Case-based approaches have been used extensively in STEM classrooms to enhance the real-world applicability of course content. Prior research in the bioeducation field indicates, specifically, that such methods lead to increases in students’ conceptual understanding and affect in the discipline relative to more traditional methods. Despite these outcomes, the majority of case study exercises are formatted in a generalist manner. In other words, the content and context of the case study itself are not framed around the communities in which the students live. In an effort to address this concern, we developed and implemented a series of place-based case study (PBCS) exercises within the introductory cell and molecular biology courses at our institutions. A comparative, quasi-experimental approach was used to evaluate the impact of PBCSs versus non-PBCSs on cognitive and non-cognitive student outcomes. Results indicated that both PBCSs and non-PBCSs led to increases in students’ content knowledge; however, no statistically significant difference existed in post-exercise performance between the PBCS and non-PBCS cohorts at the University of Texas, for instance, after controlling for confounding factors. Importantly, data also revealed that students within the PBCS cohort agreed more strongly that the case studies provided them with a better understanding of how scientific advancements and research impacted the community in which they lived than did their peers in the non-PBCS cohort. Collectively, these outcomes suggest that PBCSs offer a scalable, classroom-based approach to engage students in relevant, practical experiences that are of direct interest to them and, ideally, the broader scientific community.

INTRODUCTION

Case studies have been utilized broadly within the science classroom to deliver course content via both paper- and-pencil methods and the use of interrupted Clicker cases (1–4). Similar to other constructivist approaches, such exercises have been shown to facilitate students’ development of higher-order Bloom’s (5) skills, including application of course material, analysis of arguments, and synthesis of data (1). In addition, the use of case studies affords students the opportunity to learn by doing, leading to improved communication skills and teamwork, and many students find case-based exercises appealing, thus resulting in improved attendance among individuals exposed to such methods (2). From an affective standpoint, Flynn and Klein (6) found that the use of case studies in the classroom led to an increase in student motivation for working in groups, and Murray-Nseula (7) found that this approach increases students’ positive perceptions of the course. This increase in motivation and attitude toward one’s coursework may be because case studies can be used to highlight connections to real-world issues (2)—connections that have furthermore been found to be critical to student learning, particularly for individuals from historically underrepresented groups (8–11).

While these connections can be achieved in many ways, one mechanism to increase relevance of content in a course is to use a place-based approach to teaching. As Sobel (12) explains, “Place-based education is the process of using the local community and environment as a starting point to teach concepts in language arts, mathematics, social studies, science, and other subjects across the curriculum” (p. 6). This type of educational approach allows the instructor and student to connect learning to the local ecological and cultural contexts in which the instruction occurs (13).
Importantly, place-based learning has been shown to overcome the disjuncture between the student’s life and his or her experiences in the school, thereby strengthening connections between the concepts learned in the classroom and their application in the local environment (14). There are several different approaches to place-based instruction, but many are focused on taking students out of the classroom, where they can interact with the local environment. This can range from students visiting an area park to learn about plant conservation efforts to students visiting a community clinic to better understand access to healthcare (12–14). While these types of experiential learning opportunities have been shown to be effective (2, 3, 7), they are not practical for the large-enrollment introductory science courses found at most universities.

The goal of the curricular approach described in this article is to create a method for instructors to combine the benefits of case study teaching with place-based education by modifying case studies to orient them within one’s local context. Bonney (2) examined the effectiveness of case studies that were either produced by the instructor or taken from a non-affiliated source and found that, regardless of the source of the case study, these were an effective method of content delivery. Thus, we felt confident that we could either modify existing public case studies or create new case studies that were relevant to our local culture and ecology.

Intended audience

The traditional (non-PBCS) and place-based (PBCS) case studies described in this article were employed in two sections of an introductory cell and molecular biology course at a mid-size, research-intensive institution in the West in the fall 2015 semester. Place-based case study and non-PBCS exercises were likewise developed and implemented in two sections of an introductory cell and molecular biology course at a Hispanic-Serving Institution in the Southwest in the fall 2015 and spring 2016 semesters. Students (N = 510) in both contexts were primarily freshmen (82%) whose majors were in the science, technology, engineering, and mathematics (STEM) disciplines. While the case studies utilized in each context varied, it was our intent to determine the extent to which PBCSs could be broadly used to enhance student learning and affect in the biological sciences. Furthermore, the PBCSs created as part of this research could be used in a wide array of introductory STEM courses and would also be applicable for use with advanced high school students.

Prerequisite student knowledge

Participants were predominantly first-year students, and case study exercises were therefore selected or created such that no prerequisite knowledge was necessary. Content related to each exercise was discussed in the lecture immediately preceding the case study, providing students with foundational knowledge of the topic being investigated in the exercise.

Prerequisite teacher knowledge

Given the variation in case study content, instructors should be familiar with those topics customarily presented in an introductory cell and molecular biology course (e.g., cells; mitosis/meiosis; genetics). In addition, because the PBCSs are developed in-house, faculty need to understand local issues within their community and how they relate to the topic of a particular PBCS in a manner that could be used as the basis to craft said PBCSs. In order to accomplish this latter task (i.e., creation of PBCSs), we strongly encourage instructors to view existent case studies published on the National Center for Case Study Teaching in Science (NCCSTS) website (http://sciencecases.lib.buffalo.edu/cs/collection/) and likewise employ a backward design approach (16) in the development of their own exercises.

Learning time

Within the context of the mid-size research institution (hereafter UC), each interrupted Clicker case study (15) was conducted during a 50-minute lecture period. Multiple case studies were used throughout the 15-week semester (see Appendix 1), with one case study administered per week. In comparison, participants from the Hispanic-Serving Institution (hereafter UT) received paper-and-pencil case study exercises (see Appendix 1) to complete approximately once a month during the 15-week semester. Case study teaching episodes lasted the duration of the lecture period (80 minutes). Specific procedures and a timeline for implementation are detailed in Table 1.

Learning objectives

Student learning objectives (SLOs) and their respective methods of assessment are outlined in Table 2.

PROCEDURE

Materials

Minimal preparation is required once non-PBCS or PBCS exercises have been identified or developed, respectively. Instructors should ensure that sufficient copies are made for each student in the course (if case study exercises and accompanying assessments are distributed via paper-and-pencil format) or that students have access to Clickers (if case study exercises and accompanying assessments are delivered via PowerPoint). Clickers are akin to TV remote controls, where students push a numbered button to cast their vote or, for instance, respond to multiple-choice questions that are displayed on a computer screen (15). Data are relayed to the computer, and anonymous responses can be displayed in aggregate as a chart that is projected to the class (15). Prior studies (1–4) indicate that Clickers provide an adaptable means to enhance students’
conceptual understanding and affect in the discipline. Irrespective of format, we strongly encourage instructors to field test any novel PBCSs at least once prior to classroom implementation to ensure that the exercise is aligned with appropriate SLOs and can be presented in the timeframe of the class session.

### TABLE 1.
Lesson plan for place-based case study intervention.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Estimated Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Assessment</td>
<td>1. Distribute one copy of the pre-assessment survey to each student; if you elect to deliver the case study via PowerPoint, questions can be embedded directly into the PowerPoint, and students can respond using a Clicker device. 2. Inform students that the survey is untimed, and that they should raise their hand if they have a question or concern. 3. Collect all surveys from students once they are finished, if applicable.</td>
<td>10 min.</td>
</tr>
<tr>
<td>Case Study Exercise</td>
<td>1. Introduce the case study to provide context for the subsequent discussion/activity. 2. <em>If delivering the case study using PowerPoint</em>, ensure that there are opportunities embedded within the PowerPoint to elicit student discussion (e.g., insert closed-ended or open-ended Clicker questions). 3. <em>If delivering the case study in paper-and-pencil format</em>, direct students to complete the exercise, as a team, at their own pace; monitor student teams as they work, and address any questions that might arise. 4. Review student responses to case study questions in large-group format; address any misconceptions that students might have. 5. Conclude the case study exercise by tying real-world concepts presented in the activity back to course content. 6. Collect case studies, as necessary (paper-and-pencil)</td>
<td>30 min. (UC) or 60 min. (UT)</td>
</tr>
<tr>
<td>Post-Assessment</td>
<td>1. Distribute one copy of the post-assessment survey to each student; if you elect to deliver the case study via PowerPoint, questions can be embedded directly into the PowerPoint, and student can respond using a Clicker device. 2. Inform students that the survey is untimed, and that they should raise their hand if they have a question or concern. 3. Collect all surveys from students once they are finished, if applicable.</td>
<td>10 min.</td>
</tr>
</tbody>
</table>

a When administering the case study exercise, it is important to ensure that equal time is spent on each of the above subtasks in both the non-PBCS and PBCS conditions if you intend to collect assessment data, as differences in instructional approach could otherwise mediate the outcomes observed.

b Note that the questions and discussions embedded within each case study teaching episode address student learning objectives 1 to 3.

### TABLE 2.
Module learning objectives and methods of assessment.

<table>
<thead>
<tr>
<th>Student Learning Objective (SLO)</th>
<th>Method of Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Synthesize material presented in the place-based case studies (PBCS) and non-PBCSs to address questions of real-world relevance</td>
<td>Formative assessment of students' completed case studies/Clicker responses</td>
</tr>
<tr>
<td>2. Define key terminology associated with the content presented in the case studies (PBCS or non-PBCS)</td>
<td>Formative assessment of student discussion during case studies; Content diagnostics²</td>
</tr>
<tr>
<td>3. Explain key processes associated with the content presented in the case studies (PBCS or non-PBCS)</td>
<td>Formative assessment of student discussion during case studies; Content diagnostics²</td>
</tr>
<tr>
<td>4. Demonstrate increased understanding of case study (and associated course) content</td>
<td>Content diagnostics²</td>
</tr>
<tr>
<td>5. Demonstrate increased awareness of the connections between course content and real-world scientific scenarios in the local environment (PBCS cohorts only relative to non-PBCS cohorts)</td>
<td>Affective questionnaires²</td>
</tr>
</tbody>
</table>

² See Appendix 2 for a sample content diagnostic and affective questionnaire.
Student instructions

Both PBCSs and non-PBCSs contain an initial scenario and accompanying instructions for completing the exercise (see Appendix 1 for examples); typically, these instructions prompt students to answer a series of closed-ended/open-ended questions embedded in the case study. Faculty can likewise deliver verbal prompts and cues to assist students as they circulate around the classroom to monitor student progress.

Faculty instructions

Exemplar case studies, including both PBCS and non-PBCS exercises, are provided in Appendix 1. Notes for implementation of non-PBCSs were obtained from the NCCSTTS website, as posted by the author(s) of each case study. Suggestions for implementing the exemplar PBCS can be found in the ‘Notes’ pane. For those faculty seeking to develop their own PBCSs, we strongly recommend including similar notes within the lesson plan. In addition to embedded thought questions within each exercise, we likewise encourage instructors to allocate time for spontaneous conversation that, in our experience, will undoubtedly arise in both non-PBCS and PBCS contexts given the real-world relevance of the case study material.

Suggestions for determining student learning

We recommend pre-/post-exercise assessment of students’ content knowledge and affect, as described in the “Evidence of Student Learning” section below. Collectively, the content diagnostic and affective questionnaire for each exercise can be administered in one, 10-minute block per collection time point. In order to ensure the fidelity of assessment items, pre-test responses should not be discussed, and pre-/post-exercise measures should be implemented under identical conditions (i.e., same time allotment; same instructions for completion).

Sample data

Student responses to Clicker questions were used as a means of formative assessment at UC, affording both the instructor and the students an opportunity to review material with a less than 70% correct response rate. Importantly, even for those items that students appeared comfortable with, the instructor and students engaged in a dialogue regarding why the correct response was correct and all other distractors incorrect, ideally further enhancing the students’ understanding of the topic presented in the exercise.

Students at UT recorded responses to case study exercises in teams of four to five students, which allowed for small-group discussion and iterative opportunities for teams to revise their work. At the end of each case study session, students submitted their responses to the instructor for participation points. This offered the instructor an opportunity to formatively evaluate students’ comprehension of the topic presented in the case study.

Collectively, the above methods allowed the instructors at both institutions to measure outcomes associated with the first three SLOs.

Safety issues

There are no safety issues associated with this curriculum.

DISCUSSION

Evidence of student learning

Participant recruitment procedures. Participants (N = 510) constituted a convenience sample consisting of all students enrolled in two sections of an introductory cell and molecular biology course at UC (n = 401) and two sections of an introductory cell and molecular biology course at UT (n = 109). Participants at both institutions were primarily freshmen (82%) whose major was in the STEM disciplines. Participants in both the non-PBCS and PBCS conditions received a 50-minute (UC) or 80-minute (UT) lecture on the content topic discussed in the case study exercises prior to their participation in those exercises. No other methods of formal instruction were provided.

Description of case studies. Case studies employed in the non-PBCS condition at both institutions were selected from the NCCSTTS website (http://sciencecases.lib.buffalo.edu/cs/collection/) (see Appendix 1 for a list of those exercises used at UC and UT), based on Boolean search criteria for the desired content topic and appropriateness for collegiate learning contexts. In contrast, case studies employed in the PBCS treatment condition at UC and UT were created by the authors (GF and JO, respectively; see Appendix 1 for an exemplar), following best practices for case study development (1). These case studies were reviewed by students and experts within the fields of biological sciences and bioeducation to evaluate construct and content elements present within each exercise.

Implementation of PBCSs at UC. In order to determine the impact of non-PBCS vs. PBCS instruction, a quasi-experimental study was conducted in two sections of an introductory cell and molecular biology course at UC in the fall 2015 semester. Both sections were taught by the same instructor (GF), and each section had an enrollment of approximately 250 students. The course is the first of two within the introductory series for science majors and includes students majoring in biology, chemistry, nursing,
sport and exercise science, psychology, and audiology, as well as a limited number of students who enroll in the course due to general interest. The place-based case studies were either created by the course instructor or were modified from case studies available on the NCCSTS website (http://sciencecases.lib.buffalo.edu/cs/collection/). Two case studies were identified (non-PBCS) or developed (PBCS) on each topic, one that was place-based (focused on topics important in Colorado) and one that was not specific to the location, allowing for curricular comparisons to be made. On the day of case study implementation, one section would be given the place-based case study and the other section would be given the general case study. Each case study exercise was implemented throughout the entirety of the class (50 min.; see Table 1).

To assess the effectiveness of the case studies and to compare outcomes between PBCSs and non-PBCSs, pre- and post-exercise questionnaires were administered during each case study implementation. These questions focused on examining both the content of the case study and student interest. In addition, participant demographic data (e.g., GPA) were used to reduce confounding, and only those participants who were completing the course for the first time were included in the research.

**Implementation of PBCSs at UT.** Place-based case studies and non-PBCS exercises were implemented and evaluated in nearly identical fashion at UT as they were at UC. Notable differences included the following: a) the research was conducted over two semesters (fall 2015 and spring 2016, using the non-PBCS and PBCS curricula, respectively) due to scheduling constraints; b) case studies were implemented within an 80-minute lecture period; c) 50 to 100 students were enrolled per semester; and d) PBCSs were structured around topics local to the El Paso border region. Details related to the timeline for implementation of PBCS and non-PBCS exercises within the introductory cell and molecular biology course at UT are described in Table 1.

**Content diagnostics.** In order to assess the impact of the case study exercises on students’ content knowledge, as related to material presented in the case studies (either non-PBCS or PBCS), a multiple-choice quiz was developed and administered in pre-/post-exercise format. Items contained on the diagnostic were created by a third researcher with expertise in the areas of bioeducation and biological sciences so as to reduce instructor bias. Questions were adapted from existing instructor test bank items accompanying the Brooker et al. (17) Biology (3rd ed.) text, which was utilized by students at both UC and UT (Appendix 2). Participants in both the non-PBCS and PBCS treatment conditions at each institution received identical versions of the content diagnostic for each case study exercise. Responses at UC were collected via Clickers, whereas responses at UT were collected in paper-and-pencil format.

**Affective questionnaire.** In addition to examining the potential role of the non-PBCSs and PBCSs in mediating students’ development of content knowledge in the discipline, we sought to assess the extent to which case study exercises influenced students’ attitudes about the relevance of science to their community and to investigate students’ perceptions of the case study curriculum itself. Participants were therefore required to complete six additional affective items (Appendix 2), which were embedded within the post-intervention content diagnostic. Responses at UC were collected via Clickers, whereas responses at UT were collected in paper-and-pencil format.

**Quantitative analyses.** Student responses on the content diagnostics were analyzed using a series of paired t-test procedures to assess for pre-/post-intervention shifts in performance, and Cohen’s d values were calculated as a measure of effect size. Between-treatment (non-PBCS vs. PBCS) comparisons were likewise conducted using analysis of covariance (ANCOVA) procedures, controlling for participant gender, GPA, diagnostic pre-score, first generation status, and race/ethnicity. Participant responses on affective items were analyzed using a series of paired t-tests with Bonferroni correction to determine between-treatment differences post-intervention.

**PBCS and non-PBCS exercises led to increases in students’ content knowledge.** In order to determine the effect of PBCSs and non-PBCSs on students’ content knowledge as it pertained to case study topics (SLO #4), a series of paired t-tests were performed. Results at UT identified statistically significant gains in performance across both case study topics (cellular respiration and mitosis/meiosis) for both cohorts (Fig. 1 A and B). In contrast, statistically significant gains in performance were observed at UC across both exercises (scientific method and macromolecules) only for individuals in the PBCS treatment condition (Fig. 1 C and D). Cohen’s d effect sizes were, on average, moderate to large, ranging from 0.023 to 1.026.

Analysis of covariance (ANCOVA) procedures further confirmed no significant main effect for case study type (PCBS vs. non-PBCS) at UT (p ≥ 0.104 for all procedures) after controlling for participant gender, GPA, pre-exercise diagnostic performance, first-generation status, and race/ethnicity. Analysis of UC data confirmed, in contrast, a significant main effect for case study type (p < 0.040 for all procedures), with exposure to PBCSs resulting in greater learning gains than exposure to non-PBCSs after controlling for the aforementioned potential confounding factors. Collectively, these data demonstrate that case studies are an effective approach for advancing student content knowledge in the field, whether they are traditional or place-based in nature.

**Students engaged in PBCSs exhibit greater understanding of the role of science in their community than students engaged in non-PBCS exercises.** In
addition to determining the impact of PBCS vs. non-PBCS exercises on students’ comprehension of course content, we sought to evaluate the extent to which each case study type influenced students’ perceptions of the role of science within their community and their attitudes about the intervention itself. Paired t-tests with Bonferroni correction were conducted to examine shifts in students’ self-reported responses to six affective questions presented on the post-intervention surveys accompanying each case study exercise (Appendix 2). Results obtained at UT indicated a statistically significant between-cohort difference in students’ beliefs regarding the extent to which the case studies provided them with a better understanding of the role of science (and scientific tools) in their community, with individuals in the PBCS cohort more strongly agreeing with select affective statements than their non-PBCS peers (Fig. 2 A and B).

In contrast, significant differences in student responses at UC were observed only for one item, with individuals in the PBCS cohort more strongly reporting that the case study exercise on macromolecules increased their understanding of the topic relative to individuals in the non-PBCS cohort (Fig. 2 C and D). Given enrollment data at the two universities, we believe that one potential explanation for these inter-institutional differences is the variation in the percentage of students from the community and state in which the universities are located. At UC, approximately 20% of students are not from the state in which the university resides, whereas at UT, almost all students are from the local area.

From an instructional standpoint, we therefore implore faculty to carefully consider the student demographic at their institution (and, if different, in their course) both when determining whether to incorporate PBCSs into their curriculum and when constructing the topical narrative around which the case study is centered. In instances where the majority of students reside outside of the state/local context in which the PBCS is situated, it would be feasible, for example, to select a topic that will likely be of universal relevance to course participants (e.g., chemistry and global warming). In these instances, pre-/post-intervention assessments similar to those included herein could be used to determine the efficacy of case study implementation.

Possible modifications

Non-PBCS exercises can readily be identified via the search function present on the NCCSTS website (http://sciencecases.lib.buffalo.edu/cs/collection/). While developing PBCS exercises requires an investment of time and resources on the part of the instructor, we found that novel activities could be successfully created, on average, in two hours. Furthermore, few material resources were
FIGURE 2. UT students who participated in PBCSs report greater understanding of how scientific advancements and research could impact their community relative to a non-PBCS comparison group (A and B). In contrast, both PBCS and non-PBCS students at UC found the case-based exercises to be important in establishing connections between real-world science and their own communities (C and D). *p < 0.008. PBCS = place-based case study.
required to create the PBCSs, enhancing the accessibility of this approach for instructors across institutional contexts. Importantly, while we developed exercises aligned with the content in our introductory cell and molecular biology courses, faculty could easily modify any case study to make it relevant to the issues facing their local community. Such exercises could likewise be adapted for use in multiple course contexts (e.g., majors vs. non-majors; lower-division vs. upper-division) within STEM and non-STEM disciplines.

CONCLUSIONS

Prior research indicates that adopting case study approaches within classroom contexts in the biological sciences can serve to advance students’ conceptual understanding of core topics introduced within the curriculum as well as to promote positive shifts in individuals’ affect toward the discipline (2, 18). While such curricula emphasize connections between course content and the real world, these connections are often presented through a generic lens; in other words, the real-world examples are not immediately connected to the community in which the student resides. In an effort to increase students’ content knowledge and understanding of the relevance of science in their everyday lives, we reported herein on the development of PBCSs as a time- and resource-efficient mechanism to achieve the aforementioned objectives. Data indicated a statistically significant increase in content knowledge in both the PBCS and non-PBCS cohorts (to varying degrees) over the course of the intervention. These data highlight the importance of case studies as an active-learning technique amenable to reporting that the case studies enhanced their understanding of the relevance of science in their everyday lives, we reported herein on the development of PBCSs as a time- and resource-efficient mechanism to achieve the aforementioned objectives. Data indicated a statistically significant increase in content knowledge in both the PBCS and non-PBCS cohorts (to varying degrees) over the course of the intervention. These data highlight the importance of case studies as an active-learning technique amenable to promoting student learning in the introductory biology classroom (2, 18–20).

Furthermore, affective data indicated that students within the PBCS cohort at UT were statistically more likely to report that the case studies enhanced their understanding of how scientific advancements could impact the community in which they lived than those individuals in the non-PBCS cohorts. Students within the PBCS cohort likewise strongly agreed that the case study allowed them to better understand how they could use various sources of information to draw conclusions about topics of real-world importance. Collectively, these findings corroborate earlier empirical evidence citing the importance of case studies in promoting student interest in the sciences and their perceptions regarding the nature of science (1–3). In addition, our findings support the notion that, in contrast to most placed-based curricula (12–14), PBCSs offer a scalable, classroom-based approach to engage students in relevant, practical experiences that are of direct interest to them and, ideally, the broader scientific community.

SUPPLEMENTAL MATERIALS

Appendix 1. Case study exercises
Appendix 2. Sample intervention questionnaire

ACKNOWLEDGMENTS

We wish to thank Dr. Lynsay Marsan for her assistance in developing assessment items for the case study exercises employed at both UC and UT. Research conducted at UT was supported via an internal Scholarship of Teaching and Learning (SoTL) grant awarded by The University of Texas at El Paso’s Center for Excellence in Teaching and Learning (UTEP CETaL). The authors declare that there are no conflicts of interest. This research was approved by The University of Texas at El Paso’s Institutional Review Board (IRB) under protocol #842657.

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