountering living animals.

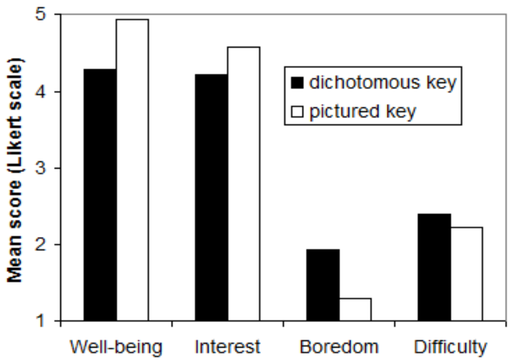

Figure 6. Differences in emotional measures between concerning identification materials (Mean scores of the variables are presented).

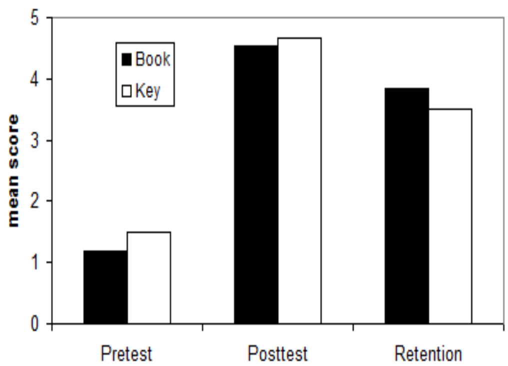

Figure 7. Comparison of different treatments and its cognitive achievement over time

Therefore, students that are not prepared by any prior teaching in a familiar setting, such as the classroom, might benefit less from outdoor education (see Falk 1983, Orion & Hofstein 1994).

To investigate the effectiveness of outdoor ecology teaching, an educational program was developed in amphibian conservation. The program was divided into two parts and was embedded into teaching activities prior to and after a specific conservation action. The indoor program was followed by all students, while the additional outdoor program was attended by half of them. After the additional outdoor program students that had participated at the conservation action told other pupils about their experience ('peer-tutoring'; Neber 1995). The additional outdoor program took place when toad and newt migration peaked. In order to minimize novelty effects of the environment (Falk 1983) a conservation action was visited located in the students' residential town. Students could participate in the outdoor work voluntarily. During this action, school students were guided by students from the University of Education which collected, determined and counted all amphibians on their annual way to the breeding pond.

The additional outdoor group (hereafter: treatment) did not significantly differ from the indoor group

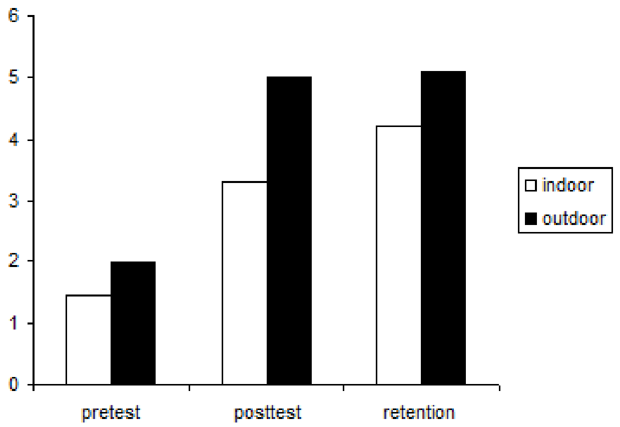

Figure 8. Cognitive effects of an additional outdoor teaching program on pupil's achievement.

(hereafter: control) prior to teaching (Figure 8), but immediately thereafter. In the delayed retention test significant differences remained. Nevertheless, students from both groups significantly improved their knowledge.

The treatment group scored significantly higher during both the post-test and the retention test (maximum of six items). This is an interesting fact because other studies failed to show such marked and significant differences regarding cognitive abilities between treatments, especially when different treatments were compared (e.g. Armstrong & Impara 1991; Bowler et al. 1999). However, there is also evidence that outdoor ecology education increases both cognitive and affective dimension among pupils that participated on field trips (Orion & Hofstein 1994, Prokop et al. 2007, Žoldošová & Prokop 2006).

Interestingly, pupils from the control group showed a significant positive shift in their knowledge from posttest to retention test while the scores of the treatment group remained similar. The posttest was applied before any further teaching took place. We suppose that the clearly visible learning effect from posttest to retention in the control group is a result of the following lessons where students were encouraged to report their experience gathered during the conservation actions to their classmates. This provides some kind of 'peer-tutoring' which was found to have a significant positive effect on learning and retention (Neber 1995). These results are encouraging since they show that students that could not participate in a specific (outdoor) activity might benefit when the participating individuals were encouraged to report their experiences, ideally in small groups of 3 - 4 (Lou et al. 1996). This could be organized in a rotating system where student groups move from one tutor to another.

Another major conclusion is that outdoor ecological settings should also take place during school life and students should visit habitats in their vicinity to reduce novelty. Although many studies showed a highly significant improvement in either cognitive learning or in environmental perception (with a focus on enhancing preservation attitudes), one should keep in mind that residential outdoor programs are rather expensive and often linked with traveling. This might lead to a lower acceptance of such programs. Schools should provide their students with such local outdoor ecological programs.

Further, outdoor activities should be properly prepared by a preceding educational unit in the classroom. Some studies found that their modern teaching approaches (e.g. outdoor ecology) scored significantly worse or did not reach any significant effect when compared with a rather traditionally taught control group (see, e.g. Killermann 1996, Randler & Bogner 2004). This was found in such different educational settings such as experiments, modern media or in different teaching strategies (learner-centered vs. teacher-centered). Falk (1983) suggested that children's perception of the novelty of the environmental setting affects their learning outcome. Extremely great novelty will inhibit learning. Therefore, such outdoor experience in elementary school students should make use of more familiar outdoor settings in the vicinity of the student's residential town, rather than making use of any farther travel if cognitive aspects are in the main focus.

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