Enhancing Students' Knowledge of Biodiversity in a Situated Mobile Learning Scenario: Using Static and Dynamic Visualizations in Field Trips

V.D.I. Pfeiffer, S. Gemballa, B. Bizer, University of Tübingen, Department of Zoology,
Evolution and Ecology Forum, Auf der Morgenstelle 28, 72076 Tübingen, Germany
Email: vanessa.pfeiffer@uni-tuebingen.de, sven.gemballa@uni-tuebingen.de, babsai@gmx.de
H. Jarodzka, B. Imhof, Knowledge Media Research Center,
Konrad-Adenauer-Str. 40, 72072 Tübingen, Germany
Email: h.jarodzka@iwm-kmrc.de, b.imhof@iwm-kmrc.de
K. Scheiter, University of Tübingen, Applied Cognitive Psychology and Media Psychology,
Konrad-Adenauer-Str. 40, 72072 Tübingen, Germany, k.scheiter@iwm-kmrc.de
P. Gerjets, Knowledge Media Research Center, Konrad-Adenauer-Str. 40, 72072 Tübingen, Germany
a: Knowledge Media Research Center, p.gerjets@iwm-kmrc.de

Abstract: The effectiveness of static versus dynamic learning material was tested using fish biodiversity as learning domain. Eighteen fish species were presented either as videos or selected freeze-frames to students. Thereafter, students exercised identifying these species in their natural habitats during snorkeling. Students' knowledge of biodiversity was measured from test videos before (posttest 1) and after (posttest 2) snorkeling as the number of recognized species. Results showed significant knowledge gains between posttest 1 and 2. For the presentation format (static vs. dynamic) there was no significant main effect. However, a significant interaction showed that the students` knowledge improved from posttest 1 to 2 to a larger extent in the dynamic group. The study was conducted within a university curriculum for which a mobile learning scenario using portable DVD-players was applied for the first time. Overall results indicate a high potential for using mobile devices in informal settings during field trips.

Introduction

Comprehension difficulties in the Natural Sciences often result from the complexity, speed or scale of dynamic contexts and the balancing act between observing concrete object configurations and the need to understand the underlying abstract scientific concepts and theories. Computer generated dynamic visualizations have the potential to support the comprehension of complex dynamics in the Natural Sciences, because in contrast to static visualizations they deliver information about temporary changes of objects and their positions. The successful knowledge acquisition with dynamic visualizations is a resource intensive process (*cf.* Scheiter, Gerjets & Catrambone, 2006), which requires simultaneous and optimized availability of different learning resources. Particularly, these resources comprise different processing capabilities of the cognitive system, functionalities of the applied computer technology and didactically substantiated contents and representations. The instructional potential can only be tested, if different learning resources are combined and related to each other in a concrete learning scenario. Therefore, there is a need for an interdisciplinary cross-linked perspective of Cognitive Science, Computer Science, and Natural Science (in this case biology). This cross-linking was realized in the present study for which we chose fish biodiversity as learning domain. One of the crucial aspects of competence in biodiversity is the ability to correctly identify species in their natural habitat. This process of species identification has to be considered as a complex task: During sometimes brief periods of observation of an animal it has to be verified by the observer if the combination of features of this animal fits with the combination of features of any species known to the observer. Furthermore, it has to be verified that the combination of features checked is unique, that is, it does not apply to any other species. If this is the case, the observer can assign the observed individual to one species, that is, the species is identified correctly. We consider this as a complex cognitive challenge. Thus, biodiversity is one adequate field to investigate whether dynamic visualizations have a potential to support knowledge acquisition in the Natural Sciences. Since teaching biodiversity requires teaching in the field, it offers the possibility to study effects linked to the use of situated mobile learning scenarios. In this study the efficiency of dynamic versus static visualizations was tested, embedded in a mobile learning scenario on fish biodiversity.

Challenges in Learning about Biodiversity: Contributions from Didactics of Biology and Psychology

Knowledge in biodiversity is one important aspect of education of biologists, especially for those who work in areas of organismal biology. One key competence to be developed is the ability to identify species in their natural habitat. For example, ecologists depend on this competence if they aim at studying organismic interactions. Furthermore, any study related to protection and conservation of species, an overall international goal acknowledged by international conventions between many states (e.g., Convention on Biological Diversity), depends on the correct identification of these species in the field. Finally, not only biologists but any person interested in wildlife will not be able to get any information about the animals they observe in the wild until they are not able to assign the observed animal to a certain species.

This study picks fishes with nearly 30.000 species as an example of a diverse group of organisms (Nelson, 2006). More specifically we choose the diversity of coastal fishes of the western Mediterranean as a learning domain within the field of biodiversity. We consider this choice to be adequate for our purposes for several reasons: (1) the selected species are easy to observe while snorkeling in the upper 5m of the water column. (2) Since there is only moderate diversity graduate students have a good chance to acquire substantial knowledge within a short amount of time when combining instructional visualizations and real-world experience (i.e., snorkeling). (3) Mediterranean fish species have a good potential to combine learning about biodiversity with a mobile learning scenario on the beach. (4) The features needed to distinguish the species are not too subtle and come from different areas. In general, a combination of color patterns, behavioral and locomotory aspects, and morphological features provides sufficient information to identify a species. (5) Since behavioral and locomotory aspects also help to identify the species in real-world situations, the chosen domain seems adequate to test the potential of dynamic versus static visualizations.

For both of these visualization formats several theoretical benefits and drawbacks are matter of ongoing discussions (*cf.* Hoeffler & Leutner, 2007 for a recent review). According to Tversky, Bauer-Morrison & Bétrancourt (2002) dynamic visualizations not only allow learners to identify the current state of objects; they also deliver information concerning changes of objects and their positions over time (motion, Bétrancourt, 2005) as well as information concerning the directions of these changes (trajectory, Rieber, 1990). Therefore, dynamic visualizations should be especially suited to convey learning contents, which are characterized by motion and trajectory themselves (congruency principle, Tversky et al., 2002). Since identifying Mediterranean fish species comprises not only static features but also dynamic features, like behavior or locomotion pattern, the congruency principle may be applicable to this domain, too. Dynamic visualizations also show the continuity of the movements. Thus, this continuity has not to be inferred by the learner (supplantation, Salomon, 1979). In comparison to static visualizations, dynamic visualizations explicitly show the dynamics of an object, an aspect that is considered to be an advantage of dynamic visualizations over static ones (Hegarty, 1992; Lowe, 1999). Fish behavior and movement patterns in their natural habitat are complex dynamic processes that can hardly be inferred from static representations. Thus, dynamic representations might be advantageous in this domain. On the other hand, multiple static visualizations facilitate comparisons between different states, positions, or locations of an object. With static visualizations the internalization of segregated states may be easier, because they are shown in the external representations. These processes may be helpful to build a mental model of a dynamic process (e.g., a type of locomotion). Concerning fish biodiversity it is possible to observe morphological characters more detailed in a static than in a dynamic visualization, an argument that might lead to static material being superior to dynamic material in this domain. Dynamic as well as static visualizations can lead to high cognitive demands (Sweller, van Merriënboer, & Paas, 1998). Dynamic visualizations can be difficult to perceive and the important states have to be defined by the learner intuitively when watching the visualization, whereas static visualizations may have to be mentally animated and thereby can lead to visual search processes to match the corresponding points of the visualizations (like the edge of a fin, or different morphological characters).

The process of fish species identification may solely rely on static features (e.g., a combination of morphological features and color patterns). However, in addition to these static features, dynamic features such as behavioral and locomotory aspects (e.g., swimming style, shoaling or interactions) are valuable to identify the species. When observing fishes in their natural habitat, while diving or snorkeling these, dynamic features are often more salient than the static ones. But, even if these dynamic aspects are used for identification, they can never be used exclusively. It remains necessary to use at least some static features (e.g., color pattern) for species identification. Thus, a learner has two options how to spend a given amount of learning time: S/he can either concentrate on the static features alone or include dynamic aspects and thus reduce the focus on static features. These two options reflect the two kinds of learning material developed for this study. (1) Static pictures showing all static features were provided to learners in the static condition for a certain amount of time (approx. 50 sec for each species). (2) The second group spent the same total amount of time but was shown dynamic (behavioral and locomotory) features most of the time and devoted less time to the static features (approx. 12-20 sec). For option (1) material was developed that consists of one or two freeze-frames of a species. For option (2) material was developed consisting of the same freeze-frames highlighting the relevant static feature interrupted by sequences that showed dynamic features. We considered the freeze-frames to be necessary in this condition since it is impossible to identify a species by dynamic features alone. The dynamic material displays a lot more features (i.e., dynamic and static) in the same time and thus has to be considered more complex and demanding for learners. Thus, it might be considered disadvantageous when compared to the static material. On the other hand, our dynamic material has some characteristics that have recently been identified to be important in making dynamic material superior to static material: It much better reflects the real world condition and conveys procedural-motor knowledge. Eventually, this is what students are trained and tested for. Thus, we suspect that the dynamic material altogether is superior to the static material since it is much closer to the real-world test condition. Hence, the first hypothesis states that dynamic learning materials lead to a higher knowledge gain in biodiversity than static learning material. Any support to this hypothesis would have an impact on the two traditional ways to teach biodiversity, because these ways solely use static material consisting of paper-based drawings or photographs.

These two ways of teaching biodiversity are formal classroom settings (e.g., fish identification courses) or informal settings (e.g., marine biology field courses). In the former students study dead and preserved specimens by using dichotomous identification keys based on verbal description and line drawings. In contrast to living specimens such dead and preserved specimens lack most of their very salient color and behavioral features. Such classroom settings have the advantage that students can handle the species manually as long as they want and explore even subtle morphological features in great detail. However, experience of biology instructors with this approach is that the students can hardly ever use the detailed morphological knowledge acquired in the classroom for species identification in real-world situations in the field because these are extremely different from the classroom: Encounters in the field are brief and specimens look much more colorful. In other words in such classrooms settings students are likely to acquire inert knowledge, which can hardly be used for real-world experience (Bransford, Sherwood, & Sturdevant, 1987). As a result students will be able to pass an exam on identification on dead and preserved specimens but will not be able to identify species in a real-world situation.

Therefore, an alternative approach is to teach biodiversity in more informal situated-learning settings in the field (e.g., field trips to seashores to explore fish biodiversity by snorkeling or diving). In such settings students use field guidebooks (i.e., photo identification books) and try to find species that match their real-world observations from snorkeling. Thus, this way of conveying knowledge of biodiversity is more informal, non-linear and includes greater amounts of free-choice learning. Therefore, learning in informal settings may be highly efficient (Falk & Dierking, 2000). In particular, it is considered advantageous that knowledge acquisition in situated-learning settings (e.g., in the field) is much closer related to the real-life problems. Resnick (1987) claims that in situated learning the often-observed disconnection between formal school settings and real-life problems is largely reduced. She explains the escapism of knowledge acquisition in schools by features of the tasks performed at school contrary to tasks performed in real-life settings. Tasks in formal school education are individual activities, involve dealing with abstract representations, symbol manipulations, abstract thinking, well-defined problems, and are subject-bounded. In contrast, real-life problems are characterized by collaborative activities, use of tools, contextualized activities, contextualized thinking, complex problems, and are interdisciplinary by nature.

The number of arguments favoring learning biodiversity in the field correlate well with the experience of biology instructors that such settings are extremely popular among students and yield learning outcomes typically not observed in the traditional classroom setting. Thus, in this study the focus is on out-of-classroom activities instead of formal classroom settings. However, we believe that the current out-of-classroom approach outlined above (i.e., students observing species while snorkeling and trying to find species in a field guide book that match their observations) is still not sufficient. The first reason is that the field guide books are designed to cover as many species as possible (e.g., all species of marine fishes of whole Europe). For example, the most widely used field guidebooks for the Mediterranean contain 368 (Bergbauer & Humberg, 1999) or nearly 600 species (Louisy, 2002). Whereas high level experts are able to deal with this high amount of information, learners will be overwhelmed (Zucchi, 2007). As a consequence, we designed a new learning scenario that focuses on a reduced number of the 18 most commonly observed fish species on the western Mediterranean coasts. In this learning scenario students used mobile learning devices (portable DVD players) in a classroom and during real-world experience (i.e., snorkeling) with either static or dynamic learning material for fish identification. Thus, the learning material was available at any time for the students during their work on the coast. We are confident that in such situated learning scenarios mobile devices force a more direct interaction between learner and learning material. Furthermore, they enable free-choice learning and self-directed learning without the help of an expert. Mobile devices are an optimal solution for the demands in the described setting, since they allow learners to get immediate access to the same learning material during an initial and more formal classroom phase and during the informal field observations. So, they serve as a powerful interface between factual knowledge and real-world experience, creating an augmented, technically enriched real-world experience, which allows for a more flexible access to information. According to Sharples (2007), mobile learning may provide expertise on demand, for instance, detailed information about fish and their behavior within a snorkeling setting. Hence, our second hypothesis is that an enriched real-world experience by mobile devices leads to a significant knowledge gain, measured by knowledge tests before and after the experience.

However, the question remains how both factors (enriched real-world experience and dynamism of the presentation format) interact with each other. The design of this study allows testing whether one of the two presentation formats (dynamic vs. static) leads to a significant higher knowledge gain when combined with real-world experience. So far, such long-term interaction effects between format of learning material and real-world experience have not yet been addressed in the research on informal learning to our knowing.

Design of the study

Procedure

The study was conducted over three days (units 1-8, see Table 1 for details). Unit 1 (*questionnaire 1*) was necessary to obtain relevant information on parameters that might influence students' performance in the study (see Material section below). Due to their answers in questionnaire 1 the students were separated in two equivalent groups for units 4-8. Units 2 and 3 were designed to achieve a level as homogenous as possible in snorkeling capabilities and fish identification background knowledge of the participants. During unit 4 (*learning phase*) the two separated groups of students learnt the features for identification of the 18 most common coastal fishes of the region using DVDs on a portable DVD player. One group used dynamic video material showing fishes in their natural habitat, the other used one or two freeze-frames extracted from these videos (see Material section below). The students of both groups were advised to make notes on preformatted forms (*fish species forms*). Right after that we measured students' performance in fish identification by *posttest 1* (unit 5) in which students had to identify fish species from unknown videos (test videos, different from learning material) from the natural habitat without using their fish species form. All videos were displayed twice to the students. Posttest 1 was the same for both groups. The students of the two groups were not told that they dealt with different learning material but were not separated over night. The third day started with the *real-world experience* (unit 6). Students were to identify as many as possible of the 18 fish species introduced to them by the DVD material. For snorkeling, dynamic and static groups were separated on two remote, but nearly equivalent spots and changed spots after half the time. During unit 6 students were allowed to verify their fish species observations by using the DVD material as well as their notes on the fish species form. During their efforts to identify fish species they were also allowed to collaborate with each other in the water and on the beach. Moreover, experts helped students in the water to find suitable places for fish observation. The experts, however, were only allowed to point out places but not to help with fish identification. Thus, feedback for the students only came from the DVD material, from the fish species form and from in-group discussions. Right after snorkeling we tested students' performance again by *posttest 2*, which was identical to posttest 1 except for the fact that the test videos were only shown once. For posttest 2 the two groups were kept separated. Finally, the students had to complete *questionnaire 2* (for details see below).

Table 1: Course of the 3-day study conducted at the Mediterranean coast of northern Spain, Costa Brava

unit	time	description	material used
1	day 1, 30 min	students complete questionnaire 1	questionnaire 1
2	day 1, 90 min	introduction to snorkeling: 30 min oral presentation by expert; 60 min practise in water guided by experts	
3	day 2, 15 min	students receive basics on fish identification and technica instructions (15 min presentation by expert)	PowerPoint presentation
4	day 2, 90 min	students learning phase with portable DVD player: features of 18 fish species to be observed in the field	fish identification DVD, fish species form for notes
5	day 2, 60 min	posttest 1, beamer presentation for test videos	fish identification testDVD
6	day 3, 240 min	real-world experience: fish identification by snorkeling (including rest and change of spot between groups)	fish identification DVD on portable, form with notes
7	day 3, 45 min	posttest 2, beamer presentation for test videos	fish identification test DVD
8	day 3, 30 min	students complete questionnaire 2	questionnaire 2

Note: 18 species were presented on the fish identification DVD, each with one video: *Parablennius sp.*, *P. gattorugine*, *Tripterygion sp.*, *Gobius bucchichi*, *Mullus sp.*, *Coris julis*. *Symphodus roissali*, *S. tinca*, *S. melanocercus, Serranus cabrilla, Diplodus vulgaris*, *D. sargus, Oblada melanura*, *Sarpa salpa*, *Chelon sp.*, *Atherina sp.*, *Boops boops, Chromis chromis.*

Participants, Design and Setting

This study was conducted with 35 students of Biology participating in a university field course in Marine Biology held in Spain, Costa Brava by zoologists of the University of Tuebingen, Germany. Twenty-one were 3rd year students, twelve 4th year students, and two 5th year students. The main goal of the field course was to enhance and broaden knowledge on marine biodiversity. The study was conducted on the three initial days of the course. For part of the study (see Table 1), students were divided into two groups (static and dynamic group;

see above). The mean age was 24.18±1.13 years (n= 17) for the static group and 25.00±1.65 years (n=18) for the dynamic group. 13 students were male, 22 female. For the snorkeling exercise (Table 1, unit 6) we chose the bay of Aiguablava, Costa Brava for its perfect conditions: It is protected from the open sea, the water is easy to enter and shallow (0-5m) A variety of habitats such as sandy bottoms, sea grass meadows and rocks covered by algae ensures that all of the 18 species in question have good conditions to develop stable local populations. On the day of the field study (i.e. students snorkeling to practice fish identification) weather was warm and sunny, visibility in the water was perfect (>15m), and the sea was calm with almost no waves. During the snorkeling exercise expert ichthyologists monitored the fish species present in the upper 5m. Due to that survey we can be sure that all the fish species mentioned in the learning material could in principle be seen on that day.

Material

Central to our study was the development of learning material that either contained dynamic or static material of the 18 most common Mediterranean fish species and test material for posttests 1 and 2 that contained videos of the same 18 species. Moreover, students had to fill in two questionnaires.

Description of learning material: We used two different DVDs: One with *dynamic videos* of 18 different fish species and one with one or two selected *freeze-frames* of these species extracted from the video. Both DVDs were arranged in the same way with a master slide including instructions and three slides I-III each with thumbnail icons for six species that had to be pressed for playing the video of the species. The students were free to switch between the videos and slides I-III but could not interrupt a video once started. The fish were filmed at Cap Roig, Spain, Costa Brava. At the beginning of each video the name and the size of the species was displayed on a black screen. During the video spoken text gave information about habitat, morphology, behavior of the species, and similar species from the DVD collection. The spoken text focused on the information necessary to distinguish the species in the video from the remaining 17 species in the collection; hence, it highlighted the features unique for this species. These features could either be behavioral features (e.g., swimming style), habitat information, or morphological features (e.g., color spots or bars on various parts of body or head, certain color pattern). Since the unique morphological features of a swimming fish species are difficult to perceive we chose one or two images from each real-time video to freeze for a few seconds (7-10sec). The features mentioned in the spoken text were superimposed consecutively on the freeze-frames (see example in Fig. 1). The dynamic condition displayed these freeze-frames for some seconds only but displayed behavioral and swimming aspects for most of the time. In the static condition these labeled freeze-frames were presented throughout the whole video of a species. The spoken text and the total presentation time for one species (47-53 seconds depending on the species) was the same in both conditions. Each species presentation ended with a black screen displaying the name of the species. The DVDs were played on portable 7'' DVD-players. Two students shared one player and one DVD.

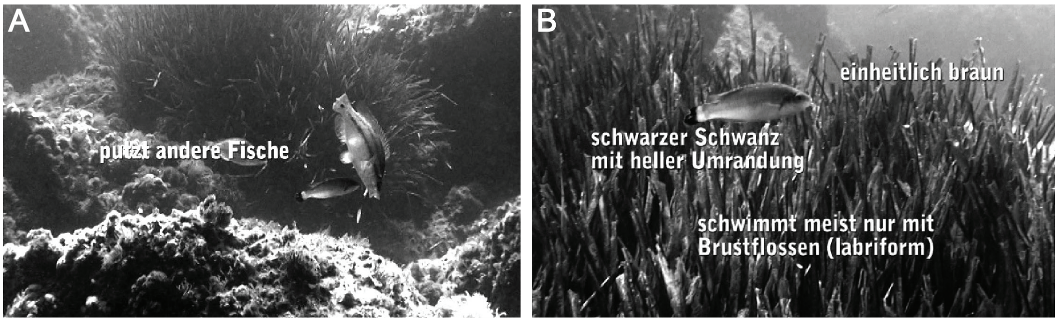

Figure 1. Screenshots of the labeled freeze-frames of the video of *Symphodus melanocercus*. A. Behavioral aspect. Translation of German text: "cleaning other fishes" B. Morphological features, swimming style and coloration. Translation of German text: "brown color (upper right), white edged black tail (middle), swimming exclusively with pectoral fins [labriform swimming mode]".

During the learning phase (unit 4) students used a preformatted printed paper, the *fish species form*, with equal space reserved for notes on each of the 18 species. Students filled in notes for each species during unit 4 and were allowed these notes during the snorkeling exercise (unit 6). Also, they had to mark each species identified in the field during snorkeling on the form. They were not allowed to use the form in posttest 1 and 2.

Description of posttest material: To measure the learning outcomes the students had to pass two posttests (units 5 and 7, see table 1). The posttest material contained real-time videos of the same 18 species as the learning material. However, it was different from the learning material in several respects: The test videos showed different individuals of the species in different local environments, were arranged in a different order. Moreover, the test videos contained no spoken text and no labels; just a number was given at the beginning. We decided to use only videos for the posttest, since this is the qualification that biology students are trained for.

The posttests simulated fish observations in the field and tested students' performance in fish identification. During the test students had to assign names of the 18 fish species correctly to a series of 18 unknown videos (length of each video approximately 40 seconds; no use of fish species forms). In order to facilitate recalling the exact Latin names the students received a list of 25 Latin fish names including the 18 species in question. For each correctly identified species the students got one point. If they wrote down nothing, or a description, or the wrong species name they got no point for this item. Hence the maximum score in one test was 18. Reliability coefficients (Cronbach´s α) were calculated for posttest 1 with $\alpha = .79$ and for posttest 2 with $\alpha = .79$. Therefore, test scores were summed up to one posttest score 1 and one score for posttest 2.

Snorkeling exercise data (unit 6): Most of the students (65.7 %) snorkeled over 90 minutes, 28.6 % snorkeled between 60 and 90 minutes, 2.9 % snorkeled between 30 and 60 minutes, and 2.9 % of the students snorkeled less then 30 minutes. Snorkeling duration did not differ between the static and dynamic condition, t (33) = -.34, $p = .74$. During the snorkeling exercise students had to mark on the fish species form which species they had actually observed in the field. Each species seen during snorkeling was scored 1 to find out whether one of the two groups observed significantly more species than the other.

Description of questionnaires: Students had to fill in two questionnaires. In *questionnaire 1* (unit 1 prior to learning phase) the students were asked for items that might influence their performance in the study, namely their age, gender, knowledge of Latin and fish, how much they were interested and experienced in fish and swimming and whether they had snorkeled or dived before. The more they knew, were interested and experienced the higher was the score. This questionnaire was used to parallelize groups and to allow later control for confounding factors. *Questionnaire 2* (unit 8) was used at the end of the study to extend control options for confounding factors. In this questionnaire the students were asked how long they had snorkeled and used the DVD and whether they considered these activities supportive for learning. The longer they snorkeled and used the DVD and the more they found this helpful the higher was the score in this questionnaire.

Results

Questionnaire 1 data reveal that both groups did not significantly differ in any of the preconditions concerning prerequisite knowledge (e.g., snorkeling and diving experience, knowledge in fish anatomy and fish biodiversity, knowledge in Latin, all ps > .10). Students were asked to list the names and features of Mediterranean fish species that they knew prior to the learning phase. However, none of the students listed any of the 18 species that were part of our learning material. Thus, with respect to the content of the field course there was no prior knowledge in fish biodiversity.

Questionnaire 2 data did not show any significant difference between the two groups either. Both groups did not differ in their assessment of the snorkeling activity, $t(33) = -0.43$, $p = .67$. Furthermore, both groups stated having used the DVD equally often during the snorkeling activity ($t(33) = -0.96$, $p = .34$). Each student from both groups stated that s/he found the DVD helpful for knowledge acquisition.

From *data on fish species forms* we have information about the performance in the field. Most fish species were identified in the field by the participants of both groups, and mostly equally often by both groups. Exceptions are *Tripterygion spec*., $t(33) = -2.58$, $p = .01$, *Serranus cabrilla*, $t(33) = -4.02$, $p < .01$, *Chelon spec*., $t(33) = -2.69$, $p = .01$, and *Boops boops*, $t(33) = -2.69$, $p = .01$; which had all been identified more often during snorkeling by the group that had received dynamic material. This fact had been taken into account during further analysis by calculating an ANCOVA including the critical items as covariates. Since the overall results did not change with this procedure, only results for the ANOVA are presented.

Results for the posttest data depending on condition are displayed in figure 2. An ANOVA with repeated measures showed a main effect for the posttest data, F (1,33) = 213.12, $p < .01$. Participants performed better in the second posttest after the snorkeling experience ($M = 14.51$, $SD = 3.21$) than in the first posttest ($M = 5.6$, $SD = 3.67$). There were no differences between learners who had studied either dynamic or static visualizations ($F < 1$). However, a significant interaction between both factors was found, $F(1, 33) = 6.72$, $p = .01$ (Figure 2). From this it follows that the knowledge gains in the group receiving dynamic material exceeded the knowledge gains in the group receiving static material.

Discussion

This study adds interesting novel insights to the field of learning with visualizations in the Natural Sciences. The fact that students had no prior knowledge of the Mediterranian fish species (see questionnaire 1 data) but could identify an average of $M = 5.6$ species in posttest 1, clearly shows that a considerable increase of knowledge took place during the learning phase (unit 4). However, at an overall level, students performed equally well in both posttests after studying one of the two visualizations formats, so our first hypothesis is rejected. This result thus mirrors the statement of Tversky et al. (2002) that even in conveying dynamic contents dynamic visualizations often fail to lead to superior learning results than static visualizations. Possibly higher processing demands of dynamic learning materials in comparison to static learning materials are the reason for this result. These additional cognitive demands may be caused by the large quantity of information, its transientness, as well as by the need to split attention across several relevant aspects (Hegarty, 2004; Lowe, 1999) and the need to identify and memorize the segregated states in the dynamic visualizations and to make comparisons between them (Rieber, 1990). Additional design guidelines based on research about perceptual and cognitive processes are needed to tap the full potential of dynamic visualizations (Lowe, 2004). The results of the current study showed, however, that the potential of dynamic learning materials could be tapped when extending the instructional scenario with enriched real-world experiences. That is, combining dynamic visualizations with a real-world learning experience improved learning to a larger extent than using static visualizations in this combination. Thus, the potential of a dynamic presentation format seems to unfold only after an enriched real-world experience. Even if the dynamic visualizations did not lead to better knowledge immediately as would have been reflected in the first posttest, they may have facilitated learning from the real-world experience nevertheless. Maybe fish that were observed during snorkeling could be easier linked to the observations made while watching the DVD, as behavioral patterns and motions (i.e., aspects not visible in the static pictures) could be used as cues for memory access. Moreover, knowledge acquired from dynamic visualizations may remain inert, as long as it is not strengthened by real-world experience (*cf.* Resnick, 1987). The current study does not allow deciding on the mechanisms underlying this finding. However, it stresses the importance of testing the effectiveness of instructional materials not only in the laboratory, but of assessing their impact in situated learning contexts, which may act as moderators for this instructional effectiveness.

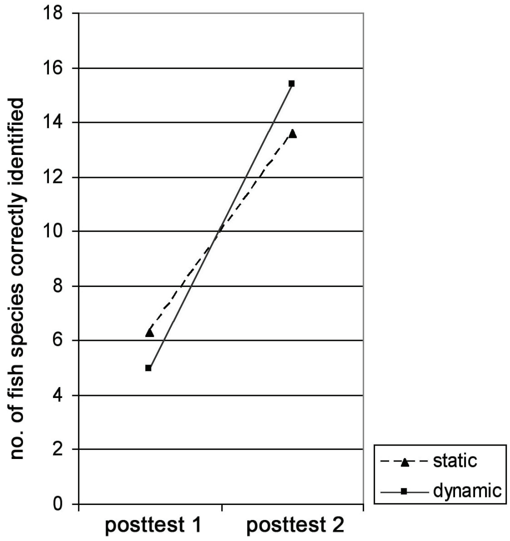

Figure 2. Average performance in the two posttests as a function of visualization condition.

Moreover, the comparison of the posttest results showed that students benefited significantly from the enriched real-world experience, thereby confirming the *second hypothesis*. In this study technology was used to support the link between formal and informal learning. The findings have important implications for mobile learning. According to Sharples (2007) big issues of mobile learning yet remain unexplored. This study addresses several of these identified issues, albeit in an indirect way. One of them is the question of how to enhance the experience without interfering with it (Beale, 2007). Even though the effectiveness of using a mobile device was not explicitly tested, experienced tutors in biology, who were involved in the implementation of this mobile device, were positively surprised. They stated that students were very contented with this new teaching form. Furthermore, instructors stated that learning outcomes were very high compared to earlier courses. Another big issue in mobile learning is to bridge the gap between formal and informal education at universities (Sharples, 2007). In this case bridging the gap between more formalized, abstract, and static textbook information (i.e., the field guide book) and the informal setting of real world observations (i.e., identifying fish species in their natural environment by snorkeling) seemed to be facilitated by introducing a mobile learning device very well. Furthermore, this study is an example of mobile learning design for innovative educational practice as requested by Milrad (2007). So far, solely unhandy books with complex, abstract, and static information were used in this scenario. Therefore, this study stands for real innovations in biological didactics. Moreover, the usage of mobile devices is integrated into a broader educational scenario as Hoppe (2007) calls for. Students, who choose Ichthyology as a major in biology, have to take the here-described course. So, the usage of a mobile device was studied within a real university context. It has to be stressed that the usage was not a one-time experiment; it was embedding a mobile learning approach within the curriculum at a university course. So, this approach has proven its value not in a well-controlled laboratory setting, but even in a complex and ill-defined real-world scenario. However, further research is needed, since the study was not designed to identify the main factors that account for the huge knowledge gains (e.g., the real-world experience itself, or the link of formal and informal setting by technology, or collaborative learning). So far, we can only be sure that an instructional scenario during field trips works well if real-world-experience, mobile learning, and collaborative activities are integrated. Furthermore, it seems that already a rather simple mobile device with very little interaction possibilities like a mobile DVD-player has strong influence on learning in informal settings. Given that the potential of mobile learning has not been exhausted with this kind of device, it is assumed that expanding this approach to more sophisticated devices like, for instance, internet tablets establishes unforeseen possibilities. Thereby, more fish species may be included and sorted according different criteria by means of the mobile device. This would facilitate finding an observed species as they could be ordered by systematic, color, area of circulation, and habitat. Then, identifying species by mobile media is not only interesting for learners, but too an adequate tool for biologists in general. A software and more flexible hardware need to be developed for these demands and therefore, collaboration between biologists, psychologists, and computer scientists is essential. In this combination we are able to exploit latest research in three specifications to find modern, more effective, and enjoyable ways in learning about biodiversity.

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