INTRODUCTION

With the expansion of the Internet, there has been increased emphasis on harnessing the information carried therein for use in the classroom. People have done this through such things as WebQuests, online conferencing with international scientists, and having students create their own Internet content (1–4). In the context of organismal biology, students can use online resources to read about and view pictures of organisms that they might not otherwise notice or interact with, thus expanding their exposure to the “natural” world. However, many pictures posted online are idealized examples of an organism and not what students are most likely to encounter in their actual environment. This disconnect may leave students still unfamiliar with their actual, daily surroundings, as well as with the diversity of organisms in their area. Despite issues with online sources, advances in mobile technology, such as quick response (QR) codes, provide alternate avenues to access Internet content that complements in-person interaction with live organisms. Quick response codes are two-dimensional bar codes (Fig. 1) that can be scanned with a smart device using free QR reader software (e.g., www.qrcode.com/en/history/). Quick response codes can be linked to content created by an instructor or to a pre-existing website. Students can simply scan the code with a QR reader app on a smart device to bring up information, thus providing a way to integrate Internet resources with the local environment in real time.

Since their advent, many people have realized the potential of QR codes, and their use has expanded into many areas including healthcare, education, tourism and manufacturing (5, reviewed in 6). However, assessment of the implementation of QR codes in undergraduate student learning is underexplored, with few examples assessing the use of QR codes in biology higher education (7, 8). Therefore, despite their apparent popularity, this lack of information makes data-driven motivation for incorporating QR codes into the classroom challenging (6). In particular, QR codes have not, to our knowledge, been used to expose undergraduates to local plant species and the issues of plant invasiveness in the context of an environmental science course. Here, we describe and evaluate a novel QR code “scavenger hunt”-type activity aimed at increasing student...
understanding of local native and invasive species in an undergraduate, nonmajors Environmental Science class at a four-year, primarily undergraduate teaching institution. We provide assessment data of its impact on student learning, specifically on student application of concepts related to native and invasive plant species.

**Intended audience**

This activity is intended for introductory, nonmajors Environmental Science students. The organisms studied and used in the assessment examples are limited to the east coast of the United States. However, this activity could be adapted to include different local species and is beneficial for any introductory class where students routinely have access to smart devices.

**Prerequisite student knowledge**

There is no expectation of prior student knowledge.

**Learning time**

The QR activity was completed outside of class time and took students approximately one to two hours to complete.

**Learning objectives**

Upon completion of the QR activity, students will be able to:

1. Identify examples of native and invasive plant species in a given geographic area
2. Compare and contrast characteristics of native, introduced, and invasive species
3. Predict the ecological effect of invasive species in a given geographic area

**PROCEDURE**

The QR activity was designed to help students learn about the concepts of native and invasive species in a local context through active learning outside of a traditional lecture classroom.

**Materials and student instructions**

After the QR codes were in place, students were provided a written, three-part assignment (Appendix 1) and given one week to complete it outside of class. The first part of the assignment directs students to reputable sources to define, compare, and contrast basic terminology, including the terms native, endemic, introduced, and invasive, so that they have a context for better understanding the ecological impact of the plants they would see. The second part of the document directs students to the QR code-labeled native plants on campus, and the final part of the assignment directs students to QR code-labeled invasive plant species on campus. After finding the native and invasive plants, students scanned the QR code to bring up the previously identified, relevant website to answer questions about the plants. Students then submitted the assignment online.

**Faculty instructions**

We present a guided activity with online resources that can be used with or without QR codes, but we focus on and present assessment data for the assignment when used with QR codes (Appendix 1). The first part of the activity (Appendix 1, Background) directs students to find general information on native, endemic, invasive, and introduced species and is generally applicable regardless of geographic location. However, the second part of the activity (Appendix 1, Plants we have on campus) should only be used as a model because plants growing on campuses will vary among geographic locations.

To prepare the second part of the QR activity presented here, four native and four invasive plant species were identified on campus. The native plants, Eastern hemlock (Tsuga canadensis), mountain laurel (Kalmia latifolia), sassafras (Sassafras albidum), and alumroot (Heuchera spp.), were located in the University of North Georgia’s (UNG’s) native woodland garden. Because an area purposely planted with only native species may not exist on every campus, instructors may need to adopt the “scavenger hunt” approach we used with invasive species. The invasive plants, English ivy (Hedera helix), Japanese honeysuckle (Lonicera japonica), multiflora rose (Rosa multiflora), Chinese privet (Ligustrum sinense), and air potato (Dioscorea bulbifera), were in landscaped or disturbed areas widely distributed across campus. Directions were given to students for how to find these species on campus. The examples provided, at least for invasive species, are useful for much of the mid-Atlantic east coast of the United States. To aid instructors in identifying native and invasive species in other geographic locations, we have provided links to online resources at the end of Appendix 1 (Instructor Resources). Contacting the institutional unit responsible for landscaping may also help instructors identify native and invasive plant species on campus.

After identifying the native and invasive plant species on campus, students were directed toward reputable websites that provided clear information about these species, including where they were from and their role in the local ecosystem. If instructors modify the native and invasive plant species used in the assignment, the websites linked to the QR codes will also need to be modified. Websites maintained by government and/or educational institutions should be used. We have provided examples of reputable national and state level resources at the end of Appendix 1 (Instructor Resources).

Reputable websites need to be linked to the QR codes following directions on a free website such as https://www.the-qrcode-generator.com/. We created a static QR code linked to a stable URL for each of the previously chosen species, and used in the assessment examples are limited to the east coast of the United States. To aid instructors in identifying native and invasive species in other geographic locations, we have provided links to online resources at the end of Appendix 1 (Instructor Resources). Contacting the institutional unit responsible for landscaping may also help instructors identify native and invasive plant species on campus.
websites. These QR codes were then printed at a final size of approximately 4” × 4” so they would be easily visible from a short distance away. Based on verbal student feedback, easy visibility is key to student enjoyment. They were laminated so that they would withstand variable weather conditions and tied with twine to the appropriate plants. Instructors wishing not to use the QR codes can instead embed links to reputable websites in the assignment directions.

Suggestions for determining student learning

We evaluated whether students met the previously stated learning objectives, through 1) use of post-assignment test questions (posttest, Appendix 2) embedded in a longer test given one to two weeks after completion of the QR activity and 2) an in-class case study given one to two days after completion of the QR activity (Appendix 3). Assessment questions are aligned with the previously stated learning objectives. The first learning objective was measured by a multiple-choice question (posttest question 1) and free-response questions with limited possible answers (case-study questions 1A, 2A, and 8A). Students achieved the first learning objective on the posttest and case-study questions if the question was answered correctly and did not achieve the learning objective if it was answered incorrectly. The second learning objective was assessed using posttest question 2 and case study questions 1B, 2B, and 8B. These were free-response questions, and achievement of this learning objective is indicated in the column headers of the rubrics used to evaluate these free response questions (from “Fully Correct – 4” to “Fully Incorrect – 0,” where 3 and 4 are considered as meeting expectations; Appendices 4 and 5). The third learning objective was measured by posttest question 3, a multiple-choice question, which had to be answered correctly for students to meet the learning objective.

Sample data

Table 1 provides samples of student answers to the free-response questions in the posttest quiz questions as well as the case study. The posttest questions, case study, and rubrics used to score free response questions are available in the Supplemental Materials (Appendices 2–5).

Safety issues

We encountered no safety issues, but care should be taken to ensure that species used with this assignment are easily accessible to students.

DISCUSSION

Field testing

We tested the QR Activity in comparison with lecture in 100 students among two instructors over three semesters at the University of North Georgia, a primarily undergraduate teaching institution. Across all classes, approximately one-third of the students were freshmen, and the remaining two-thirds were relatively equally distributed among sophomores, juniors, and seniors. We received institutional IRB approval and complied with all institutional and federal guidelines (Institutional IRB Code 201542). To assess the impact of a QR code assignment on achievement of our learning objectives, we assigned students to one of two groups: QR activity (treatment) or lecture (comparison). Students using QR codes were compared with students who were exposed to the same information in a traditional lecture. All free-response questions were evaluated using rubrics (see Appendices 4–6) by three reviewers with an intra-class correlation coefficient (ICC) of greater than 0.74. All data were analyzed in SPSS.

Evidence of student learning

Students in both the treatment (QR activity) and comparison (lecture) groups met the first learning objective, with 92% (±10%) of students correctly answering the first posttest question in the QR activity treatment and 89% (±5%) in the lecture comparison. While the percentage of students meeting the first learning objective is slightly higher in the QR activity group, the difference between the groups was not statistically significant (χ² = 0.25, df = 1, p = 0.74). This is consistent with the case study, where a high percentage of students in each treatment met the first learning objective, with no statistically significant difference between the groups (χ² = 0.25, df = 1, p = 0.74).

Students in both the QR and lecture groups also met the second learning objective, with 76% (±15%) of QR activity students meeting expectations on the posttest compared with 72% (±16%) of lecture students (Table 2). The difference between groups was not statistically significant (χ² = 0.001, df = 1, p = 0.999). Results from the case study are also consistent for this learning objective between QR and lecture groups (χ² = 0.210, df = 1, p = 0.685). However, the percentages of students achieving the learning outcome was much lower for the case study than for the posttest (Table 2). It is possible that students consider the in-class quiz in which the posttest questions were embedded as a high-stakes assessment, given that they have to study ahead of time for it. On the other hand, the case study is an assignment that students may consider as low-stakes, and one for which they are unlikely to study ahead of time. Previous studies have shown that low-stakes assessments provide unreliable data on student learning gains compared with high-stakes assessments, specifically suggesting that students perform worse on low-stakes assessments (11–13). For this reason, we believe that assessment of the QR activity using the quiz questions provides a more accurate evaluation of student learning gains.

In contrast to the first two learning objectives, significantly more students in the QR activity group than the lecture group (χ² = 8.84, df = 1, p = 0.004) met the third learning objective. In the QR activity group, 69% ± 9% of students met the learning
outcome expectations, but only 41% ± 4% of students in the lecture group met the objective. Students in the QR activity group met all learning objectives, while students in the lecture group only met the first two learning objectives.

Student feedback

To gauge student opinion of the QR activity, we solicited written feedback about student enjoyment and self-reported learning at the end of the assignment (Appendix 1, Student Feedback). A majority of students reported that they both enjoyed the QR activity (71% ± 6%) and thought they learned something from the assignment (89% ± 4%). Students reported that they enjoyed the QR activity for three main reasons: 1) it was interactive, 2) it was more active, and 3) they felt they learned something (Table 3). However, student comments also indicate that weather is an important factor influencing enjoyment (Table 3).
All of these results taken together suggest that 1) the QR activity was successful in helping students meet all three learning objectives, while students in a traditional lecture only met the first two learning objectives, 2) the QR activity was significantly more effective than traditional lecture in facilitating the development of application skills in students in the context of native and invasive species, and 3) students found the QR activity enjoyable and interactive.

Possible modification

These assignments will likely have to be modified to fit the local flora of any given area, but the QR activity could also be expanded to include non-campus areas such as local parks or community areas. This assignment could also be modified for use in nonscience classes to familiarize students with other aspects of their local environment, such as architecture or artwork. Additionally, based on our implementation of the QR activity, we recommend that instructors give students a range of time in which to complete the assignment and verbally remind them to consider that weather is a factor.

SUPPLEMENTAL MATERIALS

| Reason | Sample Student Comments |
|--------|-------------------------|
| Interactive | “Yes, I enjoyed the assignment because I could go around and look at the differences in vegetation and learn how they grow and where they are from.” |
| Activity | “I enjoyed this assignment. I liked not having to sit in the classroom, and being outside it was more interactive.” |
| Learning | “Yes I loved this assignment. It was so cool going outside and following the map that I had trying to find all the plants that are no more than 300 feet from the HNS building. I like how you could scan the labels and all of the information was there.” |
| Weather | “I did because it got me outside and gave me some much needed exercise as well as giving real life examples of invasive species. It also made for a good date.” |

ACKNOWLEDGMENTS

The authors would like to thank Sharon Blackwell for her phenomenal help entering and organizing the data analyzed for this project. The authors declare that there are no conflicts of interest.

REFERENCES

1. Dodge B. 1995. Webquests: a technique for Internet-based learning. Dist Educ 1:10–13.
2. Beaton SJ, Foster PM. 2013. Using a simple, free Voice-over-Internet Protocol service to add interest to lectures and enhance student engagement. Psychol Teach Rev 19:31–35.
3. Frisch JK, Jackson PC, Murray MC. 2013. Research and teaching: WikiED: using Web 2.0 Tools to teach content and critical thinking. J Coll Sci Teach 443:70–80.
4. Levin-Goldberg J. 2014. Webquests 2.0. Best practices for the 21st century. J Instruct Res 3:73–82.
5. Robertson C, Green T. 2012. Scanning the potential for using QR codes in the classroom. TechTrends 56:11–12.
6. Gradel K, Edson AJ. 2012. QR codes in higher ed: fad or functional tool? J Educ Technol Syst 41:45–67.
7. Lee JK, Lee IS, Kwon YJ. 2011. Scan & learn! Use of quick response codes & smartphones in a biology field study. Am Biol Teach 73:485–492.
8. Yip T, Melling L, Shaw KJ. 2016. Evaluation of an online instructional database accessed by QR codes to support biochemistry practical laboratory courses. J Chem Educ 93:1556–1560.
9. Bloom BS, Engelhart MD, Furst EJ, Hill WH. 1956. Taxonomy of educational objectives; the classification of educational goals. Handbook I: cognitive domain. Longmans, Green, New York, NY.
10. Crowe A, Dirks C, Wenderoth MP. 2008. Biology in bloom: implementing Bloom’s taxonomy to enhance student learning in biology. CBE Life Sci Educ 7:368–381.
11. Wolf LF, Smith JK. 1995. The consequence of consequence: motivation, anxiety, and test performance. Appl Measure Educ 8:227–242.
12. Wise SL, DeMars CE. 2005. Low examinee effort in low-stakes assessment: problems and potential solutions. Educ Assess 10:1–17.
13. Cole JS, Osterlind Sj. 2008. Investigating differences between low- and high-stakes test performance on a general education exam. J Gen Educ 57:119–130.