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Curriculum

Species-Recognition Program: A Computer-Assisted Approach to Recognizing Species †

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Species recognition is a crucial component for many types of biological studies. To that end, broadly trained students must be able to accurately identify many different types of organisms. Courses that focus on learning the names of different species traditionally rely on preserved specimens viewed during class or laboratory time. Unfortunately, reliance on preserved specimens comes with many challenges in providing students with an optimal learning experience. The curriculum activity described here uses a modified PowerPoint file (species-recognition program—SRP) as a means of helping students learn to recognize and identify fishes based on subtle visual cues. Our results indicate that students were better able to identify fish species when using the SRP as a learning approach than when using preserved specimens. We suggest that the SRP approach to species recognition is an effective, viable alternative or supplement to preserved specimens that can be easily implemented in any course that emphasizes species identification. Information and materials are provided to enable instructors to create their own species-recognition programs.

INTRODUCTION

This past decade has seen a remarkable shift in higher education in the sciences, with an increasing number of instructors placing a high priority on core concepts and competencies such as the process of science, quantitative reasoning, modeling and simulation, and effective communication skills (1). These enhanced priorities, embraced by science educators nationwide and endorsed by the American Association for the Advancement of Science (AAAS), the National Science Foundation (NSF), and the Association of American Colleges and Universities (AAC&U) and others, clearly help to provide students with a modern and forward-thinking approach to biology—they reflect how scientific progress is actually achieved.

Despite the recent transformative shift in the scope and goals of science education, there is still a need for certain types of courses that emphasize lower cognitive skills—for example, courses whose focus is on the recognition and identification of different species. This is especially true for many organismal courses such as plant taxonomy, ornithology, ichthyology, and mammalogy. These types of courses tend to require students to identify a specimen, connect the specimen with a particular name, and recognize and correctly identify the organism at some later time and in a different context. The ability to correctly identify an organism connects it to all existing knowledge about the species. This level of knowledge then serves as a base for higher-order learning.

The traditional approach to teaching and learning names of organisms often involves presenting students with representative samples (e.g., dried herbarium plant specimens, taxidermied or otherwise preserved animals). Students then go through a process to identify the organisms to species (perhaps using a dichotomous key or an answer key provided by the instructor) with the goal of correctly connecting a species name or common name with the specimen. This traditional approach to learning species is not always ideal since dried or preserved specimens often do not look like organisms as they appear in nature (e.g., loss of color in preserved fishes), which may hinder the ability of students to transfer knowledge gained in the course to actually recognizing and identifying species in natural field conditions.

A computer-aided instructional resource was recently developed by one of the authors (SK) to help students in an upper-level ichthyology course. The "species-recognition program" (SRP) is a PowerPoint-based program that can be used to present images of organisms along with distinguishing visual characteristics of each species. Although fish images were used for the purpose of this report, faculty can substitute their own images and defining characteristics of taxa of their choice for their classes. The purpose of

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this report is to present the SRP to the broader academic community and report the effectiveness of the SRP versus a traditional method (TM) of learning to recognize fishes. The traditional method involved students observing preserved fish as a means of learning to identify species and common names. Our results indicate that students actually learn to identify fish species more effectively (and are therefore more likely to transfer these skills to field settings) when using the SRP versus the TM approach. These results have implications for faculty who are considering "virtual learning" versus "wet lab learning" in their organismal courses.

Intended audience

The curriculum activity described here uses routine, widely available computer software (PowerPoint). It is appropriate for students at all levels ranging from first-year undergraduate students to graduate students. However, faculty who teach courses whose primary focus is species recognition will find this activity particularly useful.

Prerequisite student knowledge

There is virtually no prerequisite student knowledge required for this SRP activity. However, since the SRP incorporates descriptions of distinguishing characteristics of each organism (as determined by the instructor), students should have a basic understanding of those characteristics. For example, if a description of a caudal fin is given for a fish, then students should know what a caudal fin is. For our study, this type of information was presented to students in preliminary laboratory sessions and in an introduction at the beginning of each lab session.

Learning time

This curriculum activity is meant to be a student-guided, self-study module. Therefore, the amount of time spent on this activity is entirely dependent upon the student and guidance given by the faculty member. The SRP activity as described here was used during weekly three-hour ichthyology laboratory sessions over a total of six weeks. Students spent roughly two hours of each three-hour lab period studying specimens using either the TM or SRP. Faculty can assign this activity according to the scope and needs of their individual courses.

Learning objectives

After using the SRP as a learning and study aid, students will be able to:

1. Recognize and correctly identify the species and common name of select organisms.
2. Identify the distinguishing characteristics of select species.

PROCEDURE

Materials and student instructions

The SRP is a PowerPoint file that includes images of organisms added by the instructor. Over 100 different fish species were included in the SRP used for this report. The SRP presents the user with representative images (three to five) of each species. Different taxonomic levels (including species and common name) are available for each fish, as are distinct visual cues that are often used during species identification and may not be clearly visible in the image. However, the actual text for those items does not appear when a fish is first presented to the user (Fig. 1A). The user must mouse click the taxonomic categories before the names are revealed. Likewise, users can mouse click the hints and different regions of the image to reveal distinguishing characteristics (Fig. 1B). With a PowerPoint add-in, users can shuffle images prior to each run-through so they are not in the same order (a free version tested for the PC can be found at www.pptalchemy.co.uk/Downloads/shuffler.zip). The SRP essentially represents a systematic way for students to quiz themselves as they learn to identify different species.

The SRP can be either distributed to students for use on their own computers on their own time or set up on designated computers. Students are then instructed on general use of the program and given guidance on how to use it as an effective learning tool. Students are instructed to carefully observe each image and look for distinguishing features of the organism. Students can then begin to mouse click image regions that they think represent key features. Descriptions of the distinguishing features come into view when students mouse click certain regions on the image. Students are instructed to run through the program multiple times and quiz themselves on species names as they do. This interactive, positive learning reinforcement can be used as often as students wish.

Faculty instructions

To employ the SRP in a laboratory section, we recommend that the instructor give an introduction to the species to be covered during that period. This is a good opportunity to cover distinguishing characteristics and provide instructions to the students prior to their work individually or in small groups. During this study, students typically worked collaboratively with the SRP in groups of three. They were instructed in advance not to click any species identification answers or to state their identification until all in the group had a chance to independently arrive at their own identification and agreed to check the correct answers using the program.

For this report, the SRP was used and tested during the laboratory portion of an ichthyology course. A total of six lab sessions were used for this study. For each session, students were organized according to last name and assigned either the SRP as a means of learning fish names, or the traditional method (TM). For the traditional method, students were presented with preserved fish in jars as well as dichotomous keys to help identify the species and common name. Correct species identifications were also made available as a coded species list so that students could check for accuracy of their identification. Students were asked to quiz themselves on species recognition using either the TM or SRP as learning techniques as they studied and learned species and common names. Toward the end of each lab session, students were given a species identification quiz that consisted of five preserved fish (representing the TM approach) and five digital images (representing the SRP approach). Each student took the quiz including both preserved specimens and digital images. In order to test whether students could transfer their species identification skills to new situations, the specimens and images used for quizzes were different from the ones students used to study during the lab session. The learning approach was alternated each week so that each student would, for example, use the SRP one week and the TM the following week. Final exam performance, which also consisted of specimens and images not viewed previously by students, was also used to compare the SRP versus TM approaches.

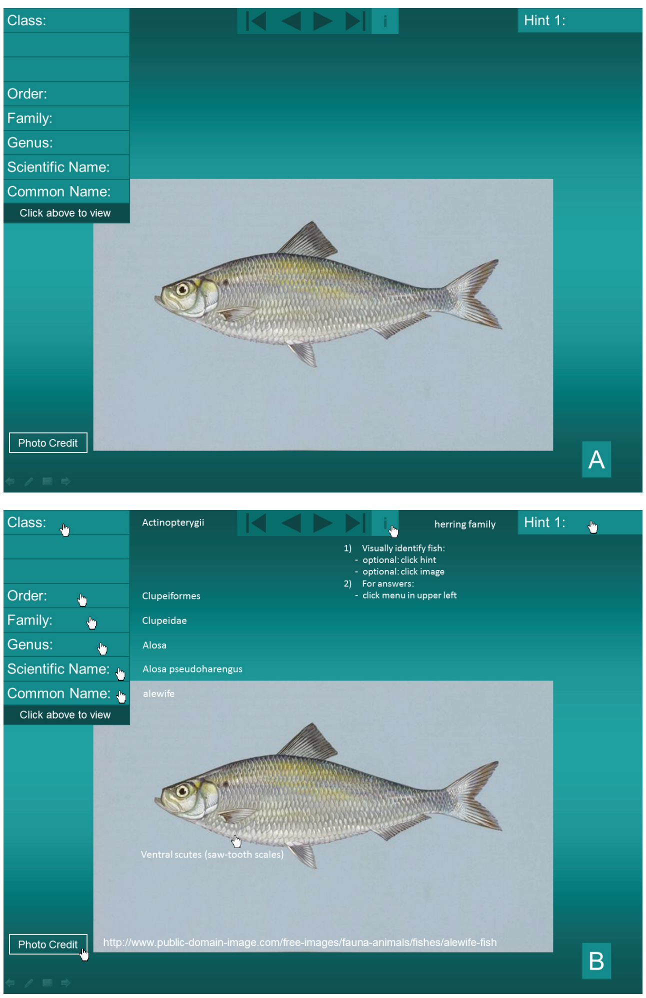

FIGURE 1. Screen shot of SRP showing viewable items when image is first presented to the user (A) and items revealed after mouse click (B). Fish image was obtained online from the public domain at www.public-domain-image.com/free-images/fauna-animals/fishes/alewife-fish.

Suggestions for determining student learning and sample data

The flexible nature of the SRP allows for a range from minimal intervention from the faculty member to highly structured assessment activities. At a minimal level, faculty may provide students with the SRP and later administer quizzes or exams based on the organisms used in the SRP. For this report, students were asked, among other things, to keep track of their learning gains while using the SRP. Specifically, students were asked to record whether they correctly identified specimens over consecutive trials (most often three trials were completed during the available time). By the end of the third trial, students using the SRP self-reported an average species recognition rate of nearly 95% (Fig. 2).

Safety issues

This curriculum activity does not pose any notable safety issues since it involves only computer-assisted instruction.

DISCUSSION

Humans have a remarkable ability to recognize subtle visual features, stemming from our highly developed ability to recognize human faces. Facial recognition requires a period of seeing and learning but is astonishing, considering that a human is likely to be able to identify a known friend among all other humans. The SRP has been designed to help adapt this ability to recognizing subtle shape differences in organisms. The traditional method of learning the fishes or

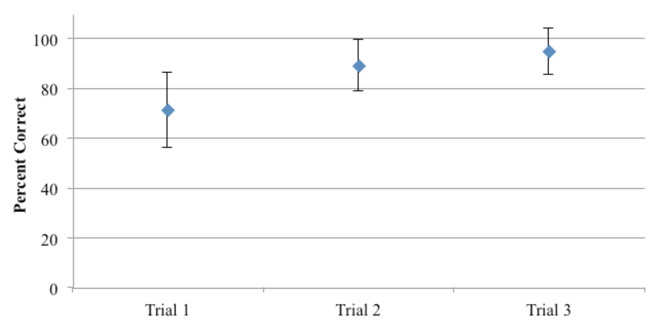

FIGURE 2. Self-quiz scores for species recognition by students using the species-recognition program (SRP) over three consecutive trials. Scores are self-reported. Data represent mean ± standard deviation. N = 77, 75, and 60 over the three trials respectively.

other organisms relies more on the use of dichotomous keys and specific distinguishing characteristics. This is akin to describing a friend to someone (height, hair color, etc.) in comparison with simply recognizing that person. The key to applying the innate human ability to recognize subtle visual differences among fishes is creating a learning environment where species can be quickly and repeatedly identified with immediate feedback.

Computer software developers have made significant progress in mimicking the human ability to recognize individuals through "computer vision" (3). Indeed, field guides now include web-based and stand-alone interactive keys and visual-recognition software adapted for species recognition (4, 10, 11). For example, an individual using Leafsnap (http://Leafsnap.com) (9) can simply take a digital photo of a leaf from a tree and get a reasonably accurate identification of that species. Despite the progress in visual-recognition software, students broadly trained in biology still need training in species recognition, and our results indicate that the SRP approach is an effective way to achieve this.

Field testing and evidence of student learning

The SRP was used for two sections of ichthyology laboratory offered over two different semesters. For both sections, students used both the SRP and the TM approaches to species recognition during each laboratory session, with half of the students using the TM and half using the SRP. Each student was assigned to use the SRP and TM on alternating weeks. Weekly species recognition quiz scores, final exam scores, and survey responses were used to test the effectiveness of the SRP.

Overall quiz performance for all six labs combined reveals that students were able to identify and learn significantly more species when using the SRP than when using the TM approach (Fig. 3; $p < 0.05$, *t*-test). For the SRP approach, the overall percent correct was 71.24 (standard deviation [sd] = 17.97) while it was 63.16 (sd = 19.21) using the TM approach. Recall that quizzes consisted of ten fishes—five digital images and five actual specimens—*that students had not seen previously* (although they had seen other images or specimens of the same species). These results suggest that students will be more likely to recognize and identify fish in natural field settings when using the SRP than the TM learning approach.

Beyond short-term learning of fish species for quizzes, student performance on final exams demonstrates an even more dramatic impact of the SRP. When students were presented with previously unseen digital images and preserved specimens, they were able to identify significantly more fish based on images than specimens (Fig. 4; $p < 0.05$, *t*-test). The average correct identifications based on specimens was 36.83% (sd = 23.78) while it was 62.67% (sd = 25.11) with digital images. These results highlight the importance of the interactive, user-guided interface provided by the SRP in helping students conceptualize mental constructs of distinguishing features that can be used to recognize different species. These scores are

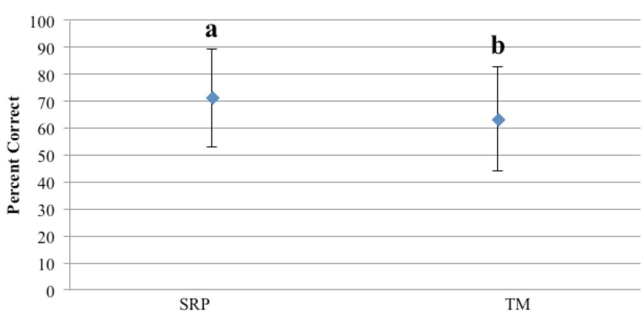

FIGURE 3. Quiz scores for species recognition by students using either the species-recognition program (SRP) or traditional method (TM) as the primary learning strategy. Each quiz consisted of five digital images and five specimens, all of which were previously unseen by students. Data represent mean ± standard deviation for all six quizzes combined. Mean values labeled with different letters are significantly different ($p < 0.05$). $N = 79$ quizzes for SRP and 73 quizzes for TM.

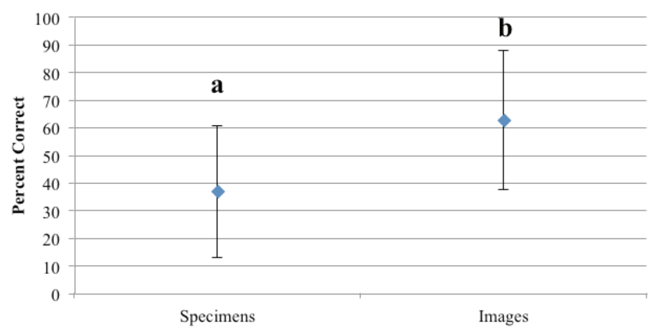

FIGURE 4. Performance results for portion of final exam based on specimens and novel images (images of fish that had not been presented to students previously). Data represent mean ± standard deviation. Mean values labeled with different letters are significantly different ($p < 0.05$). $N = 9$ students.

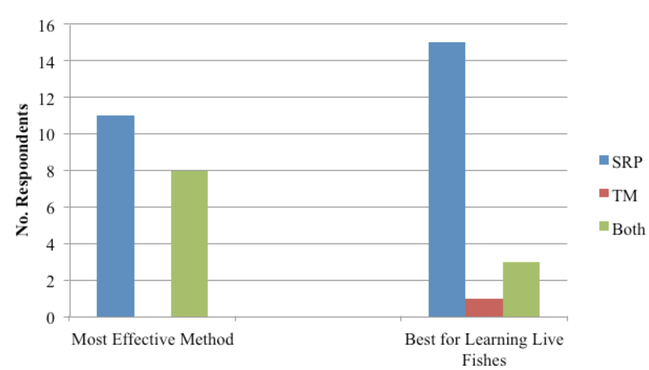

FIGURE 5. Student survey results showing their perceptions of the effectiveness of the species-recognition program (SRP) versus the traditional method (TM) in promoting species recognition.

low, but questions about higher taxa and extra credit for knowing both common and scientific names led to low rates of failure.

Indirect assessment data were fairly well aligned with the direct assessment data discussed above. Students were asked about their perceptions of the effectiveness of the SRP versus TM for learning fishes (Fig. 5). Most students (57.9%) agreed that, overall, the SRP was the most effective way to learn fish species. When asked specifically which method would be best for learning to identify live fishes, the majority (78.95%) indicated that the SRP was the best approach. Interestingly, relatively few students (15.8%) indicated that a combination of both SRP and TM would be the best approach to learning to identify live fishes. Students clearly value the role of the SRP as part of the learning process. The fact that students prefer the interactive SRP format is in alignment with a recent study that found that students prefer interactive, web-based species identification guides versus printed guides (2).

The results presented here indicate that the SRP is an effective way for students to recognize and identify fish species. However, it is not entirely clear *why* the SRP appears more effective than a traditional approach involving actual specimens. It is possible that it is simply easier for students to click through slides than to engage with actual specimens (and they thus spend more time using the SRP than the TM). The self-quizzing nature of the SRP is likely a major part of its effectiveness. Although both the TM and SRP provide the opportunity for students to quiz themselves as frequently as they wish, it is likely that students using the SRP quizzed themselves more frequently (and in a more systematic fashion) than those using the TM approach. Indeed, the frequent quiz approach (and repeated information retrieval) has been identified as an effective way for students to learn (5, 6, 7, 8, 12). We suggest that the SRP approach to learning and recognizing species is effective because it not only allows students to create their own visual construct of each species, but also allows for easy, repetitive, self-quizzing of the key features and taxonomic categories associated with each organism.

The hidden visual clue feature of the SRP may also contribute to its effectiveness. By encouraging the user to mouse over different regions of an image without any real guidance, the SRP forces users to use their observational skills to focus on key features and provides a positive reinforcement (in the form of revealing a clue) when a key feature is found. It should also be noted that a learning tool such as the SRP may be more effective for learning organisms such as fish (or perhaps plants) since preserved fish (or dried plant) specimens are often discolored or may otherwise not reflect the actual appearance of the live organism in its natural environment. Nevertheless, a learning tool such as the SRP is an effective, engaging, low-cost, easily implemented alternative to relying solely on specimens for courses whose goal is to help students recognize and identify different species.

Creating an SRP

Faculty can create their own SRP for any set of species using the materials provided (Appendix 1). Without modification, the SRP is limited to providing only names, hints, and species characteristics of each species. Appendix 1 contains a template slide that can be duplicated and modified to create a new SRP or add new species, along with instructions, and working example slides. To create an SRP, the materials required are 1) the template file from Appendix 1, 2) a data file with species names to be copied and pasted into the template, 3) a file or website with species images to paste into the template (e.g., http://eol.org/; www.public-domain-image.com/; https://commons.wikimedia.org/wiki/Main_Page), and 4) a file or website that includes image source or credit if desired. It would also be helpful to have available any identification tips for placement on the images. The purpose of these tips is to provide distinguishing characteristics and diagnostic information that may not be clearly visible in the image. The SRP should be prepared and tested in advance of student use. Allow approximately five minutes for adding each new slide. The template works in PowerPoint 2010 and has been tested on both PC and Mac computers.

Opportunities for peer and group learning

The SRP was used to facilitate numerous opportunities for students to engage in peer and group learning during this study. Students typically worked in groups of three when working with the SRP, primarily because of the limited number of computers; however, it is likely that they benefited from combining their observations and knowledge in learning to recognize species. Students also had the opportunity to work together when viewing specimens for the TM approach, so the SRP is not superior in this aspect.

The SRP offers an easy way to review species and to quiz or test students on their ability to recognize species by using the program to project images and query the class as a whole or individually. In review sessions, the instructor can use the program, asking for student identifications while providing advice on distinguishing species that are very similar in appearance. Individual testing can be done by projecting the SRP with a selected subset of species as students provide their identifications on an answer sheet. In contrast, setting out preserved specimens for a practical examination takes substantial space and time.

We imagine that in the future, two-dimensional images will be replaced by three-dimensional views of species that can be rotated and zoomed. At present, such views are not available in sufficient numbers for most taxa. The results of our study show that in helping students learn to identify species, the use of images with instant feedback as available in the SRP is a viable alternative to using preserved specimens. It is likely that three-dimensional views will only enhance the digital learning experience.

SUPPLEMENTAL MATERIALS

Appendix 1: Species-recognition program template with instructions and examples

ACKNOWLEDGMENTS

The authors declare that there are no conflicts of interest.

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