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Learning How to Identify Species in a Situated Learning Scenario: Using Dynamic-Static Visualizations to Prepare Students for Their Visit to The Aquarium

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This study investigated whether studying dynamic-static visualizations prepared first-year Biology students better for an out-of-classroom experience in an aquarium than learning how to identify species with more traditional instructional materials. During an initial classroom phase, learners either watched underwater videos of 15 freshwater fish species (video-group, *n*=46) or they were asked to identify preserved specimens of the same fish with the help of a dichotomous identification key (key-group, *n*=43). Subsequently, all students were asked to identify the taught species during their visit to the aquarium. Our results indicate that the video-group was able to identify more species correctly than the key-group directly after the classroom instruction, whereas both groups performed equally well after the aquarium visit.

Keywords: Biodiversity, Visualizations, Field Trips, Situated Learning, Species Identification

INTRODUCTION

Knowledge about biodiversity among other things comprises the ability to identify species in their natural habitat as one of the key competences of biologists. For example, ecologists rely on this competence when studying organismic interactions and geneticists when they are collecting samples to extract DNA. No study on the protection and conservation of species, an international goal acknowledged by international conventions among many states (e.g. Convention on Biological Diversity) could be conceivable without the correct identification of species in the field. Whereas such expertise is essential for effective global conservation (Basset, Hawkins, & Leather, 2009), taxonomy is underrepresented in current Biology education curricula at the university level and often seen as something boring by students (Leather & Quicke, 2009). On the other hand understanding biodiversity is thought to be an important issue in education (cf. van Weelie & Wals, 2002) and learning about species identification is considered as one important prerequisite for understanding biodiversity (Leather & Helden, 2005; Lindemann-Matthies, 2002; Prokop, Kubiatko, & Fancovicova, 2007; Randler, 2008, 2009). In line with this position, finding new effective and attractive ways of teaching how to identify species in the field is one aim of the study presented here.

In formal university Biology curricula students usually start learning about biodiversity by distinguishing preserved specimens with dichotomous identification keys in a classroom setting. Subsequently, they are often given the opportunity to apply their knowledge during guided field trips because identifying species in their natural habitat is a matter of practice and needs to be trained. Such out-of-classroom activities are highly recommended for teaching biodiversity in general (Barker, Slingsby, & Tilling, 2002; Dillon et al., 2006). In

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State of the literature

- Species identification is considered as one important prerequisite for understanding biodiversity and field trips are highly recommended. Pre- and follow-up activities in the classroom increase the value of learning during field trips.
- Static illustrations compared to verbal explanations of important characteristics seem to be a key issue of identification books and identification keys for learning how to identify species.
- Dynamic-static visualizations compared to static visualizations used to prepare a field trip seem to unfold their potential especially after or in combination with a real-world experience.

Contribution of this paper to the literature

- The paper confirms the value of prior classroom instruction because students improve their species identification skills during the aquarium visit.
- Dynamic-static visualizations compared to learning with preserved specimens and identification keys enhance learning during the pre-activity in the classroom.
- Learning with dynamic-static visualizations compared to learning with identification keys and preserved specimens do not increase knowledge gain during the aquarium visit.

line with this reasoning, Hamilton-Ekeke (2007) conducted a study, which showed that students learning about ecology during field trips in Nigeria performed better in a domain-specific achievement test than students who were taught in the classroom only. Field trips also resulted in better understanding of connections between biotic and abiotic factors as well as in understanding of ecology in general (Prokop, Tuncer, & Kvasničak, 2007). In a study conducted by Randler, Ilg, and Kern (2005) students who participated in an Amphibian conservation programme performed significantly better on achievement tests than students who did not join this activity. Comparable results have been observed for out-of-classroom learning in museums (Wilde & Urhahne, 2008; Krombass & Harms, 2006). However, it has been suggested that field trips will be most effective if embedded in the current curriculum (Orion, 1993) or at least if students have been prepared for it in advance in the classroom (Randler, 2008). Similarly, Shonfeld, Erez, and Litvak (2003) suggest that having students participate in so called virtual field trips with pictures, maps and stimulating texts prior to the real-world experience might raise their benefit of the trip itself. Supporting this view, Dillon et al. (2006) review evidence that preparatory instructional units increase the value of out-of classroom learning. These findings are consistent with those by Wilde and Bätz (2006) who also found some evidence that learning in a museum is especially effective when prepared in the classroom. With their framework for museum practice DeWitt and Osborne (2007) also encourage pre- and follow-up activities in the classroom. Thus, it seems very recommendable to prepare field trips. However, what is actually meant with field trip preparation varies widely from providing a spatial orientation of the destination to acquiring knowledge that will be needed during the trip. This study focuses on the latter aspect and asks how students can be prepared most effectively for knowledge application during an aquarium visit.

It is often been noted and criticized that in general classroom instruction differs largely from the way knowledge is acquired and applied outside of the classroom, that is, in the real world (Resnick, 1987). In particular, classroom instruction is often more abstract, decontextualized and emphasizes formal reasoning, whereas on the other hand, in real-world scenarios the problems to be solved are situated in a specific context, which will be used for reasoning. The use of dichotomous identification keys for teaching species identification in formal Biology education shares many of the criticized features of typical classroom instruction and may hence not be optimal for preparing students for a field trip, where a different form of situated reasoning may be more appropriate. Typically, identification keys require a student to decide upon the absence or presence of a specific, most likely morphological feature in the species at hand based on an idealized verbal description of this feature, thereby asking the student to apply abstract decision rules. Because these keys refer to the prototype of a species, abstraction across (irrelevant) variations among members of this species is inevitable. Contextual information (e.g. habitat) is deliberately left out in identification keys, because it is considered to be not sufficiently reliable for coming to a decision in contrast to, for instance, morphological features. Moreover, identification keys are used to determine preserved specimens, which are bleached and thus look very different from coloured species in the real world in particular in the case of European freshwater fish species. There a species' colour may vary depending on its sex or the brightness of its surroundings, thereby reflecting salient, but arbitrary rather than distinctive features. The type of abstract reasoning reinforced when using identification keys may interfere with the type of reasoning enabled during real-world observations, for instance, during a field trip. In particular, contextual information is omnipresent during field trips and will affect a student's reasoning. On the one hand, contextual information may be misleading in some cases; moreover, it can also withdraw attention from more important features, thereby making species identification more difficult and error-prone (Law & Lynch, 1990). On the other hand, contextual information may also be helpful, especially because it is often easier to access than information on morphological features, which may be very difficult to observe in a living species (e.g., because the feature in question is too small, obscured, or the animal is moving too fast). Moreover, in addition to static features addressed in identification keys, real-world observations are often based on the observation of dynamic information, in particular, on a species' behavioral characteristics, which may help identifying the species. Because the abstract reasoning processes reinforced through the use of dichotomous identification keys may be not optimal for preparing students for the type of reasoning required in the field, we investigated the effectiveness of an alternative instructional method for teachings students about biodiversity, namely, the use of dynamic visualizations (i.e., digital videos) of species.

Dynamic visualizations as an instructional method to teach species identification

Dynamic visualizations as videos or animations convey visual information and provide information on change over time (Tversky, Bauer-Morrison, & Bétrancourt, 2002). Thus, dynamic visualizations differ from dichotomous identification keys in at least two important aspects: First, they convey information in a pictorial rather than a verbal format; thereby supporting concrete rather than more abstract rule-based reasoning (cf. Scheiter, Wiebe, & Holsanova, 2008). Second, they do not only convey information on static, but also on dynamic features. With respect to the use of pictorial formats, it has already been shown that augmenting (but not replacing) identification keys by means of illustrations is more effective for learning about biodiversity than purely verbal identification keys (Randler & Knape, 2007). Moreover, verbal dichotomous identification keys that are augmented by black-and white pictures have been shown to yield similar learning outcomes as illustrated identification books (Randler, 2008; Randler & Zehender, 2006). Therefore, one key issue of learning materials that appears to be helpful for distinguishing among different species seems to be the illustration of important characteristics.

Whereas both illustrated identification books and identification keys have the potential to describe static features, they have only little potential to show dynamic features, such as movement, behavior, or locomotion of a species. However, current research is not conclusive whether dynamic or static visualizations are more recommendable for learning. While most studies mentioned in a review by Tversky et al. (2002) could not reveal a superiority of dynamic over static learning materials, a recent meta-analysis by Höffler and Leutner (2007) supported the view that dynamic visualizations can be effective for learning. Plass, Homer, and Hayword (2009) suggest that the efficacy of visual representations should be evaluated with respect to the learning objective that one wants to achieve through them. Following this recommendation, we will analyze the benefits and drawbacks of video clips deliberately produced for educational purposes compared to preserved specimens and identification keys for learning how to identify fish species in an aquarium after a preparing unit in the classroom.

Although static materials can describe dynamic features with words or depict them as sequences of static pictures, they fail to show an object's changes over time that is likely to occur in dynamic phenomena (Bétrancourt, 2005). For example, with respect to fish species identification it is important how frequently a species is moving: Sculpins are lurking predators and therefore frequently lay on stones, whereas trouts "stand" in the water and rudds permanently swim around searching for algae and water plants. Such differences among species pertaining to dynamic aspects can be easily demonstrated with short video clips. A recent study by Imhof, Scheiter, and Gerjets (2009) supports this assumption by showing that dynamic visualizations (underwater videos or computer-generated animations) of marine fish were more helpful for learning to distinguish different species according to their locomotion patterns than a series of static pictures extracted from the videos and the animations, respectively.

Moreover, static visualizations require mental animation of the trajectory of changes by the learner (Hegarty, 1992) and thus additionally demand cognitive resources, which are then no longer available for understanding what is being explained (Sweller, van Merriënboer, & Paas, 1998). This might be another reason why the lack of directly conveyed dynamic information might be a shortcoming of identification keys and books when compared to learning materials that include dynamic visualizations.

In the current study, dynamic visualizations were used to prepare students for applying and broadening their knowledge about fish identification in an aquarium. Learning from these dynamic visualizations may be especially helpful because of the high congruency of the display format with the appearance of the animal moving in its natural habitat (congruency principle, Tversky et al., 2002) and the appropriateness of the video for the species identification task in the real world (task appropriateness, Plass et al., 2009). Furthermore, when producing the educational videos we took precautions against a potential shortcoming of dynamic visualizations, namely their transient nature (e.g. Bétrancourt, 2005) by freezing the video display when important morphological features of a species were shown. Additionally, important features were labeled during these static periods. Freezing the video display might also help to reduce visual complexity, which is thought to be overwhelming for the learner at a perceptual level (Ayres & Paas, 2007; Lowe, 2003).

A recent study by Pfeiffer, Gemballa, Jarodzka, Scheiter, and Gerjets (2009) yields preliminary evidence in favor of dynamic visualizations containing freeze-frames (called dynamic-static visualizations hereafter) compared to static visualizations. In this study, learners first studied either dynamic-static or purely static visualizations depicting different marine fish species and subsequently went snorkelling in the Mediterranean Sea to observe these species in vivo. The results showed that the dynamic-static visualizations unfolded their potential especially after or in combination with the real-world experience (i.e., the diving trip). Hence, it can be assumed that dynamic-static visualizations are well suited to prepare students for knowledge acquisition about biodiversity in the field and may be a promising tool to bridge the gap between classroom instruction and situated out-of classroom scenarios when compared to dichotomous identification keys that may over-emphasize abstract reasoning activities.

To integrate the dynamic aspect of out-of-classroom observations into the classroom we used mobile devices since they have the technological prerequisites to implement dynamic visualizations, namely video clips, as a new kind of learning material in learning how to identify species not only in the classroom, but also in the field. That is, mobile devices such as PDAs (personal digital assistents) can be used to link in- and out-of-classroom activities due to their portability (Naismith, Lonsdale, Vavoula, & Sharples, 2006) and are considered to be highly motivating (Jones, Issroff, & Scanlon, 2007). PDAs have already been successfully implemented in learning scenarios concerning biodiversity. For example, the Ambient Wood Project offered children the opportunity to discover an outdoor environment by mobile digital technologies (Rogers et al., 2002, 2004). Furthermore, mobile devices have been successfully applied as a source of information during bird and butterfly watching (Chen, Kao, & Sheu, 2003; Chen, Kao, Yu, & Sheu, 2004) as well as in the context of problem-based learning (Liu, Chu, Tan, & Chang, 2007). The results of the study of Pfeiffer et al. (2009)conducted at the Mediterranean Sea mentioned earliealso suggest that mobile devices are suited to learn about biodiversity in a combined classroom-out-of-classroom setting at the beach.

Hypotheses

The current study picked up the approach of enhancing students' knowledge of biodiversity by preparing them for an out-of-classroom experience as well as supporting them during this experience by means of deliberately designed dynamic-static visualizations presented through mobile devices. We compared this approach of preparing students for field trips to a more traditional instructional approach where students were asked to identify preserved specimens with the help of paper-based identification keys during the classroom phase. As learning domain we chose freshwater fish species for which the out-of-classroom activity could be carried out under controlled conditions in an aquarium. Students first prepared the aquarium visit in the classroom and subsequently applied their knowledge in the aquarium. According to Dillon et al. (2006) this arrangement gives them the chance to deepen and elaborate their knowledge. Thus, our first hypothesis was that the real-world experience in the aquarium would lead to a significant knowledge gain.

Because the learning task refers to recognizing moving species, the dynamic learning material and the to-be-learned content should be more congruent with each other (cf. congruency principle, Tversky et al., 2002). Moreover, the learning material should be more appropriate for the species identification task (Plass et al., 2009). For these reasons, our second hypothesis was that dynamic-static visualizations presented on mobile devices would lead to a higher knowledge gain compared to more traditional learning materials like studying preserved specimens with the help of identification keys.

Furthermore, Pfeiffer et al. (2009) found some evidence that static-dynamic visualizations and real-world experience complement one another and therefore result in better learning outcomes than if pure static learning materials are combined with an outdoor educational unit. Hence, our third hypothesis was that the group using dynamic-static visualizations for acquiring species identification skills would benefit more from the aquarium visit than the group who prepared for the aquarium visit by using identification keys and preserved specimens.

METHOD

Participants and Design

This study was conducted with 89 students (60 male, 29 female) of Biology or Geoecology, each participating in one of four university field trip courses in freshwater fish biodiversity. The courses were held at the aquarium of the Wilhelma, Stuttgart by zoologists of the

University of Tuebingen, Germany and were an obligatory part of the first year program for all of the students. The field trips consisted of two learning phases with the first phase taking place in the classroom, where students prepared for the second phase in the aquarium. Immediately after each learning phase students passed a post-test. There were two experimental groups who prepared differently for the aquarium visit. Always students of two courses were assigned to one experimental group. The video-based group (n= 46 students) prepared with dynamic visualizations presented on mobile devices, while the identification key-based group (n= 43 students) used identification keys and preserved specimen. Both groups were additionally allowed to use paper sheets to take notes. In the aquarium, the video-based group were allowed to use the mobile devices and their notes for species identification. The key-based group used only the identification keys with their notes in the aquarium, while the preserved specimens were not available. In the remainder of the paper, we refer to the two groups as the video-group and the key-group.

Materials

Learning materials. The dynamic-static visualizations of the video-based group were presented on a DVD, which was especially developed for this study. The DVD consisted of videos of 15 different fish species each represented by one video. These videos were arranged on three subsequent slides of a DVD menu. Each slide of the DVD menu contained five thumbnail icons. Students started a video by clicking one of these icons. Each video started with the name and size of the species displayed on a black screen and was interrupted by one or two selected freeze-frames, which highlighted the relevant characteristics of the species (Figure 1a). The videos included spoken text describing habitat and morphology, that is, the species distinct features when compared to other species. At the end of the video the name of the species appeared again on a black screen. One video had a total length of approximately 40 seconds including one or two freeze frames of about 5 seconds. The DVD was provided on a 7" DVD-player (XORO HSD 7100) equipped with headsets. Students could switch between the three menu slides and start visualizations by clicking the play button. The DVD came with a preformatted printed paper, on which schemes of the species were arranged in the same pattern as in the DVD menu (i.e., three sheets each showing icons of five species). On these sheets students were asked to add notes such as the name of the species and its specific characteristics during the first learning phase (Figure 1b).

The students of the key-group used a dichotomous identification key to distinguish among the same 15 species as the video-group. To do so they used preserved specimens of the 15 species during their initial classroom phase. The preserved specimens were presented in bowls with water (Figure 2a). Students could touch them and take them out of the water to hold them in their hands. The dichotomous identification key consisted of three pages (Figure 2b). Each page presented the same five species as the corresponding page of the preformatted printed paper of the video-group (Figure1b, 2b). The identification key comprised verbal descriptions of the species' characteristics as well as black-and-white drawings of the species' prototype. Students were allowed to take notes on the identification keys.

During the second learning phase students of both groups identified the 15 species from the first learning phase in the tanks of the aquarium. The video group had available the dynamic-static visualizations on the mobile devices and their notes on the prepared sheets to help them with the identification task, while the key-group had available only the identification keys, but not the preserved specimens.

Experts supervised the species identification during both learning phases of the key-group and during the second learning phase of the video-group. Students were always asked to attempt to identify the species on their own but received feedback from the experts whether their answer had been correct. If they failed, they tried again and experts helped them if neccessary.

Post-tests. The post-test material was designed to measure students' ability to identify species in their natural habitat by mimicking a controlled real-world scenario. Both groups received the same post-test material. Students were shown videos of eight fish species out of the 15 species to be learned (see note in Table 1 for test species). These videos were essentially different from the videos on the DVD of the group learning with dynamic-static visualizations. Students were asked to write down the name of the species or to mark "don't know" on preformatted test sheets after watching each test video. They received one point for the correct identification of each species (see below). The test videos were used for both post-tests. The only difference between post-test 1 and 2 was the order in which the videos were shown to the students. Both post-tests showed satisfactory reliability scores with Cronbach`s α for post-test 1 being α = .71 and for posttest 2 α = .70.

Questionnaires. We used two questionnaires to test the knowledge and the motivation of the participants, to find out whether they liked the learning experience and to analyze for possible confounding factors. The first questionnaire (pre-questionnaire) had to be completed before the course and the evaluation questionnaire afterwards. In addition to their age and gender, in the

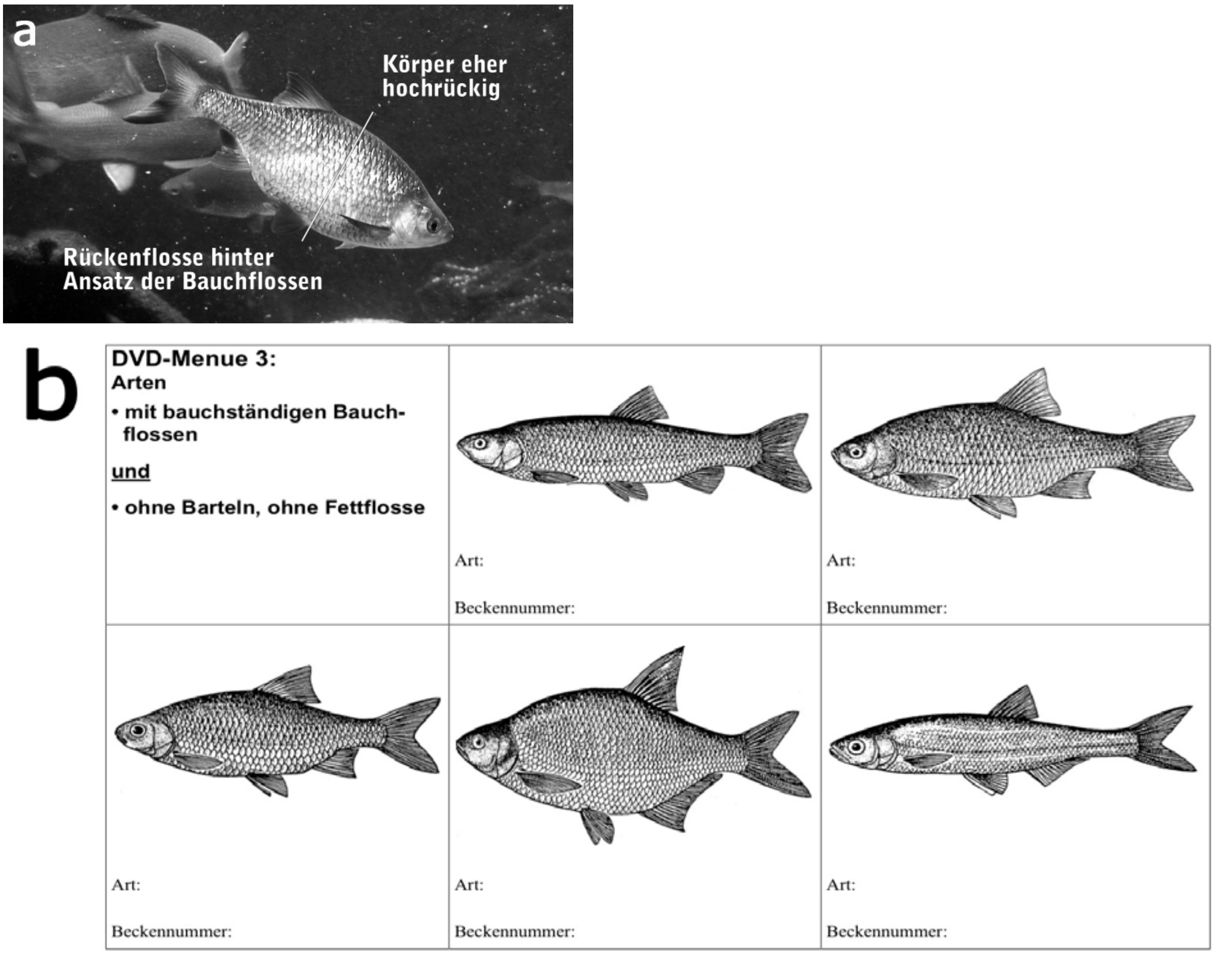

Figure 1. Learning material of the video-group. a: selected freeze-frame of the video about *Scardinius erythrophthalamus.* German text: "body rather high shaped"(right at the top), "dorsal fin behind beginning of pelvic fin" (left at the bottom). b: 3rd sheet of preformatted printed-paper for notes. *Scardinius erythrophthalamus* left at the bottom.

Table 1. Course of the study conducted at the Aquarium in the Wilhelma, Stuttgart, Germany

Unit	Time	Description	
		video-group (n= 46)	*key-group (n= 43)*
1	8 min	students complete pre-questionnaire	
2	15 min	students receive basic introduction in fish identification and technical instructions (PowerPoint Presentation by an expert)	
3	60 min	learning phase with portable DVD-player, fish identification DVD and fish species form for notes (Fig. 1b)	learning phase with preserved specimens and a dichotomous identification key (paper-based, Fig. 2b)
4	10 min	*posttest 1, laser projector presentation of test videos (fish identification test films)*	
5	60 min	real-world experience: fish identification by visiting an aquarium, students use their notes (Fig. 1b) and the portable players with the DVDs	real-world experience: fish identification by visiting an aquarium, students use the dichotomous identification keys (Fig. 2b)
6	10 min	posttest 2, laser projector presentation of test videos	
7	5 min	students complete evaluation questionnaire	

15 species were presented either on the fish identification DVD or on the dichotomous identification key, each with one video respectively with one preserved specimen: *Cottus gobio, Perca fluviatilis*, Gymnocephalus cernuus, Thymallus thymallus*, Salmo trutta*, Siluris glanis, Barbatula barbatula, Tinca tinca, Cyprinus carpio, Barbus barbus*, Leuciscus cephalus*, Scardinius erythrophthalamus, Rutilus rutilus*, Abramis brama*, Alburnus alburnus*.* The 8 species, which were tested in post-test 1 and 2, are marked with an asterix.

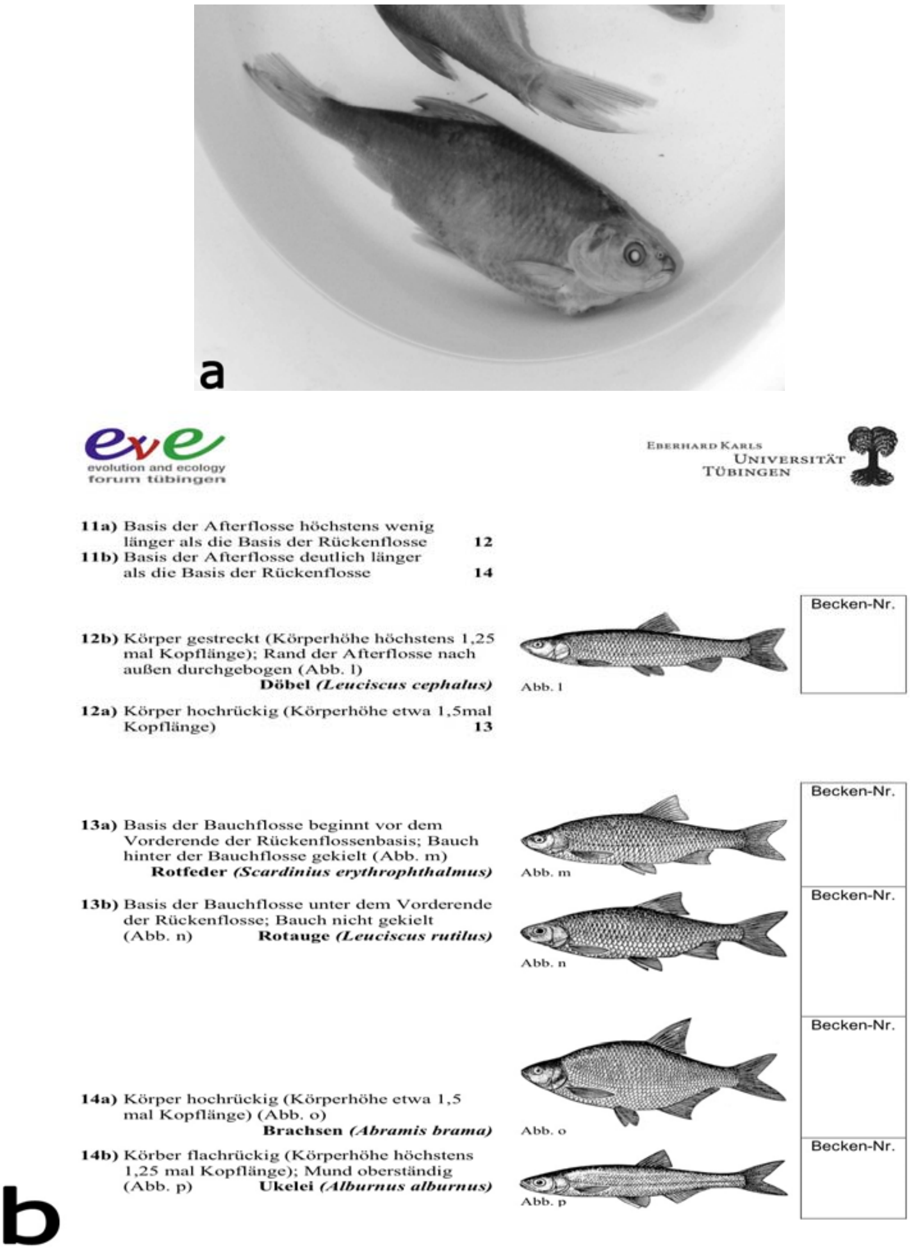

Figure 2. Learning material of the key-group, a: Example of a preserved specimen, in this case *Scardinius erythrophthalamus*. b: One of the three pages of the dichotomous identification key. Five species are shown on each page. *Scardinius erythrophthalamus* is the second fish from above.

pre-questionnaire, students were asked to state on a 5-point Likert scale whether they were interested in fishes or freshwater fish species and if they liked visiting aquaria. The pre-questionnaire also included a pre-test, in which students were asked to name five freshwater fish species based on color photos and specify the characteristics they used for identification if possible. These five species were chosen out of the group of 15 later used in the learning phase. We used different subsets of five species for different students to control for possible artefacts arising from the selection of a specific species. Students were randomly assigned to these subsets. One point was awarded for the correct identification of a species, yielding a maximum of five points for the pre-test. The evaluation questionnaire asked students on a 5-point Likert scale (a) how much they enjoyed learning with the identification key / the videos, (b) to what extent they considered the classroom learning phase to be helpful for learning, (c) to what extent they considered the identification key / the DVD helpful for learning in general and (d) to what extent they considered the learning phase in the aquarium to be helpful for learning fish species. A value of 1 reflected a low level of enjoyment and helpfulness, whereas a rating of 5 corresponded to a high level of enjoyment and helpfulness.

Procedure

The study was conducted at the Wilhelma Zoo and Botanical Garden, Stuttgart, Germany. The classroom phase took place in a seminar room located in the zoo, followed by a second learning phase in the public aquarium nearby. Two courses were assigned to each instructional condition. The procedure for each course was the same except for the experimental differences between the video- and ID-based instruction (see Table 1 for details). First, all students had to complete the pre-questionnaire (unit 1). In unit 2, students of both groups were introduced to the basics of fish identification by means of a PowerPoint-presentation given by a university lecturer. Additionally, the video-group received technical instructions and the key-group was instructed how to use a dichotomous identification key to make sure that they would be able to manage the learning task. Afterwards (unit 3), students of each group worked in pairs, where they learned to distinguish 15 freshwater fish species. The video-group used video material showing the morphology and movement of each species, whereas the key-group worked with 15 preserved specimens along with a dichotomous identification key. Both groups were advised to take notes, either on preformatted forms (video-group; Figure 1b) or on the identification key (key-group; Figure 2b). The learning time was held constant across the two groups. Subsequently, students` performance in fish identification was measured by post-test 1, in which students had to identify eight fish species from unknown videos without using any additional information, an arrangement that was assumed to mimic encountering a species in nature (unit 4). After that, the real-world experience was implemented in the public aquarium (unit 5). Pairs of students were allocated to different tanks from which they visited the other tanks in a clockwise direction. One expert supervised two tanks. Because within each tank there were also species other than the ones that had to be identified during the test, experts showed the species in question to the students. The students had to determine the species using their material without receiving any further help from the expert. Sheets of paper covered all signs in the aquarium that displayed information on fish species during this learning phase. Finally, the students had to present their results to the expert and explain their reasons for obtaining these results. In case they failed with identification or reported incomplete descriptions the experts asked the students to try again. The video-group identified the fish species in question through the use of the DVD on the portable DVD player and their notes on preformatted forms (Figure 1b); whereas the key-group used the identification keys with their notes for fish identification (Figure 2b). After that, students were tested a second time with post-test 2, which was the same as post-test 1 with the exception that the test videos were shown in a different order (unit 6). Eventually, students were asked to fill in the evaluation questionnaire (unit 7).

RESULTS

Concerning demographic data, prior knowledge, interest, motivation, etc. measured with the pre-questionnaire no differences between the groups could be observed. Students were equally interested both in fishes in general and in freshwater fishes and liked going to the aquarium to the same extent. The pre-test showed that both groups had little prior knowledge (see Table 2 for means and standard deviations).

Concerning learning outcomes measured by post-test 1 and post-test 2, a repeated-measures Anova showed a main effect for the time of testing, $F(1, 87) = 104.31$, $p < .01$. Students performed better in the second post-test than in the first, indicating as expected that the situated learning scenario improved students' understanding. No main effect for instructional condition was found ($F < 1$). However, a significant interaction between both factors could be observed ($F(1,89) = 5.89$, $p < .05$). As can be seen in Figure 3, the video-group ($M = 3.48$, $SD = 2.06$) outperformed the key-group in the first post-test ($M = 2.61$, $SD = 1.84$), $t(87) = -2.10$, $p < .05$), whereas both groups performed equally well on post-test 2 ($M_{video} = 4.74$, $SD_{video} = 2.33$, $M_{key} = 4.65$, $SD_{key} = 1.84$, $t(87) = -0.20$, $p = .85$).

The evaluation questionnaire showed that the groups assessed the learning experience differently. The key-group enjoyed learning with the identification key more than the video- group enjoyed learning with the videos. Moreover, they found the identification keys more helpful than the video-group the videos. However, the video-group assessed the first learning phase as more helpful than the key-group. Both groups found the aquarium visit similar helpful for learning, with no significant differences between the groups (see Table 2 for means and standard deviations).

SUMMARY AND DISCUSSION

The study was designed to investigate the instructional effectiveness of a multimedia approach of linking classroom and out-of-classroom learning about species identification. In formal university Biology curricula students typically prepare for identifying species outdoor through identifying preserved specimens with the help of dichotomous identification keys. This strategy may however reinforce a way of abstract reasoning that may not be very helpful for solving real-world identification tasks (Resnick, 1987). Hence, in the current study educational videos presented via mobile devices were implemented to bridge the gap between both settings by providing contextualized and dynamic information in a direct way already during the preparation of an aquarium visit. This approach was empirically compared to the more traditional scenario with respect to its instructional effectiveness.

Because all students performed significantly better after visiting the aquarium than before our first hypothesis that an enriched real-world experience leads to a significant knowledge gain is supported. Learning in the aquarium gives learners the chance to learn and to deepen their knowledge acquired in the classroom and all students found it very helpful to work in the aquarium. Hence, situated learning during field trips – at least if students are prepared for it during prior classroom instruction (e.g., Dillon et al., 2006; Randler, 2008) – will improve their species identification skills. An explanation for these findings might be the suggestion of Bransford, Sherwood, and Sturdevant

Table 2. Means (and standard deviations in parentheses) as a function of instructional condition as well as results from pairwise comparisons

Item	key-group	video-group	*df*	*t*-value	*p*
Pre-questionnaire					
Are you interested in fishes? *	3.00 (0.93)	3.17 (1.06)	87	-0.82	>.10
Do you like visiting aquaria? *	3.72 (0.93)	3.52 (1.21)	87	0.87	>.10
Are you interested in freshwater fishes? *	2.6 (0.82)	3.00 (1.14)	87	-1.90	>.05
Name the following fish species. (Pretest, max. 5 points)	0.58 (0.94)	0.77 (1.17)	86	-0.83	>.10
Evaluation questionnaire					
How much did you enjoy learning with the identification keys? * How much did you enjoy learning with the videos? *	4.21 (0.94)	3.80 (0.86)	87	2.12	<.05*
Was the learning phase before the aquarium visit helpful for you? *	3.98 (1.07)	4.46 (0.75)	86	-2.45	<.05*
Was the identification key helpful for learning? * Was the DVD helpful for learning? *	4.56 (0.67)	4.09 (0.59)	87	3.54	<.01**
Was the aquarium visit helpful for learning? *	4.74	4.67	87	0.58	>.10

* Ranging from 1 = not at all to 5 = very much

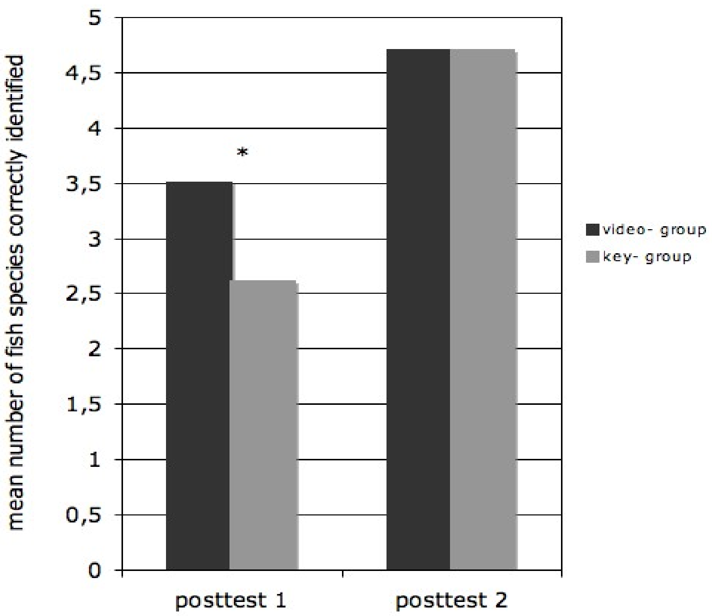

Figure 3. Mean number of fish species correctly identified by the dynamic and the traditional group in the first and second posttest (maximum score is 8). * marks the significant difference in the performance of the two groups in the first posttest (t-test, see text for details)

(1987) that factual knowledge remains inert, when it is not transformed into a more applied expertise in a real world context. Thus, inert knowledge acquired in a preparatory setting is likely to become more accessible to students once it is actively applied during field trips (see also Krombass & Harms, 2006; Wilde & Urhahne, 2008). It should be noted though that since a control group which did not visit the aquarium was missing, it can not be completely ruled out that repeated testing using the same questionnaire might already have improved knowledge. However, as our findings receive strong support from other studies (e.g. Randler et al., 2005; Hamilton-Ekeke, 2007) we are confident regarding the stability of the effect.

When assessing the efficiency of the more traditional learning material and the dynamic-static learning material, we have to take into account the supplementation that was achieved by the real-world experience. Before visiting the aquarium, the group learning with dynamic-static visualizations outperformed the group with the more traditional learning scenario indicating a superiority of the video material, but after the real world experience students who prepared with the traditional learning materials caught up and both groups showed equal performance in the second post-test. Thus, our second hypothesis that dynamic-static visualizations would be superior to traditional learning materials is rejected although the video-based material enhanced initial learning. One reason for this initial support might be the motivational aspect of the mobile devices itself (Jones et al., 2007). Learning with them might be more engaging and stimulating than learning with more traditional media resulting in better initial learning outcomes. Another reason might be the type of information provided in the first learning phase. The videos provided more realistic information as well as information on behavioral aspects, whereas the preserved specimens and the identification keys naturally did not include such information. Participants who learnt with the identification keys had to mentally animate the movement of the species, which may have required additional cognitive resources (Sweller et al., 1998). Moreover, the information provided in the classroom by the video-based material was more congruent with the learning objective and the test items used to assess learning outcomes (Plass et al., 2009; Tversky et al., 2002), which might have led to the superiority of the dynamic-static visualizations before the aquarium visit. Students who learnt with identification keys and preserved specimens profited more from the aquarium visit than those students who learnt with dynamic-static visualizations. This is converse to our expectations and our third hypothesis is thus rejected. We suppose that this effect is strongly related to the question why the video-based material enhanced initial learning only, while the traditional materials caught up during the real-world experience and both groups performed equally afterards. Instead of enhancing those students' knowledge that learnt with dynamic-static visualizations, the aquarium visit rather seems to have compensated for the initial inferiority of the more traditional learning materials. The reasons for this compensatory effect must lie in the real-world experience itself. Observations made by the experts may shed some light on potentially relevant aspects that may explain the larger knowledge gain for those students who had worked with identification keys earlier. It appeared that during the visit to the aquarium participants who prepared with the preserved specimens were more active during learning. Students made intensive use of the identification keys while the mobile devices were used only rarely and students who prepared with them mainly used their notes which had been taken during the initial learning phase. One explanation for this observation may be that in the aquarium those students were better motivated who were the ones who had prepared with the identification keys. Apparently, the motivational aspect of the mobile devices in the first learning phase was not transferred to the aquarium. Here all participants were exposed to the living specimens, a drastic change in learning conditions when compared to the classroom learning. Under these altered conditions the application of the identification keys appeared to be more challenging in a positive sense than the videos and the notes. We can mainly think of two reasons why this more challenging application of the identification keys in the aquarium could have had a positive impact on learning outcomes assessed after the aquarium visit.

First, the type of information provided in the aquarium and by the identification keys and the preserved specimens in the initial learning phase differed to a greater extent than the type of information provided by the videos and in the aquarium. This fact might have helped those students who prepared with identification keys to fill in their knowledge gaps during the aquarium visit and might have caused the equal performance of all participants after the aquarium visit. Before visiting the aquarium only those students who had initially learnt with the videos had the chance to make use of information about locomotion, behavior and coloration of species, whereas the other students were forced to rely on external morphology only (e.g., position of fin) and to mentally animate the movement of a certain species. However, during the aquarium visit all students received information on locomotion, behavior, and coloration by observing living species. Under these conditions new information that had so far been considered as little relevant for species identification became very salient for those students and mental animation of the species` movement was no longer necessary. Those students who worked with the videos in the preparing learning phase, however, were already familiar with these aspects and may hence have benefited to a lesser extent.

Second, students who participated in the more traditional learning scenario were confronted with two different approaches towards knowledge acquisition about biodiversity. In the classroom these students had received more abstract instructions, which were subsequently augmented by the real-world experience in the aquarium. They had to overcome the incongruence between both approaches during the aquarium visit (cf. Tversky et al., 2002). In contrast, for students learning with dynamic-static visualizations both phases followed a realistic approach, in the first learning phase by videos and in the second learning phase by the aquarium visit. Maybe the change of instructional approaches for students participating in the more traditional approach assisted mental processes in a constructivist way in the aquarium (Reinmann & Mandl, 2006), forcing them to engage more intensively in the learning task by using the identification key from the initial learning phase.

After the first post-test the video-based learning material was superior to the more traditional learning material, whereas all students performed equally well after the aquarium visit. Mobile devices or videos seem to have a great potential as learning materials as shown by the results of the first post-test, but in the aquarium students had relatively little benefit from it, indeed, they rarely used the players. One reason might be the inconvenient handling of the portable DVD-players used as mobile devices in the current study. They were relatively heavy and the notes students made in the classroom were paper-based and could be handled more easily. For future studies it is worth testing whether smaller mobile devices can reduce this problem and therefore dynamic-static visualizations could actually be used in the aquarium. Furthermore, it remains to be tested whether mobile devices with more sophisticated technical options are suitable for learning environments such as an aquarium or museum. For example, the notes that have been taken in the classroom could be stored electronically; moreover, the motivation to use the devices during learning might be increased by adding features such as interactive test items. So far studies on teaching biodiversity including the use of mobile devices are scarce. However, they seem promising (e.g., Chen et al., 2004; Liu et al., 2007). Pfeiffer et al. (2009) demonstrated that the use of mobile DVD players led to a high knowledge gain about fish biodiversity when integrated into a learning scenario on the beach. Students had to identify species while snorkelling and were allowed to verify their fish identifications later on the beach by the use of mobile DVD players. However, in contrast to the present study, species observation / identification and use of mobile devices did not occur simultaneously but subsequently.

Since participants in the current study who used identification keys compared to those who used videos for learning did not show significant differences in their interest in fishes, in their motivation for aquarium visits or in their prior knowledge of fish species, it is unlikely that measured differences in learning outcomes are due to one of these variables.

Students` evaluation after the learning experience showed that they had more fun with the identification keys than with the videos and that they found the identification keys more helpful than the videos. However, the students who worked with the videos assessed the first learning phase as having been more helpful than the students who worked with the identification keys. Combining the high potential of the videos with the identification keys and preserved specimens in the initial preparing learning phase might be a way to achieve even better learning results.

Although video based material did not turn out to be superior to traditional learning material in teaching biodiversity it still seems recommendable as also suggested by Berk (2009). The videos clips in the study presented here are superior during the preparing classroom activity and of equal value after the aquarium compared to identification keys. Hence, they have the potential to prepare real-world experiences and to solve the problems between classroom and outdoor learning outlined above. Practitioners might favour the video-based learning materials because they more easily connect activities to each other that are considered to be essential for preparation as well as for the real-world experiences in the field. Moreover, the use of digital videos may be less time-consuming for both teachers and students, because teachers no longer need to prepare the preserved specimens for classroom use. Whereas in the current study the learning time was held constant for experimental reasons, it moreover appears to be reasonable that watching dynamic-static visualizations will be more efficient than handling preserved specimens under less controlled settings. Nevertheless, concerning affective and motivational factors, the videos and the applied mobile devices have to be improved. Some aspects outlined in the discussion have not yet been addressed in any study and will probably have a potential to further improve learning outcomes. It is a challenge of future research to investigate the technological potential of mobile devices in order to become an efficient tool to link learning activities in the classroom and in the field as for example recommended for teaching biodiversity.

The results and conclusions of this study were drawn using fish biodiversity as learning domain, but we assume them to be applicable to any kind of domain in biodiversity, e.g. birds, mammals or any species that is characterized by dynamic features and that needs to be identified in the field. Furthermore, mobile devices provide the technological resources to include acoustic features as well, which are additive to visual features in bird identification according to Prokop and Rodák (2009).

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