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Using a Deliberation of Energy Policy as an Educational Tool in a Nonmajors Chemistry Course

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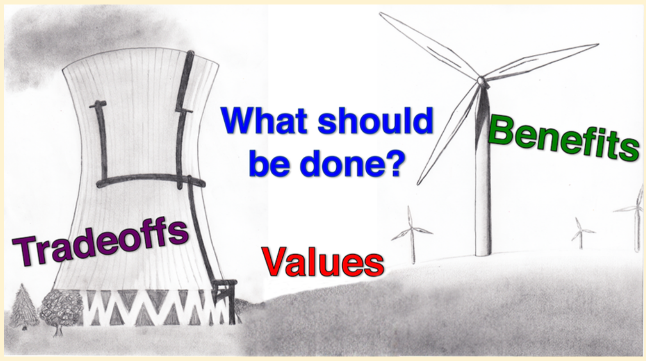
S *Supporting Information*

ABSTRACT: A central goal of nonmajors chemistry courses is to instill within students the sense that chemistry does not occur in a vacuum but rather permeates everyday life. To encourage students to consider chemistry within the broader context of society and public policy, a week-long module in a survey course for nonmajors was designed to connect scientific principles and energy policy. This module featured a deliberative discussion to facilitate students' evaluation and consideration of multiple viewpoints, rigorously examining different perspectives, trade-offs, benefits, and values represented in multiple alternatives. Our results demonstrate that this approach was highly impactful, resulting in several significant positive outcomes, including a deeper awareness of the connection between chemistry and other disciplines, an increased level of understanding and confidence in their knowledge, and a greater sense of urgency regarding energy policy.



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A common goal of general education science courses is to enable students majoring in other subjects to better appreciate and understand the scientific aspects of public issues such as climate change, regulation in the food and drug industry, health care, and energy consumption.[1] Significant public issues facing our society require knowledge from multiple fields, and those who have careers outside science fields are impacted by scientific public policy issues in their respective positions as voters, community members, business owners, government leaders, and so on.[2] Among biologists, there has recently been a strong call to action based on the need for all students to "graduate with a basic level of biological literacy in order to participate as informed citizens and thrive in the modern world."[1] However, data in a 2015 report confirm previous studies' findings that there are significant differences in the way that the public and scientists view scientific evidence, science issues, and the role of science and technology in society.[3,4] This gap between public perception, attitudes, understanding of scientific research,[5] and recognizing the need to seek scientific information during decision-making in social issues and policies represents a significant challenge that requires immediate action, beginning through science education.[1]

As undergraduate educators, our goal is to develop science-literate citizens who will be prepared to confront technology-related issues, process relevant information, and take action to address public concerns. Recently, some pedagogical efforts have focused on making concrete connections between the chemistry content discussed in the classroom and real-world issues.[6] This can take the form of an adapted approach to the course itself, as in the *Chemistry in Context* textbook developed by the American Chemical Society,[7] or the incorporation of activities based on popular press news articles and students' daily lives,[8] through online projects[9] or oral presentations.[10] Others have designed entire courses focused on the fundamental chemistry involved in one application, such as energy.[11] We were interested in incorporating a shorter, interactive module to highlight a socioscientific issue within a larger survey of chemistry topics. Wabash College offers a survey course in chemistry for nonmajors that has specific course goals, including teaching students to apply scientific thought toward problem-solving by gathering, analyzing, and evaluating evidence and encouraging students to think about

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how they consume and communicate scientific information. Students in this course learn fundamental chemistry concepts and see their application to real-world problems. We want each student to incorporate scientific and technical information in decision-making,[12,13] but many problems require input from a variety of stakeholders in the community. Within this context, deliberation can be used as a pedagogical method to encourage critical thinking, communication about science, multilateral communication, and collaborative problem-solving.[14,15] Public deliberation is a process where small groups of community members gather to work through understanding a problem and rigorously consider multiple approaches to address that problem.[16,17] In so doing, participants—often led by a trained facilitator—consider information relevant to the problem, possible actions, benefits, and trade-offs within the multiple approaches, all the while encouraging the sharing of information and opinion, the development of new ideas, and the process of coming to a more public, inclusive decision.[18,19]

When used in a classroom setting, public deliberation can serve to inform students about scientific policy issues and encourage habits of active civic involvement.[14,20] Deliberation enables the public's capacity to offer knowledge and experience relevant to policy debates. While we are proposing a classroom-based deliberation for public education purposes, this approach has been used on a much larger scale for public deliberations about energy production and policy in the United Kingdom[21,22] and Finland.[23] Scholars have suggested that deliberative pedagogy, the process of integrating deliberative decision-making with teaching and learning, is an innovative teaching strategy for encouraging the habits of citizenship in students and prompting civic action.[24,25]

Our goal was to develop and investigate the use of a deliberation module in three 50 minute periods in a single-semester chemistry course for novices. Specifically, this study sought to evaluate the following questions: Does a deliberation help students make connections between fundamental chemistry concepts and social and/or economic policies? Does a deliberation help students internalize or utilize chemical knowledge? Does engaging in deliberation increase student belief in the urgency of the public problem?

■ METHOD

The activity described here was implemented in the fall semester of 2014 at Wabash College in a course entitled Chemistry 101: Survey of Chemistry. This course is intended for nonmajors and highlights fundamental topics throughout the field of chemistry as well as the scientific approach to problem-solving. There were a total of 52 students in the course (23 seniors, 19 juniors, 6 sophomores, and 4 freshmen), and because Wabash College is a single-sex institution, all of the participants were male. All of the students in the course participated in aspects of the deliberation, with 43 students (20 seniors, 16 juniors, 4 sophomores, and 3 freshmen) completing both the pre- and postactivity surveys described here. All of the research was approved by the Wabash College Institutional Review Board, and all of the participants gave informed consent.

This activity took place in the 11th week of the semester, after students had been introduced to fundamental concepts and problem-solving related to the energy of chemical reactions, including the combustion of common fuels like propane, coal, biodiesel, and ethanol. In that unit, we asked students to compare the energy produced for these fuels per gram used, per dollar cost, and per mole of carbon dioxide generated to initiate a discussion of fuel efficiency from several perspectives. Immediately prior to the deliberation, we also spent time investigating nuclear reactions and nuclear energy from a chemical perspective. With this background, we entered a week-long deliberation on energy policy.

The Deliberation Module

The first day of the activity consisted of a 50 minute interactive lecture to frame the issue of energy policy and connect it to previously covered content. In addition to a brief review of the chemistry behind hydrocarbon-based and nuclear fuels that was introduced earlier in the course, there was a discussion of the energy production process that occurs with different forms of nonrenewable and renewable sources. To add perspective, current data about local and national energy consumption and production were presented and some comparison of energy processing infrastructure, efficiency, and health impacts were highlighted. This technical information was provided without bias and was meant to provide background information to equip students to form their own opinions about the best approach to energy policy in the subsequent deliberation.

In preparation for the deliberation, students were assigned a short reading: *A Citizens' Solutions Guide: Energy*, prepared by Public Agenda, a nonprofit, nonpartisan organization that provides tools that allow the public to navigate divisive issues.[26] This document provides key facts about energy and challenges to consider in energy policy, including economics, energy security, and environmental impact. To aid deliberation, the guide also suggests three different approaches that could be taken to design an energy policy and arguments for and against each approach. This is a key factor for our deliberation, as it gave students a framework to begin conversation.

On the second day of the activity and the first day of the deliberation, participants were randomly placed in six groups of 6−9 students along with one trained facilitator, either a professor or a fellow student who was not enrolled in the course. The facilitator's role was to pose questions to move the conversation forward in a productive manner without introducing bias, an ethic termed "passionate impartiality" because facilitators are passionate about the process of involving citizens in public conversations and problem-solving but politically impartial as they guide the process.[27] The facilitators actively encouraged all of the participants to add their voices to the deliberation, but since they were primarily focused on mediating the conversation, they did not assess individual participation. The facilitators were trained using resources from Public Agenda[26] and the Kettering Foundation,[28] both of which give guidelines on how to encourage productive deliberation. Facilitation style has been noted to be an important variant in deliberation outcomes, and training facilitators to remain moderate, rather than active and opinionated, is an important component of deliberation.[18,19]

The groups were physically separated to allow for independent deliberations without distraction or influence from other groups. There was ample time in the 50 minute class period to introduce the activity and discuss the first two approaches in the reading. In addition to individual perspectives and opinions about these approaches, the facilitator encouraged the student participants to identify both the benefits and the trade-offs that are inherent in those choices. This draws attention to the idea that policy decisions have values at their core but that different directions might emphasize one value,

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like economic security, over another value, like long-term environmental impact.

On the third day of the activity, the same groups assembled and students discussed the third approach provided in the reading and spent significant time talking about what the ideal approach might be. Students could choose among actions presented in the guide but were also encouraged to articulate and discuss new, innovative solutions. The students were also asked to decide on the most important first steps in both short- and long-term recommendations and to elect someone to speak for the group in a larger discussion. Finally, all of the groups came together to report back the conclusions of their deliberation to see the variety of perspectives that were represented and the common themes that emerged.

Assessment

To evaluate the deliberation activity, students completed a survey before and after the week-long sequence[29] as well as an open-ended assignment that asked them to describe their own ideas of the best approach to energy policy. The predeliberation survey had demographic and Likert-scale survey questions on civic engagement, critical thinking, and chemistry knowledge, and the postdeliberation survey had many of the same Likert-scale questions with five additional open-ended qualitative questions.[30] This report will focus on the critical thinking and chemistry-based questions, but the complete text of the survey is available in the Supporting Information. The quantitative Likert-scale survey data were later analyzed using independent sample *t* tests to determine any changes in responses as well as their significance. The survey evaluation program setup did not allow for the use of a consistent, unique identifier for each participant in both the pre- and postactivity surveys, forcing assessment through a more conservative independent *t* test.

To gauge the chemistry knowledge gained through this experience, the survey included 10 energy-related statements and asked the students to read the statement and choose one of the following: "I know it is correct", "I think it is correct", "I do not know", "I think it is incorrect", or "I know it is incorrect". This allowed us to assess both the accuracy of the responses (whether they have identified the correct answer) and their confidence level (whether they "think" or "know" their answer is correct). One question about the efficiency of electricity generation was discarded because the phrasing of the question was deemed to be unclear. The other statements can be found in Table 1. Five of the nine statements were specifically stated in the first day's lecture or notes, while the other four statements could be implied from the information that was covered on that first day.

The qualitative, open-ended survey questions were analyzed by two of the authors using critical-qualitative methods[24,31] to identify substantial rhetorical themes in the postactivity survey responses. Differences in interpretation were resolved by returning to the text and analyzing specific answers, discussing context, and determining a consensus on the theme, an established method for deliberation research designed to interpret meaning from qualitative, diverse textual information; it is sometimes termed applied rhetorical criticism.[31,32] Substantial themes are included in the Supporting Information and discussed below.

■ RESULTS

After the deliberation on energy policy, students were asked five open-ended, qualitative questions that reveal some of the themes that were discussed, thought processes that students used, and suggestions generated for moving forward on the issue. These questions were (1) "Describe the issues discussed in your deliberation in 3−5 sentences."; (2) "What are 3 things you learned in this deliberation?"; (3) "What is the most challenging aspect of energy policy?"; (4) "In your opinion, what is the most important first step in addressing this issue?"; and (5) "Why is this first step the most important?" Two main themes that emerged from students were the tension between the gains in energy efficiency and the economic viability of a policy as well as the need for public involvement and willingness to participate in the solution.

When asked what they learned in the second open-ended question, students identified scientific facts, particularly about nuclear energy, the deliberation process and its benefits, and the relationships of science to values in public policy. Other answers identified the urgency and severity of the "energy crisis" as a significant challenge, with some noting the difficulty in convincing the public to change behaviors.

When asked about the most important step to address energy policy, students responded with steps to increase public awareness of the problem, encourage education, and raise support for innovations. Generally, students saw energy as a critical issue and felt that educating the public about the issue and common misconceptions will be necessary to bring about the impetus for societal change. In particular, several students identified investment in scientific research related to renewable energy or increasing energy efficiency on a broad scale as important first steps as well. Specific comments made by students in response to these open-ended questions are included in the Supporting Information.

The quantitative portions of the surveys taken before and after the deliberation activity allow us to see more detail in the self-reported learning gains our students made during this week of the course. Table 2 shows selected statements to which students responded using the Likert scale, with 1 indicating a response of "not at all" or "strongly disagree" and 5 indicating a response of "a great deal" or "strongly agree." Each statement shows some degree of statistical significance and is related to the questions initially posed in this study. First of all, students reported a significant increase in their understanding of connections between chemical concepts and their relationship

Table 1. Statements about Energy Knowledge Presented in the Pre- and Postactivity Surveys

Item No.	Statement
1	Coal power plants are Indiana's primary source of electricity.[a]
2	The burning of fossil fuels is a major contributor to atmospheric carbon dioxide levels.[b]
3	The burning of fossil fuels remains the safest form of electricity generation in terms of human health.[b]
4	The majority of electricity production in the U.S. does not use steam turbines to generate electricity.[b]
5	Nuclear and fossil fuel plants raise temperatures in lakes and rivers used for cooling.[a]
6	Burning natural gas releases less carbon dioxide than burning coal to release the same amount of energy.[b]
7	About 40% of the corn grown in the U.S. goes to ethanol production.[a]
8	Saudi Arabia is the world's largest oil producer.[a]
9	More electricity in the U.S. is produced from wind power than from biomass, geothermal, and solar combined.[a]

[a]These items were specifically stated in the Day 1 lecture. [b]These items can be implied from the Day 1 lecture.

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Table 2. Comparison of Responses for Highlighted Likert-Scale Statements on the Pre- and Postactivity Surveys

Statements for Response	Preactivity Mean[a,b]	Postactivity Mean[a,c]	Statistical Significance, p Value	t Value	Effect Size, r Value
Presently, I understand how ideas we will explore in chemistry relate to ideas I have encountered in classes outside of this subject area.	2.70	3.33	0.002	3.251	0.32
Presently, I understand how studying chemistry helps people address real-world issues.	3.13	3.76	0.002	3.248	0.33
I am knowledgeable about energy policy.	2.65	3.82	0.001	5.999	0.54
I would feel confident discussing energy policy with friends.	2.70	3.89	0.001	5.592	0.51
Energy policy is an important issue facing us.	4.11	4.42	0.043	2.054	0.21

[a]Scores on both the pre- and postactivity surveys could range from 1 ("not at all" or "strongly disagree") to 5 ("a great deal" or "strongly agree"). [b]N = 46. [c]N = 49.

Table 3. Comparative Student Confidence in Energy Knowledge Statements

	Responses by Category[b]					
	Preactivity Survey, % (N = 46)			Postactivity Survey, % (N = 49)		
Item No.[a]	Very Confident	Moderately Confident	Not Confident	Very Confident	Moderately Confident	Not Confident
1	13	43	43	47	43	10
2	33	54	13	71	22	6
3	28	48	24	61	27	12
4	11	41	48	45	35	20
5	9	48	43	45	31	24
6	9	54	37	47	37	16
7	4	70	26	51	33	16
8	11	67	22	45	49	6
9	7	46	48	22	49	29

[a]See Table 1. [b]Student responses were coded in the following manner: an answer of "I know" = "Very Confident", "I think" = "Moderately Confident", and "I don't know" = "Not Confident".

to classes in other subject areas as well as issues that people face in the real world. Second, this exercise seems to have provided students with a significant increase in their feeling of being knowledgeable about and confident in discussing energy policy. Finally, there was a small but significant increase in students' reporting about the importance of energy policy.

Student responses to the statements listed in Table 1 that relate to energy policy knowledge were also evaluated to complement their self-reported gains in confidence and knowledge. The quantitative data were examined in two ways, which are shown in Tables 3 and 4. To analyze the confidence gains students experienced, Table 3 describes student responses in both preactivity and postactivity surveys. A response of "I don't know" was rated as "Not Confident", a response that began with "I think" was rated as "Moderately Confident", and a response that began with "I know" was rated as "Very Confident". This did not take into account the accuracy of a student's answer, so even if students misidentified a true statement as false but were certain in their response, that demonstrated confidence, albeit misplaced. Comparing the pre- and postactivity results, there is a universal trend toward increased confidence in student responses for each statement in the postactivity survey. Furthermore, a χ^2 test of independence for the total measure of confidence over all nine statements compiled for each student comparing the pre- and postactivity surveys reveals a statistically significant change in the pattern of responses. This change has a $\chi^2(2)$ value of 122.47, $p < 0.0001$.

Table 4. Comparison of Correct Student Responses in Energy Knowledge Statements

	Correct Responses,[b] %	
Item No.[a]	Preactivity Survey (N = 46)	Postactivity Survey (N = 49)
1	39	78
2	85	94
3	74	78
4	24	45
5	54	67
6	50	76
7	57	82
8	24	49
9	21	35

[a]See Table 1. [b]Student responses were coded in the following manner: an answer of "I know" or "I think" that was also correct was coded as "Correct"; any other answer was coded as "Incorrect".

Alternatively, the same data can be analyzed in a different way to describe any gains in correctness of student responses to these energy policy statements, as shown in Table 4. Here, confidence in the answer is no longer taken into account. A correct response of "I think" or "I know" are both counted as "Correct", and any other answer is "Incorrect". Overall, the data show a trend toward better accuracy in the survey completed after the deliberation, with an increases in correctness ranging from 4% to 39% with a median increase of 21%. The χ^2 test of independence for the total number correct over all nine statements compiled for each student comparing the pre- and postactivity surveys reveals a statistically significant change in the pattern of responses. This change has $\chi^2(1) = 32.59$, $p < 0.0001$.

A final set of open-ended responses was collected when all of the students in the course answered the following question on the final exam: "Name three useful/interesting things that you learned in this course." In this question, which asked students to reflect on their whole 14-week experience, 31 of the 53

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students enrolled in the course mentioned the deliberation or some aspect of energy policy. Several representative responses are included in the Supporting Information.

■ DISCUSSION

The quantitative and qualitative survey results indicate that the week-long deliberation activity was a valuable addition to the introductory survey of chemistry course and had a positive effect on the learning goals for the course. In particular, the interactive energy policy deliberation was designed to help students place the chemical knowledge they were gaining in the course into a larger context, to promote learning about the chemistry of energy and electricity, and to recognize the importance of technology-related issues like energy policy.

The first area of interest, which asks whether the energy policy deliberation helps students make connections between fundamental chemical concepts and social and economic policies, is addressed with the first two survey items listed in Table 2, with both showing significant improvement over the course of the week. Before the deliberation, students reported an average response between "just a little" and "somewhat" when asked about how well they understand how chemical ideas relate to ideas they encountered in other classes. They also reported that, on average, they "somewhat" understand the connection between studying chemistry and addressing real-world issues. Particularly in a course for nonmajors, these are two key points the instructors want to convey, that chemistry and the scientific approach to problem-solving are not isolated from other areas of study and that they are useful for the general public for practical application in society. After this in-class experience, students reported significant and substantial increases in their understanding, indicating that the deliberation activity helped the instructors attain these critical goals for the course.

Assessing whether the deliberation helped students internalize or utilize scientific knowledge is more challenging. Certainly, significant gains in knowledge and confidence discussing energy policy were evident in the pre- and postactivity survey responses to the third and fourth statements presented in Table 2. This is an important factor to consider, but these are self-reported gains that reflect student feelings about the activity and their progress rather than an objective measure of their progress.

The data represented in Tables 3 and 4 and the χ^2 analyses serve to evaluate the question of student knowledge gains from a different perspective, as students identify statements about energy policy as correct or incorrect. As mentioned earlier, this assessment highlights that students are more confident in their answers across the board after the deliberation module (Table 3). There may be several reasons for this, including recent exposure to the material, but confidence in the subject is a critical factor that will contribute to student utilization of their chemical knowledge in problem-solving situations or discussions outside the classroom. Alternatively, Table 4 represents an analysis of the ability of students to correctly identify energy policy statements as true or false. There is a general and statistically significant positive trend in the overall accuracy of responses. Additionally, students answered items 2 and 3, which had to do with the contributions of fossil fuels to carbon dioxide levels and their safety for human health (Table 1), fairly accurately in the preactivity survey, so there was not much room for significant improvement. It may be troubling, though not surprising given cultural cognition research,[33] that confidence gains seem to outweigh knowledge gains, as the student responses show that when they are incorrect, they are also sometimes more certain in their incorrect position. This reflects a scenario that is not uncommon in the public sphere, and we hope that scientific education using methods like deliberation can help to combat this problem. The facilitator of a deliberation should encourage participants to acknowledge when they are not certain of information and suggest "fact-checking" to encourage more accurate information in an unimposing, nonthreatening way. Overall, this analysis indicates that a thoughtfully designed deliberation about a public problem like energy policy can, in itself, lead to student learning about related scientific facts as well as a gained confidence in their knowledge.

The third critical question posed asks whether engaging in deliberation increases student belief in the urgency of the problem. Quantitatively, the last survey question in Table 2 addresses this issue directly. While there appears to be only a small, but significant, increase in response about whether energy policy is an important issue facing us, it is important to point out that before the deliberation, students already reported that they, on average, "agree" with the statement. A significant increase toward "strongly agree" with no responses in disagreement after the deliberation activity is substantial evidence that this type of education about energy policy issues does increase student belief in urgency.

The open-ended questions reflected the same conclusions about the main points explored in the quantitative results already discussed. The qualitative thematic analysis of the five open-ended postactivity survey responses indicates that students focused on interdisciplinary tensions that place chemistry in a broader context, for example, the environmental benefit of energy-efficient practices and the economic trade-off these practices represent. They also placed high importance on scientific knowledge to help solve public problems in their responses after the deliberation. The key next steps students identified included educating others about the science behind the issue and common misconceptions as well as convincing the general public of the urgency of the problem and the need for behavioral changes. Clearly, students valued their participation in the activity and felt it was necessary for others to carefully consider the issue in a similar way in order to make progress toward a solution as a society. This interest is further reflected in their end-of-semester responses about the course as a whole.

The study described here provides significant evidence for positive learning outcomes associated with the use of this three-day module using deliberation in the introductory chemistry classroom, though there are some limitations to recognize. By the nature of our institution, the students participating in the activity were all male, and further studies into coeducational or all-female classrooms would be interesting to pursue. Future iterations of this activity will use paired t test measures to add precision to the statistical analysis and more fully explore the results as well as examine individual student participation patterns in terms of quantity and quality. Furthermore, in the previous two years at Wabash College, deliberation had been incorporated into several courses offered by the Rhetoric Department and had been used at all-campus events that addressed a myriad of issues, so some students were exposed to the technique before this activity and may have had a subtle bias when reporting gains made through their experience. However, we believe this does not affect the group data

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significantly. This activity incorporates trained facilitators for deliberation, and while information provided here can aid in an instructor's preparation for implementation, results may vary in different environments or with different topics of deliberation.

There are resources available for those unfamiliar with deliberation to aid with its incorporation into the classroom. Nonprofit, nonpartisan organizations such as the National Issues Forum[34] and Public Agenda[35] produce policy issue deliberation guides on a variety of topics and frequently have a moderator's guide offering questions. These organizations often are able to provide preliminary guidance for instructors who wish to begin holding deliberations in their classrooms. The facilitation guide created at Wabash College and used for the module described here is available in the Supporting Information. The Kettering Foundation also provided a connection point for scholars interested in deliberative pedagogy, with an interdisciplinary workgroup that connected with instructors interested in developing deliberative modules for their courses.[36]

■ CONCLUSION

Deliberation is a unique way to discuss complex problems that slows down a decision-making process by emphasizing participant input and conversation based on the values expressed in proposed solutions and the associated benefits and trade-offs. As an introductory chemistry activity, this allows students to synthesize the scientific information they have learned with their broader education and experiences to formulate ideas that move toward resolving a concrete public issue. Through quantitative and qualitative measures, we found that a deliberation about energy policy within a course for nonmajors meets important course goals as well by helping students form connections between the material and other subjects, learn new information related to energy and electricity, and recognize the urgency of a public problem. With the qualitative survey feedback emphasizing education and scientific research as important parts of the issue, this exercise also contributes to developing nonscience majors as citizens who appreciate the need and the place of scientific expertise in discussing and deciding on future public policy issues.

While this is an early study of a deliberative module in the science classroom, it contributes to broader discussions of how to encourage multilateral exchanges that take both scientific knowledge and public values into account.[20,21] Deliberation in the chemistry classroom holds much potential and opportunity for understanding how students connect scientific concepts to public policy.[37] Future research needs to investigate scientific deliberation experiences in multiple campuses and course settings as well as compare these classroom processes to real-world deliberation results. This activity may also have implications for student views on civic engagement, which could be explored in depth.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.6b00514.

> Pre- and postactivity survey questions, further analysis of the quantitative and qualitative survey responses, and the Wabash College Deliberation Facilitation Guide (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

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