Because of institutional resource constraints, dual-listed courses will persist in most universities’ programs of study. The pedagogical differences between undergraduate and graduate STEM student groups and the underlying distinction in intellectual development levels between the two student groups complicate the inclusion of undergraduates in dual-listed courses. Active learning techniques are a possible remedy to the hardships undergraduate students experience in graduate-level courses. Through an analysis of both undergraduate and graduate student experiences while enrolled in a dual-listed course, the authors implemented a variety of learning techniques used to complement the learning of both student groups and enhance deep discussion. This manuscript provides readers with details concerning the implementation of four active learning techniques used to help undergraduate students critically discuss primary literature. On the basis of undergraduate and graduate student perceptions and experiences, the authors suggest techniques to enhance the quality of dual-listed courses and provide an outline for easing the transition of these techniques into any science classroom.

Science, technology, engineering, and mathematics (STEM) education is now responsible for cultivating 21st-century scientists to be analytical and creative in developing practical solutions to current and future societal problems. Increasingly complex and diverse challenges require knowledge of concepts within disciplines that traditionally are not presented in undergraduate science education, including human values, attitudes, and behavior and the interrelationships of global social, political, environmental, and economic systems (Geppert, 1995; Splitt, 2002). Consequently, many undergraduate students are seeking graduate education to gain the necessary skills to meet these challenges. Undergraduate students are not waiting until graduate school to enroll in graduate-level courses either, with many seeking preparation during their undergraduate study through graduate course enrollment. Universities are accommodating this demand by offering dual-listed courses—courses that are available to both undergraduate and graduate students and taught by a single instructor with a common meeting schedule.

Dual-listed courses will persist, in part because of institutional resource constraints, even though each level of education has a different emphasis and mission. Undergraduate STEM programs promote development of reasoning skills and proficiency in problem definition, problem solving, and quantitative expertise. Although alternative teaching techniques have been suggested to improve instruction, routine learning and assessment avenues in undergraduate education are traditional lectures, practice problems, and conventional exams (Freeman et al., 2014). Graduate study, however, provides opportunities to contemplate issues, think reflectively, and engage with theory in ways that notably differ from those generally permitted by traditional undergraduate courses of study. These pedagogical differences between undergraduate and graduate STEM student groups are a reflection of the underlying distinction in intellectual development levels between the two student groups (Barna & Haws, 1982; Luthy et al., 1992; Perry, 1970, 1981); subsequently, this complicates the inclusion of undergraduates in dual-listed courses. In our experience, this variation in epistemic development contributes to possible difficulties that undergraduate students may have while learning to communicate about complex issues in the same way as graduate students, particularly in a course in which students are asked about topics rather than told about topics (Freeman et al., 2014). Active learning techniques are a possible remedy to the hardships that undergraduate
students experience in graduate-level discussions (Bozorgmanesh, Sadighi, & Nazarpour, 2011; Driscoll, 2005; Ellington, Fowlie, & Gordon, 2013; Freeman et al., 2014). The ultimate goal of an active learning technique is to limit the quantity of students who simply watch, listen, take notes, and quickly exit the lecture session and thereby encourage student-centered learning (Felder & Brent, 2009; Prince, 2004). Discussions, collaborative and cooperative learning experiences, and active learning techniques, although often mentioned separately and differing in some ways, are actually more similar than different (Slavich & Zimbardo, 2012); all can be categorized as settings that firmly support student-centered instruction (Prince, 2004). Cooperative and active learning in STEM disciplines has been shown to consistently have positive academic impacts on students (Springer, Stanne, & Donovan, 1999; Freeman et al., 2014). Collaboration provides an environment that promotes interpersonal skills, positive student attitudes, and material retention, and active learning strategies, such as role play, create an environment conducive to teaching students how to be lifelong learners in the field (Prince, 2004). Furthermore, discussions have been shown to increase student learning (Hollander, 2002), and students are more likely to retain information if it is placed in a larger context, rather than only hearing the information in lecture (Hollander, 2002; McKeachie & Svinicki, 2011). Because discussion requires critical thinking and logical evaluation of others’ perspectives, it should follow only after material has been sufficiently covered through other instructional avenues (McKeachie & Svinicki, 2011). Therefore, active learning techniques can be implemented to enhance discussions through increased student engagement (Freeman et al., 2014).

This differentiation in instruction appeals to students’ needs, abilities, interests, and learning styles (Bozorgmanesh et al., 2011; Brown Wright, 2011; Kilic, 2010; Slavich & Zimbardo, 2012) and enhances student learning by allowing them to experience the practical side of the content (Driscoll, 2005).

The objective of the project described in this article was to engage undergraduate students enrolled in a graduate-level course in discussion through various active learning techniques. The dual-listed course was designed to provide learning opportunities for both undergraduate and graduate students. Many of the topics and instructional techniques originally included in the course, however, heavily favored graduate student learning. Information on how active learning techniques were implemented, an evaluation of what worked and did not work, and suggestions for modifying these techniques are provided in this article.

**Context and Description**

**Course design and topics**

This course was very different from traditional environmental science courses, focusing on the scientific, technological, philosophical, and social issues surrounding the energy-water nexus (Figure 1). The course was open to graduate students at the masters and doctoral level and to senior-level undergraduate students. The classroom course delivery was equally divided between lecture and discussion, and the course used informal assessments of students’ participation, as is common for discussion-based courses. The first class of each week was lecture based and taught by the course instructor, whereas the second class was discussion based, with the discussion material drawn from the weekly lecture topic and two to three peer-reviewed articles. Both undergraduate and graduate students were required to participate in instructor-led Monday lectures; graduate students, however, were held responsible for the additional task of preparing for and facilitating Wednesday discussions. Grades for both student groups were based on participation in weekly lectures and discussions and completion of a research project and paper; no traditional exams were given. Both undergraduate and graduate students were required to participate at least three times during each Wednesday discussion.

This was the second time that the course had been offered at the graduate level, but it was the first time that the course was a requirement for a particular undergraduate minor. After the initial week, the instructor and graduate students recognized that changes in the way that the course was previously taught were needed to accommodate the undergraduate students. Therefore, Wednesday discussions were adjusted to incorporate active learning techniques in an effort to increase undergraduate students’ engagement, attitudes, and ability to successfully participate in a graduate-level discussion (Slavich & Zimbardo, 2012).

**Active learning techniques**

The active learning techniques used to enhance students’ discussions were role play, game, debate, and small group. Although each active learning technique was original, these techniques are generally variations of one another. Activities begin with topic and activity introductions by the discussion leaders; relevant materials are also distributed to students. Discussion leaders then form the student groups and establish group roles. Because a new discussion topic is presented each week, groups are randomly assembled by the discussion leaders on a weekly basis. Time is given for individuals to reflect on their assigned positions, draw on knowledge gained from as-
signed primary literature and personal experiences, formulate ideas and responses, and record their thoughts. Groups are given time to discuss their roles and thoughts among themselves. Discussion leaders then bring groups together so that the class can discuss group analyses. Activities conclude with a recap from discussion leaders and closing thoughts. A general framework for implementing any of the permutations provides readers an outline to facilitate installation into their own classrooms (Figure 2). Prior to implementing each technique, content-specific learning outcomes should be established, questions should be aligned with these outcomes, and questions and thoughts should be prepared to guide discussion should discussion veer from the preestablished learning outcomes. Also, strategies should be embedded within the activity to provide student groups who are often reluctant to participate with the opportunity for involvement at their own pace (University of the Sciences, 2014).

**Role play**

Role play was one of the first techniques implemented, specifically during the discussion on water for energy (transportation). By experiencing the perspectives of four different regional stakeholders (i.e., a farmer, a real estate developer, a barge company owner, and an environmental activist), students were able to build on their knowledge of the topic by working to understand the experiences they were presented (Driscoll, 2005). Differentiating instruction by combining role-play activities with small group discussion settings is essential for students to gain a deeper understanding of key concepts (Bozorgmanesh et al., 2011). The role-play activity worked well with small group instruction and provided an activity for learners who perform best by doing and remaining active.

**Game**

The game technique was the second technique used, specifically

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**FIGURE 1**

Course topic description and assigned literature.

<table>
<thead>
<tr>
<th>Course topic</th>
<th>Course topic description</th>
<th>Assigned literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water resources</td>
<td>Difficulties in meeting the demand for freshwater resources, pursuant to global population and economic growth; challenges in planning for future demands under the uncertainty of a changing climate.</td>
<td>Falkenmark, 2008; Gleick &amp; Palaniappan, 2010; Oki &amp; Kanae, 2006</td>
</tr>
<tr>
<td>Energy resources</td>
<td>Peak oil; alternative energy resources and their implementation challenges.</td>
<td>Lewis, 2007; Owens &amp; Driffill, 2008; Tsoskounoglou et al., 2008</td>
</tr>
<tr>
<td>Water for energy (electricity)</td>
<td>Water consumption, water withdrawal, and the magnitude of each type by thermoelectric power industry.</td>
<td>Feeley et al., 2008; Sovacool &amp; Sovacool, 2009</td>
</tr>
<tr>
<td>Water for energy (transportation)</td>
<td>Patterns in U.S. fuel consumption for transportation; water requirements of various alternative transportation fuels and propulsion technologies.</td>
<td>Fargione et al., 2008; Harto et al., 2010; King &amp; Webber, 2008</td>
</tr>
<tr>
<td>Energy for water</td>
<td>Electrical energy requirements to treat and distribute publicly supplied water at a national and global scale; effects of water source and location on this electrical requirement.</td>
<td>Lofman et al., 2002; Stokes &amp; Horvath, 2009; Zilberman et al., 2008</td>
</tr>
<tr>
<td>Climate change</td>
<td>Effects of global warming on energy consumption; mechanisms of climate impacts on various energy supplies, specifically alteration of water availability.</td>
<td>Anderson &amp; Bows, 2011; Fung et al., 2011; Markoff &amp; Cullen, 2008</td>
</tr>
<tr>
<td>Water for energy (agriculture and food)</td>
<td>Intricate coupling of social and economic issues within an unpredictable global food system, specifically world population growth; solutions to address the future quality of life.</td>
<td>Godfray et al., 2010; Pimentel et al., 2010; Walker, 2010</td>
</tr>
<tr>
<td>Virtual water (water scarcity)</td>
<td>Social and economic consequences with using virtual water (i.e., water embedded in commodities) to address global water deficits; water footprints of various human diets.</td>
<td>D’Odorico et al., 2010; Hoekstra &amp; Hung, 2005; Rijsberman, 2006</td>
</tr>
<tr>
<td>CO₂ sequestration and shale gas development</td>
<td>Technological potential and implementation barriers to carbon capture and sequestration; plausible environmental impacts from carbon capture and sequestration and shale gas development.</td>
<td>Bachu, 2008; Kargbo et al., 2010; Rubin et al., 2007</td>
</tr>
</tbody>
</table>
during the discussion on energy for water. Four groups of three to four students represented four sectors (agriculture, industry, thermoelectric power, and public water supply). The goal of the exercise was to meet the sectors’ stated needs by purchasing and trading water, as a commodity, in the most economically efficient way possible under constraints of high-energy costs. In addition to enhancing students’ communication, interpersonal, and social skills, games are an excellent instructional strategy that provides students the opportunity to simulate real-life events and elevate their political and social awareness (Ellington et al., 2013). The activity first allowed students to analyze independently the situation; small-group collaboration followed, and the activity concluded with a whole-group discussion. Similar to the benefits provided by the role-play activity, students were able to experience firsthand the difficulties and constraints each sector experiences and learn through the challenges presented to them.

**Debate**

The debate technique was used during the discussion on virtual water (water scarcity). Two groups of seven to nine students were presented statements derived from issues included in the literature readings and assigned mutually exclusive viewpoints to defend (i.e., agree or disagree) regardless of personal opinion. Students had to formulate both their own arguments and counterarguments for each statement. Students were provided a viewpoint to defend, in hopes of reducing students’ fears of having a personal viewpoint that differed from the group. Each student group discussed their thoughts and developed a strategy for debating opposing groups. Controversial issues within scientific disciplines containing dis-

**FIGURE 2**

General procedure for implementing an active learning technique.

**Example learning objectives**

1. Students will think critically about the topic, identifying concerns and circumstances, and develop the advantages and disadvantages of each possible fuel.
2. Students will consider how individual stakeholder’s needs are both similar and different from one another and assess the interrelationships between these various sectors.
3. Students will experience firsthand the emotions, fiscal responsibility, and peer influence associated with discussion topics.
4. Students will explore topics from viewpoints other than their own (e.g., governmental perspective, private citizen perspective, entrepreneurial perspective, etc.) and experience the influence each stakeholder has during the decision-making process.
5. The learning technique will create an environment that promotes interaction, critical thinking, interpersonal skills, positive student attitudes, and material retention.

**Time allocation**

<table>
<thead>
<tr>
<th>Duration of activity</th>
<th>Time balance</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 minutes</td>
<td>70 minutes</td>
<td>Introduction; hand out materials</td>
</tr>
<tr>
<td>5 minutes</td>
<td>65 minutes</td>
<td>Form groups; establish individual roles</td>
</tr>
<tr>
<td>20 minutes</td>
<td>45 minutes</td>
<td>Individual reflection</td>
</tr>
<tr>
<td>20 minutes</td>
<td>25 minutes</td>
<td>Intragroup discussion</td>
</tr>
<tr>
<td>25 minutes</td>
<td>0 minutes</td>
<td>Whole-group discussion and recap</td>
</tr>
</tbody>
</table>

**Implementing an active learning technique—role play**

1. Divide students into groups of three to four.
2. Hand out and go over the role-play instructions and assumptions; assign each group a specific stakeholder group.
3. Allow 20 minutes for students to individually reflect on their group assignment and record their thoughts on paper.
4. Allow 20 minutes for groups to internally analyze the alternative fuel sources and choose one to endorse for inclusion in federal policy.
   a. Groups should analyze these alternative fuel sources from the perspective of their assigned stakeholder group; therefore, their alternative fuel choice should support the interests of their assigned stakeholder.
   b. However, groups should be careful to consider the effect their choices will have on the environment, climate, society, and other stakeholder groups.
5. At the end of the allotted time for intragroup analysis, bring all of the groups back together for a class discussion.
6. One person from each stakeholder group will report the group’s recommendation and the rationale for their selection, without interruption.
   a. Students and discussion leaders will then be allowed to ask the stakeholder groups questions about their choices and rationales, to which the stakeholder groups may respond. Hopefully, a natural exchange between all students will ensue.
   b. Ask students, especially those reticent to participate, to read their written responses. Ask these students if, after hearing the group discussion, their prerecorded opinion(s) have changed.
   c. Discussion questions are meant to help guide the open discussion that follows all stakeholder groups’ recommendations.
7. The discussion leaders will provide a recap of the discussion and entertain closing thoughts during the last 10 minutes of class.
tinctive and varying opinions often lend themselves to a debate setting. P rearrangement of debates reduces student focus on personal opinions and allows students to see the complexities associated with the content’s real-life practice.

Small group
The small-group technique was used during the discussion on carbon dioxide sequestration and shale gas development. Three groups of three to five students internally discussed a series of counterarguments to other groups’ positions, regardless of personal opinion. Groups were given 15–20 minutes to confer internally before presenting their case. After 30 minutes of oral group presentations, students coalesced into one large group for a discussion. This technique established a classroom environment conducive to collaborative learning and allowed students more of an opportunity to focus on the quality of their response rather than worrying about their personal opinion. Independently, implementation of small group activities into science classrooms elevates students’ ability to fine-tune their oral communication skills in science. More important, the small-group teaching strategy is interrelated with all the aforementioned active learning techniques and is a technique critical to the success of all other active learning strategies.

Assessment
General feedback about the course was gathered through an anonymous, end-of-course evaluation that contained basic questions comparing the course to other courses at the university and other salient aspects of the course. These were given as a Likert scale on which students rated a variety of statements (1 = strongly disagree, 3 = no opinion, and 5 = strongly agree). Students were also asked several different specific questions about the types of group-discussion techniques used in the course, including how much they enjoyed each technique, how the technique enhanced their learning, and how much they learned from each. The Likert scale for questions pertaining to enjoyment allowed students to rate each type of technique from 1 (not enjoyable) to 5 (very enjoyable). For the rankings of how each style enhanced student learning, the Likert scale ranged from 1 (enhanced learning very little) to 5 (enhanced learning a lot). All 14 undergraduate students completed the survey. The active learning techniques were also assessed on the basis of the graduate students’ observations and reflections.

Undergraduate students’ perceptions of what worked
Students indicated that they focused on listening and responding to others’ comments during the Wednesday discussions (3.93 on average) but only occasionally read additional material to enhance their understanding of the required readings (2.54 on average). They indicated that the course was slightly more difficult than their other courses at the university, but that reading literature rather than a textbook increased their learning in the course (Table 1). Undergraduate students perceived this course as any other—slightly difficult, but the format allowed them to learn the material successfully. There were some interesting trends among the undergraduate students, who found the small-group discussions to be the most enjoyable and the best at enhancing learning, but although they found the game enjoyable, they did not feel it enhanced their understanding of the material (Table 2). Note that they found discussions with no active learning technique to be the least enjoyable and, on average, to not enhance learning.

Graduate students’ perceptions on what did and did not work
Creation and guidance for implementation of each active learning technique required a sizeable time commitment from the graduate student discussion leaders. Selecting relevant primary literature outside of those articles assigned by the instructor also required a large time investment. For each active learning technique implemented, graduate student leaders spent approximately 1 week reading assigned literature, researching additional literature relevant to the topic and active learning technique, writing guiding discussion questions, outlining the activity, and creating required materials. This was particularly discouraging, as it was obvious that undergraduate students rarely read additional material to enhance their understanding of the required readings.

The degree of participation by any one undergraduate student varied from meeting to meeting, although 3 of the 14 students made considerable contributions on a weekly basis. The instructor formally evaluated participation on the basis of the evidence that the assigned papers had been read carefully, and serious participation in discussion accounted for 40% of the course grade. A written research paper analyzing water and energy resources for an assigned U.S. state accounted for the remaining 60% of the course grade. All of the weekly discussion topics were to be included, at some level, into this article.

Graduate students evaluated participation also on the overall quality of the discussion. At times, discussions lagged, and graduate student leaders had to pry information out of many of the students using prepared questions. Responses on some topics lacked depth; students provided rich contextual background information, but they avoided the details of techniques and experimental procedures.
Discussion in Dual-Listed Courses

and shied away from interpreting results. This is consistent with the findings of Janick-Buckner (1997), where similar observations were made when grades were based solely on class participation instead of jointly with a written assignment. Similar to the experience of Prud’homme-Généreux (2013), students also lacked the skill of posing a series of insightful questions to each other to drive a discussion toward a goal; instead, they relied on graduate student discussion leaders to steer conversation.

On the basis of the anonymous evaluations, the group discussion techniques that undergraduate students responded best to were the debate and small groups. There are some factors other than the activities themselves that may have contributed to the success of these techniques. These discussions occurred toward the end of the semester—in fact, they were the last two discussions; thus, students were acclimated to interacting with each other and graduate students and participating in group discussions. Graduate students had more experience with implementing learning strategies and were better able to align discussion material with these techniques. Undergraduate students may have responded well to these techniques because both complemented their overall intellectual development level. Predefined dichotomous positions on various issues were assigned to groups, leading to a more intimate understanding of the issues and increased confidence for executing the technique.

Although active learning techniques are aimed at enhancing students’ learning, some inherent factors exist that may hinder discussion, which instructors must consider when preparing for each activity. First, dual-listed courses inherit varying levels of intellectual development, which may impede deep discussion. Second, low confidence may stifle discussion. Low confidence may stem from inexperience with reading peer-reviewed literature to learn course information and from a weak knowledge base of course topics. Discussions revealed that all of the students had difficulties comprehending certain aspects of an article. Although this impeded discussion at times, it was important for students to learn that reading literature was a shared challenge—even for those with more research experience or an advanced degree. Third, ambiguity of discussion expectations and inexperience with discussion mechanics may hinder dialogue, especially in the beginning. Consequently, active learning techniques may better facilitate discussions based on primary literature, when students are given written assignments to guide their reading of journal articles that will be discussed (Glazer, 2000; Janick-Buckner, 1997). Fourth, students from more reserved cultures and students who are introverted by nature may not do well in discussion groups, even though they may have a lot to offer to the discussion. Written assignments may also offer an avenue for participation for these students. Students can share their written thoughts and analyses, which they have prepared ahead of time, during both intragroup and whole group discussions. Alternatively, students may be given class time for individual reflection and written discussion prior to group dis-

<table>
<thead>
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<th>TABLE 1</th>
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<tr>
<td><strong>Student ratings of course aspects for Wednesday discussions (N = 14).</strong></td>
</tr>
<tr>
<td>Aspect of course</td>
</tr>
<tr>
<td>Difficulty compared with other courses</td>
</tr>
<tr>
<td>Outspoken students inhibiting participation</td>
</tr>
<tr>
<td>Variety of discussion styles enhancing learning</td>
</tr>
<tr>
<td>Inclined to contribute based on topic</td>
</tr>
<tr>
<td>Material covered best through discussion</td>
</tr>
<tr>
<td>Learned from reading literature instead of textbook</td>
</tr>
<tr>
<td>Graduate students encouraged participation</td>
</tr>
<tr>
<td>Participation enhanced by tables in circle</td>
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<table>
<thead>
<tr>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student ratings of active learning techniques—enjoyment and learning (N = 14).</strong></td>
</tr>
<tr>
<td>Active learning technique</td>
</tr>
<tr>
<td>Small group</td>
</tr>
<tr>
<td>Role play</td>
</tr>
<tr>
<td>Game</td>
</tr>
<tr>
<td>Class debate</td>
</tr>
<tr>
<td>None</td>
</tr>
</tbody>
</table>
cussion. Written discussions encourage different people to participate, providing timid students and those who experience language barriers an opportunity to record thoughts and arguments at their own pace (University of the Sciences, 2014). Minimizing or eliminating these hindrances may facilitate successful discussion and enhance the overall implementation of instructors’ active learning techniques.

Conclusion
Dual-listed courses will continue to exist in higher education because of resource limitations. Consequently, instructors of such courses will inherit the challenge of accommodating various levels of intellectual development and determining what teaching strategies will accommodate both student groups. In our experience, active learning techniques may aid in improving discussion in these types of course environments. In hindsight, students of all cultures may be better able to take advantage of such approaches and to critically read and discuss primary literature when written assignments are used to guide their reading. Applications of active learning techniques can not only address the gap between differing levels of students, but also serve as a complement to student engagement in any science course design.

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