



Students' Civic Engagement Self-Efficacy Varies Across Socioscientific Issues Contexts

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In STEM learning focused on science literacy, socioscientific issues instruction is often proposed as a way to bolster students' civic engagement, however few studies in science education have explicitly examined this connection. We define civic engagement as the work of influencing legitimately public matters using means within the existing political structure. In this work we investigate students' feelings of self-efficacy for this type of civic engagement in the context of four socioscientific issues (prairie dog conservation, food insecurity, biofuels and water conservation). This study was in the context of a large enrollment introductory science college course, where students used a structured decision-making process to examine alternative policy solutions to complex socioscientific issues. We qualitatively examined students' response about their perception of the importance of the issue, their self-efficacy in exploring actions they could take to impact the issue, and the effectiveness of those actions. We found that students' ideas about impact and effectiveness varied across the four different issues contexts due to students' sense of the issues' importance and scale. Generally, students' ideas about actions they could take to impact the issue were narrow and rarely included political actions like voting. We also found post instruction increases in students' civic engagement attitudes and skills related to social justice, interpersonal and problem-solving skills and political awareness. Finally, we suggest that socioscientific instruction must have an explicit connection to policy-level decisions and reveal how individual actions can influence the societal system. Our course using a structured decision-making process in the context of socioscientific issues is one model to help students make these connections.

Keywords: stem, civic engagement, socioscientific issues, self-efficacy, science literacy, decision making, postsecondary

INTRODUCTION

A frequently cited goal for science education is to prepare scientifically literate students who actively participate in decision-making about science-related societal issues throughout their lives. The implicit hope of educators, policymakers, and researchers is that with improvements in science instruction and increased science learning, a better informed and skilled citizenry will be more fully engaged and make important decisions to shape and advance our society. This is echoed in many of the documents outlining the objectives of science education goals both in the United States and

Europe (National Research Council, 1997; NGSS Lead States, 2013; Hazekorn et al., 2015; National Academies of Sciences Engineering and Medicine, 2016). These goals are often a focus at the postsecondary level as well. The National Task Force on Civic Learning and Democratic Engagement (2012), for example, the United States Department of Education and the Association of American College and Universities has declared that higher education should make “democracy and civic responsibility . . . central, not peripheral” (Brammer et al., 2012).

A path by which instruction may improve student civic engagement is by supporting students’ self-efficacy for citizenship. Self-efficacy has been defined in social cognitive theory as an individuals’ perceived ability to deal with a task or situation, which further leads to a sense of agency, or their actual ability to deal with the task or situation (Bandura, 1997; Chambon et al., 2014). An individuals’ sense of self-efficacy and agency is developed early in life Bandura (1997), Pastorelli et al. (2001), and supports civic engagement because successful civic engagement requires motivation and continued action on the part of the individual. Prior work has found that if individuals do not feel that their actions will be effective within the system they are engaging, they will avoid or reduce their involvement (Beaumont, 2010; Cicognani, 2014). Indeed, studies have found that strong sense of self-efficacy positively predicts adolescents’ intentions to participate in civic activities Schulz et al. (2010), Ainley and Schulz (2011), Manganelli et al. (2014) as well as actual participation in civic activities (Krampen, 2000; Pasek et al., 2008). As exposure to civic engagement can translate to lifelong commitment to civic involvement Jennings and Stoker (2004), Chan et al. (2014), it is critical to develop a positive civic identity early on in an individuals’ life (Finlay et al., 2010).

Scholars have posited that educational settings are an ideal context for students’ development of civic engagement ideals Spiezo et al. (2005), Beaumont et al. (2006), Manganelli et al. (2015) and sense of self-efficacy toward civic action (Beaumont, 2011; Levy, 2013). However, complex and unwieldy issues have a danger of creating action-paralysis Jensen (2004) and may not always produce increased feelings of self-efficacy. For example, after learning about climate change, students felt that their actions toward solving the problem may be ineffective and therefore experience a sense of apathy or helplessness (Taber and Taylor 2009; Aitken et al., 2011; Kenis and Mathijs, 2012; Ojala, 2012). Therefore, it is worthwhile to explore students’ development of self-efficacy for actions that are embedded within the context of specific, tractable, local issues during the course of classroom instruction. It is also important that we investigate and document classroom models that contribute to action-competence through a focus on building action-oriented knowledge and skills. Documentation will help elucidate whether, due to classroom learning on a given issue, students feel motivated to act, what actions hold appeal, and if students think their actions will have an impact on the issue. Students may envision themselves engaging in many types of actions—individually or collectively, or directly or indirectly (Jensen, 2002; Jensen, 2004). Each of these behavior types may have radically different environmental or societal significance (Stern, 2000). Understanding students’ general conceptions of

civic engagement and their own role in societal issues is important as a basis for instruction in order to meet students where they are and consider potential gaps in their understanding that would allow them to more fully and confidently engage as citizens.

Despite the value placed on developing students’ civic engagement, work remains to be done to determine instructional models that best support student practices in civic engagement. Much of science education practice in postsecondary classrooms remains centered on science content knowledge. An assumption underlying this idea is that scientific understanding is enough to prompt informed and reasoned action, akin to early research focused on the “deficit model” where if students’ knowledge increases then their attitudes and behavior follow (Sturgis and Allum, 2004). However, research suggests a lack of a direct connection between scientific understanding and the civic decisions made by people (Kollmuss and Agyeman, 2002; Allum et al., 2008). Similarly, in classroom settings, students often do not make connections between science content and stances or potential actions regarding the issue (Sadler, 2004). One reason for this lack of connection is that traditional classroom instruction often focuses on dimensions of knowledge related to the impacts of problems on physical systems (e.g., the impact of increased carbon dioxide in our atmosphere to temperature or natural systems), but less often knowledge about the root causes of the problems, strategies for change, and alternatives and visions for where society should go (Jensen, 2002). However, when instruction is centered on embodied civics (Payne et al., 2020) and requires students to actively engage in aspects of *both* knowing and doing, for example planning a community event around green energy, researchers have documented an increased student impetus for taking civic action (Birmingham and Calabrese Barton, 2014). At a college level, this type of action instruction is traditionally reserved for settings such as service-learning, which has been shown to successfully increase motivation for civic engagement (Celio et al., 2011; Felten and Clayton, 2011). Unfortunately, service-learning opportunities are difficult to implement at the large scale that typically exists in introductory science courses at the postsecondary level.

We propose, along with others Ratcliffe and Grace (2003), that it may be tenable to develop students’ civic engagement through classroom models. In particular, these models should use place-based socioscientific issue (SSI) instruction with a focus on decision-making that impacts society at a policy level. SSI instruction centers on learning through the lens of issues that require scientific reasoning but are inherently nested in societal elements such as culture, economics and ethics and is frequently focused on the goal of supporting students’ scientifically literate civic engagement (Sadler 2004; Sadler and Zeidler 2009). We describe an effort to create this type of instructional approach in a large enrollment required introductory STEM course. The civic engagement framework for our course is influenced by Rudolph and Horibe (2016) who recently noted that scholars have not clearly defined goals for civic engagement around issues that intersect with science nor have we clearly documented a link between science instruction and improvements in civic

engagement. Rudolph and Horibe (2016) make the case that “civic engagement” needs to be precisely defined in order to target instruction, research or policy around the development of civic engagement in science classrooms. They lean on Levine (2007) to define civic engagement as having two key components: 1) activities around civic engagement must be related to the common good rather than personal or private interests, and 2) engagement should focus on setting general policies or rules for society, for example, around questions of how goods are distributed in society (who gets what) and what behaviors should be promoted and which discouraged (who should be allowed to do what). These two components taken together can be expressed as “civic engagement is the work of influencing legitimately public matters using means within the existing political structure” (Rudolph and Horibe, 2016). Defining civic engagement as such is important in order to develop cogent strategies for supporting and researching the phenomenon. It may also represent a slight shift in focusing science classroom topics at a policy-level, which is important in supporting students’ understanding of dynamic networks of power relationships that shape society, and the sense that they are capable actors within these systems (Westheimer and Kahne, 2004; Zouda et al., 2019).

The course in this study was designed specifically to engage students in thinking critically and making policy-level decisions about SSIs. We used a structured decision-making framework (Dauer et al., 2021) to focus students on the separate roles of scientific information and valued outcomes, and the tradeoffs among alternative policy-level solutions to the SSI problem. In this context we seek to understand students’ civic engagement attitudes and their perceived self-efficacy. Specifically, in this work, we ask the following questions: 1) For each focal SSI from the class, how do students perceive the importance of the issue, their self-efficacy around the issue, and the effectiveness of their actions? 2) Do students’ civic engagement attitudes and skills change as a result of their participation in course focused on SSIs and decision-making? This work can help us understand how students perceive their individual self-efficacy in their civic engagement across various focal SSIs and how classrooms could potentially contribute to supporting student civic engagement.

MATERIALS AND METHODS

The research for this work took place in a large-enrollment, required course within the College of Agricultural and Natural Resources at the University of Nebraska-Lincoln during fall 2016. This course, Science Literacy 101 “Science and Decision-Making for a Complex World” (hereafter SCIL 101), is an introductory course that is required for all students matriculated within the college, reaching about 600 + students each year. The course includes a combination of STEM (72%) and non-STEM (28%) majors and is conducted in a lecture format, with five different lecture sections (of approximately 125 students in each lecture section) meeting two times per week for 75 min per lecture, and a

weekly recitation discussion (of approximately 30 students) meeting once a week for 50 min.

SCIL 101 is an interdisciplinary science course designed to develop students’ science literacy and is described in detail in Dauer and Forbes (2016) and Dauer, Sorensen, Jimenez, *in press*. In this context, science literacy is being defined following the National Research Council (NRC) as “knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (1996, p. 192). The primary learning goal of the course is science-informed decision-making skills. The instructors use focal case-studies using salient place-based issues as a context for students to learn and develop decision-making skills. In this way, the course aims to foster students’ interest in and understanding of local issues, supports students’ understanding of themselves as stakeholders, and gives insight into potential solutions. By focusing on decision-making to resolve local SSIs, the course may potentially cultivate students’ civic engagement attitudes, skills and sense of efficacy.

The focal SSI case-studies, developed by the instructional team, are introduced as separate modules, each framed by a societal question related to the module. Specifically, the questions posed to the students at the beginning of each module for this study were: 1) Should we conserve prairie dogs and their habitat? Prairie dogs are herbivorous burrowing rodents endogenous to the Midwestern United States. Prairie dogs are ecosystem engineers creating a heterogenous habitat that supports endangered species, however are regarded as competing with cattle for forage. Prairie dogs exist in short-grass prairie ecosystems, primarily in western Nebraska. Prairie dog populations are substantially reduced in Nebraska and are legally exterminated. 2) Should we burn biofuels for energy? Most gasoline in the United States is blended with up to 10% ethanol, the majority of which is produced using corn. Biofuels are seen as reducing greenhouse gas emissions, but corn-based biofuels have a smaller margin of benefit compared to other feedstocks like switchgrass due to high agricultural inputs. Corn and soy based biofuels have been an economic boon to the Midwestern United States. 3) How should we reduce food insecurity? In 2014 14% of households in the United States experienced food insecurity, many of these households with children and at least one full time working adult. Solutions to this problem may include increasing the minimum wage, expanding federal welfare programs or encouraging private and non-profit food banks. 4) Should we further restrict irrigation for agriculture in Nebraska? Nebraska irrigates more acres than any other state in the United States, and in Nebraska 70% of groundwater withdrawals across all sectors occur in agriculture. Groundwater levels have declined in some parts of the state but not appreciably due to the extremely deep High Plains Aquifer that resides below the state. These four questions were chosen because they were policy questions that were locally relevant and related to common fields of interest of the student body.

Each SSI requires students to investigate the economic, environmental, ethical, social, and cultural aspects that are

relevant to each problem as well as develop an opinion about the best course of action to take to help resolve the SSI based on a structured decision-making process (Dauer and Forbes 2016; Dauer et al., 2017; Sutter et al., 2018; Dauer et al., 2021). The decision-making steps are based on normative models of decision-making (e.g. Hammond et al., 2015) and previous work at a K-12 level (Ratcliffe, 1997; Grace and Ratcliffe, 2002). The steps as given to students in the Fall 2016 semester were:

1. **Define the issue**- What is the problem that needs to be solved?
2. **Objectives/Evaluation Criteria**- What are the important things to consider? What do you care about?
3. **Options**-List or identify the possible alternative courses of action in considering the problem or issue.
4. **Information** - Estimate the consequences of each option. What additional information do you need to know about each option? Clarify the information known about possible alternatives, with particular reference to the outcomes/criteria identified and to any scientific knowledge or evidence.
5. **Analysis of options based on the criteria (tradeoffs)**- Rank the importance of each criteria. Evaluate each option against the criteria identified.
6. **Choice**-Choose an option based on the analysis undertaken.
7. **Review**-Evaluate the decision-making process undertaken

Students followed these steps for each module as a lecture class, in small groups, on discussion board posts and in recitation (see **Supplementary Tables S2, S3**), and finally, students integrate all steps of the structure decision-making as an individual for their module summative assessment [see **Supplement Table S4**, and (Dauer et al., 2021) for more details]. In the module assessment the seven steps are followed by a series of additional reflection questions. The purpose of the questions is to deepen students' reflection on the issue, particularly related to their own interests and engagement.

To address our research questions we collected student coursework that contained open-ended questions that asked students to reflect on each SSI topic during the summative module assessment for each of the four SSI topics (research question 1), and we collected data before (pre) and after (post) the class using surveys (research question 2). Only students who completed the pre- and post-survey and gave consent for their responses to be used as a part of the research were included for analysis. Demographic data were not collected on the specific students in this study, however, the population of students within the College in Fall 2016 self-reported as 46% female, 54% male, and 86% white, 5% non-resident of the United States, 3% Hispanic, 2% two or more races, 1% African American, 1% Asian and less than 1% Indigenous. All research was done with University of Nebraska-Lincoln IRB approval (#20140813907 EP). The data were qualitative and

quantitative in nature to give more insight into student conceptions of civic engagement.

Qualitative Data of Students View of the Issue

To answer the first research question about student views of importance and perceived self-efficacy to impact the focal SSI topics, students were asked to respond to a series of open-ended questions. The questions followed the structured decision-making steps in the summative module assessment for each of the four SSI topics (see sample for Prairie Dogs **Supplement Table S4**), and only students who consented to research and completed all four assessments were included in the qualitative data set ($n = 145$ out of 234 students enrolled in two lecture sections of the course). The three prompts that generated the qualitative data were as follows:

- (1) Importance-Is this issue an important issue? Rank the issue on a scale of 1 (not at all important) to 10 (one of the most important issues). Why?
- (2) Self-Efficacy-Is there anything you could do to impact this issue? What are some things you could do?
- (3) Effectiveness-Do you think your actions regarding this issue will make a difference? Why or why not?

To analyze the responses from the three prompts, an inductive coding process was undertaken in which we developed codes that characterized the various responses given by students for each of the three follow-up questions on the module assessment. We read student responses, noted sub-themes and created a coding framework representing sub-themes within each SSI. We noticed commonalities between sub-themes and consistent patterns of sub-theme categories across all SSI topics. These commonalities between sub-themes (e.g., "spread the word through social media" and "talk to the farmers around me" were later combined into themes (e.g., "Educate Others") that existed across SSI topics. Authors went through multiple iterations of independent coding of these themes, checking for reliability, then reconciliation and revising the coding framework. Ultimately, independent coders achieved independent agreement of over 90% for all theme codes. A single student may have given a response that touched on several themes, and was coded for each theme, therefore individual students were given between 1 and 5 codes for each prompt response. Finally, for the Self Efficacy prompt, we combined the theme codes to represent major theme categories (e.g., "Direct Actions") that emerged across all SSIs topics.

For the Importance prompt, three themes emerged from student responses across all four SSI topics were: 1. *Not important* (sub-themes included that other issues are more important, the issue already has solutions, or stating that "this issue is not important"), 2. *Justification of importance attributed to external reasons* (sub-themes include that the issue impacts "people" generally or the environment, for example "we need to find sustainable fuels" or "prairie dogs are important for ecosystems"), 3. *Justification of importance attributed to*

internal reasons (sub-themes include future career interest or personal connection to issue, etc., for example, “My future job involves biofuels” and “I grew up on a farm so water regulations on farmers impact me”).

For the Self-Efficacy prompt, six themes emerged: *Cannot Impact The Issue*, *Personal Action*, *Educate Self*, *Educate Others*, *Advocacy and Political Action*, that captured student thinking across all four SSI topics. From this, we identified and integrated these themes into three major theme categories of student responses: 1. *Cannot Impact Issue*, 2. *Direct action* (actions they themselves could take to impact the issue), and 3. *Indirect action* (actions that would impact the issue indirectly). In the direct action category, we included those behaviors students reported that would contribute to the SSI in the immediate context (e.g., consumer behavior, volunteering, giving of resources), whereas indirect category encompassed behaviors that might broadly impact the issue by influencing the decision-making context around the issues (e.g., educating others, advocating for policy change, donating money for broader initiatives).

Finally, for the Effectiveness prompt, we identified four themes in student responses based on Jensen, (2004) direct/indirect, individual/collective behavior types. These themes crossed all of the SSI topics: 1. *My individual actions will not make a difference* (sub-themes included stating that students individual actions could not make a difference in the issue, or students were unsure or doubtful that individual actions could make a difference), 2. *My individual actions can make a difference* (sub-themes included stating that the actions—direct or indirect—they took personally could make a difference in the issue, or stating what they are already doing related to the issue), 3. *Collective action is necessary to make a difference* (sub-themes included that students felt it would require the actions of many people to make a difference). Additionally for this prompt we noted instances when student responses contained a combination of the above categories (e.g., student response contained reasoning that their individual actions would make a difference but collective action was also necessary) to create a fourth and fifth category because of interesting patterns that arose when single students combined both categories within their responses.

Quantitative Data of Pre and Post-instructional Attitudes and Skills

To answer the second research question about changes in civic engagement, attitudes, and skills, after course participation, the Civic Attitudes and Skills Questionnaire (CASQ) Moley et al. (2002a), Moley et al. (2002b) was used. These items were included as a part of a larger pre/post survey ($n = 174$ out of 234 students enrolled in two lecture sections of the course). The CASQ was administered to the students at course onset and during the final week of the course. The goal of CASQ is to measure increased self-enhancement (self-esteem, confidence), understanding of self and world (personal growth, empathic understanding), and value expressions (expression of humanitarian and prosocial values) in students. The CASQ is comprised of 45 items on a 1–5 Likert

scale (one being strongly disagree, three being neutral, and five being strongly agree) and are divided into six different scales (with 5–12 items per scale): civic action (intentions to become involved in the future in some community service or action), interpersonal and problem-solving skills (ability to listen, work cooperatively, communicate, make friends, take the role of another, think logically and analytically and solve problems), political awareness (of local and national events and political issues), leadership skills (ability to lead and effectiveness as a leader), social justice attitudes (concerning the causes of poverty and misfortune and how social problems can be solved), and diversity attitudes (toward diversity and the respondent's interest in relating to culturally different people). The internal consistencies for each scale reported by Moely et al. (2002a) ranged from 0.69 to 0.88 and test-retest reliabilities for each scale ranges from 0.56 to 0.81. An average score was generated for each student for the six scales from the pre and post responses. Differences in overall student responses pre-to-post for each of the six scales were analyzed using a paired *t*-test. For scales that indicated a significant increase from pre to post, we subtracted the pre and post-test means of individual test items and reported on the items with the largest pre-to-post gain to further describe and understand student changes before and after the course (Supplement Table S1).

RESULTS

Overall the trends in our qualitative data suggest most students considered the SSIs covered in the course to be important and that they perceived self-efficacy in contributing to the solution for solving the SSIs. Students had multiple ideas about ways they could impact each SSI both directly and indirectly and thought their actions could make a difference at both individual and collective levels. Below we review student responses to each of the three open-ended question prompts.

Student Responses on the Importance of the Socioscientific Issues

Overall, in terms of Importance, students felt that the SSIs covered in the course were important to address. Biofuels, food insecurity, and water conservation were ranked highly important with a fairly narrow spread in their average scores (between 7.88 and 8.29 out of 10, Table 1), with prairie dog conservation ranked lower with an average of 5.44 out of 10. From student responses to the Importance prompt across all four SSI topics (Table 1), less than one third of students highlight internal reasons for why they think each SSI is important. Students who do highlight internal reasons for why the focal SSIs are important often cite familial or community connections. One such student said about food insecurity, “I think that food insecurity is a huge issue. If you look around, there are all kinds of people that are food insecure. And sometimes, they are people you would never expect . . . I volunteer at middle school where I see underprivileged kids twice a week. I now want to do more for kids who do not get sufficient food.” Students that cite internal

TABLE 1 | Student responses to “Importance” prompt: “How important do you think this issue is to you personally? Rank the issue on a scale of 1 (not at all important) to 10 (one of the most important issues). Why?” The mean rank and the % of students who responded in each coding category for each topic. Some students reported multiple reasons (i.e., personal connection and impacts the environment) therefore each column sums to greater than 100% ($n = 145$).

	Prairie Dogs	Biofuels	Food Insecurity	Water Conservation
Average Rank and (Standard Deviation)	5.44 (1.98)	7.89 (1.36)	8.29 (1.36)	8.16 (1.66)
Not Important/other issues are more important/already solutions to this issue	52%	7%	13%	13%
External reasons (important to others, impacts the environment, etc.)	49%	92%	77%	84%
Internal reasons (personal connection to the issue)	25%	10%	25%	32%

TABLE 2 | Student responses to “Self-Efficacy” prompt: “Is there anything you could do to impact this issue? What are some things you could do and how might they impact the issue?” The % of students who responded in each coding category for each topic. Some students reported multiple behaviors (i.e., educating and voting) therefore each column sums to greater than 100% ($n = 145$).

	Prairie Dogs	Biofuels	Food Insecurity	Water Conservation
Cannot Impact the Issue	17%	10%	2%	4%
Direct Action				
Personal Action (consumer choice, change behavior, career choices etc.)	29%	66%	86%	70%
Educate Self	10%	7%	3%	6%
Total Direct	39%	73%	89%	75%
Indirect Action				
Educate Others (in-person, social media)	43%	44%	28%	46%
Advocacy (petitions, raise money)	38%	11%	15%	12%
Political Action (voting, contacting gov. officials, etc.)	18%	11%	10%	11%
Total Indirect	99%	66%	52%	68%

reasons also highlight personal connections in terms of careers or regional connections to the issue. This is exemplified by one student saying about water conservation, “The water in Nebraska is one of the prime resources that is the driving force of strong agriculture production and stabilizing our economy.” In these two examples, students justify their importance rankings by explaining how these SSIs are impacting specific elements of society or the environment around them. However, most students cited external reasons—such as an impact on society or the environment at large—for why they thought these issues were important. One representative example of this external reasoning comes from a response to the biofuels SSI, “Global warming is the biggest issue facing our planet as a whole. If we do not find a cleaner and more sustainable source of energy, our future is not looking very bright.”

Additionally, a number of students gave vague external justification for their rationale for why these issues were important, exemplified by one response to the water SSI, “I think this issue is very important because it has future consequences if we do not pay attention to it and start resolving it ASAP.” In these examples, we see students justify their importance rankings by acknowledging that these SSIs will have an impact, but do not necessarily connect this impact back to themselves as individuals. On the other hand, for the prairie dog SSI, which was generally ranked lower in importance than other SSIs, many students explicitly reported feeling more disconnected to the issue. One student highlighted this lack of connection by saying, “I don’t think this is [important] because I am not a part of this issue. I have only seen prairie dogs once on vacation and I feel like it is not my issue to worry about.” Some

students felt that “this issue only really affects people that have a lot of land to ranch on . . .” and that other issues are more important. While most students highlighted either specific or vague external reasons in their justifications for how they ranked these SSIs across the board, there was variation in the personal connection students reported to each issue, which likely influenced students’ ranking of importance.

Student Responses Regarding Their Potential Self-Efficacy on the Socioscientific Issues

In terms of Impact (Table 2), students reported high levels in their confidence in their ability to impact the SSIs either directly, indirectly, or both. Only a small percentage of students responded that they could not have an impact across the SSIs (Prairie Dogs at 17%, Biofuels at 10%, Food Insecurity at 2%, and Water Conservation at 4%). Personal Actions and Educating Others were the behaviors that most students reported as actions that could be taken to have an impact on SSIs. The majority of students felt they were able to take some form of direct personal action toward the Biofuel (66%), Food Insecurity (86%), and Water Conservation (70%) issues, whereas fewer (29%) students felt they could take direct action to impact prairie dog conservation.

A closer examination of the food insecurity and water conservation SSIs reveals a common pattern of thinking across the SSI topics; students generally perceive their role as agents for change as primarily revolving around their personal actions and their influence on a community. For example, one student said “I

TABLE 3 | Student responses to “Effectiveness” prompt: “Do you think your actions regarding this issue will make a difference? Why or why not?” The % of students who responded in each coding category for each topic. Each code category is mutually exclusive such that no one student response was counted for more than one code ($n = 145$), a small number of students were missing a response so not all columns add to 100.

	Prairie Dogs (%)	Biofuels (%)	Food Insecurity (%)	Water Conservation (%)
1. My individual actions <u>will not</u> make a difference, or unsure	32	20	7	21
2. My individual actions <u>will</u> make a difference	46	50	70	60
3. Collective action <u>will</u> make a difference	12	17	6	8
4. My individual actions <u>will not</u> make a difference, AND collective action <u>will</u> make a difference	3	6	3	5
5. My individual actions <u>will</u> make a difference, AND collective action <u>will</u> make a difference	5	7	13	6

think that I could impact this issue in the way that I could use more technology on our own farm and ranch and get the word out to others that we need to be more aware of using our water more efficiently.” Here, the student notes specific water conservation actions (direct personal action) they themselves could take on their family farm to impact the issue and highlights how they could help share information for others to take action (indirect action, educate others). Similarly, for the food insecurity SSI, one student said, “As an individual I could go to my local food bank and donate food. While I am not impacting the issue on a large scale, I am doing something that will impact another individual directly. I could also share my experiences on social media to spread the word about food insecurity and hopefully inspire others to do the same.” Many of the students’ response about educating others were focused on a proximate and known community such as family and friends, contacts through social media or known local community groups. In contrast, few students recognized their ability to impact SSIs via political actions or to participate as a citizen in a system of governance and policy. Students were less likely to mention political action such as voting or contacting representatives across all four focal topics (Prairie Dogs at 18%, Biofuels at 11%, Food Insecurity at 10%, and Water Conservation at 11%). Engaging in advocacy through signing petitions, protests, lobbying or raising money for advocacy groups was also rarely mentioned in three of the four SSI topics (Biofuels at 11%, Food Insecurity at 15%, and Water Conservation at 12%).

The actions that students thought would have an impact on an SSI varied across SSI topic, particularly, patterns differed in responses to the prairie dog issue. A higher percentage of students reported that they could not impact the issue, fewer students reported personal actions that could impact the issue, and more students mentioned advocacy as a means of impact. Some students felt that people do not care enough about prairie dogs for a change to occur, or some felt that landowners should decide the fate of prairie dogs on their property. One students’ comment captures this sentiment: “I do not think that this is an extremely important issue due to the fact that the prairie dog numbers are not dropping to the point where we should be extremely worried. It should be up to the landowner and that’s it.” In contrast, the biofuels SSI also had higher percentages of students who reported that they could not impact the issue, although for strikingly different reasons. For biofuels, many

students felt that individual actions were less effective in making a change because of the scope or complexity of the issue. One student highlighted this by saying, “To be honest, it [my actions] will not make a huge impact because this is a more complex issue where solutions can’t happen just over night. Obviously further research is still being done such as in second generation biofuels and figuring out how to expand cellulosic ethanol production.” Therefore, students had differing underlying reasons that were unique to the SSI that drove patterns in students’ responses on how they envisioned their potential impact.

Student Responses on Their Effectiveness for Change Within Each Socioscientific Issues

Generally, half or more than half of students reported that they thought their individual actions could make a difference (sum of percentages in categories 2 and 5, **Table 3**): Prairie Dogs at 51%, Biofuels at 57%, Food Insecurity at 83%, Water Conservation at 66%. Those who did not think their actions would make a difference in the prairie dog issue often reasoned about their lack of connection with the issue, for example, “No, because I have no experience with prairie dogs and they have never impacted my life . . . if I lived around them then I would have more of an impact on their status.” In contrast, in the food insecurity issue that had the highest number of students who felt that they could make a difference on the issue, students responded with affirmation of their efficacy within the sphere of their own influence: “I think any actions can make a difference. By volunteering at a local food bank, I may not change the world in its entirety, but I may change the world for one person or family.” In the water conservation context, many students noted actions that could happen at a household level, despite the focus of the unit on water consumption in agriculture which dwarfs household use in the state. For example, “All actions regarding this issue are needed to make a difference. Even if the actions are as simple as taking shorter showers, they all add up in the long run to make a difference on our groundwater levels.” Additionally, many students reasoned about collective action that makes a difference but that happens at a larger scale (sum of percentages in categories 3, 4, and 5): Prairie Dogs at 20%, Biofuels at 30%, Food Insecurity at 22%, and Water Conservation

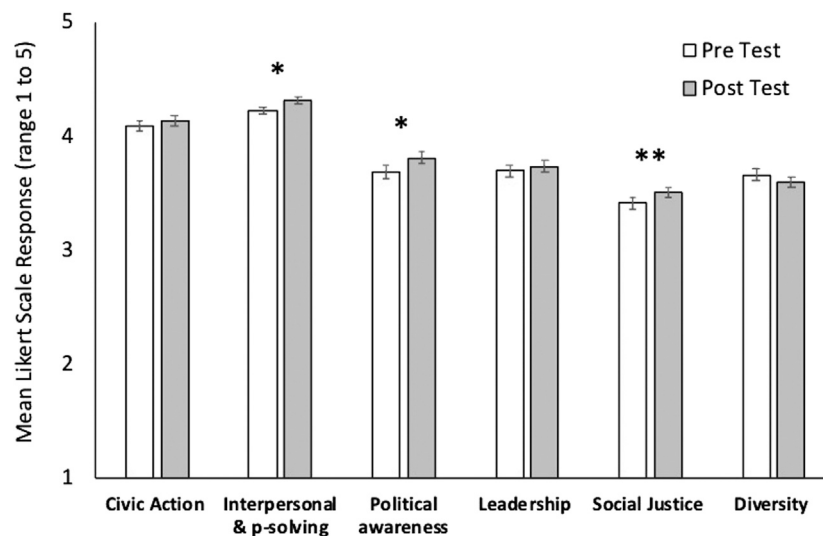


FIGURE 1 | Difference between the average response between the pre and post tests for the CASQ data in the Fall 2016 semester with standard error shown ($n = 174$). Significant differences in the paired t -test between pre and post-test is indicated with a ** ($p < 0.05$) and a * ($p < 0.1$).

at 19%. For example, in the biofuels context a student said “I believe everyone’s actions regarding this issue will make a difference. It will take the will of many to make this worldwide change.”

There was an interesting pattern that emerged from the responses in the Effectiveness prompt (Table 3), with at least some students (between 3 and 6%) across all four SSIs reporting that their individual actions could not make a difference but collective action of many people could make a difference (category 4). One student noted about biofuels “I don’t think my actions will impact it, I am just one person, but, if more of us will stand together on this issue, we can make a difference.” Others stated that their actions would make a difference but with the caveat that collective action was necessary (between 5 and 13% across all four SSIs, category 5). Exemplifying this type of response, one student said about the food insecurity SSI, “I think that my actions could help a few people by giving them food to eat however, I don’t think that my small actions would change the whole problem. The problem is very large and complex, and I don’t think that my actions alone would change anything. But if more people pitched in to help, then yes, I think we could make a difference on the issue.” These students seem to parse apart the scale at which they think their actions would be effective, noting that individually they could make a difference at the local scale, but at a broader scale they could not, and it would require collective action to address the issue.

Pre and Post-instructional Attitudes and Skills

From the CASQ data, the majority of the data were not normally distributed according to a Shapiro-Wilk test, though our sample size is large enough (>40) that the violation of the normality assumption should not cause major problems (Ghasemi and

Zahediasl, 2012). Three of the six scales were significantly different pre-to-post indicating increases in students’ self-reported attitudes and skills (Figure 1). There was a significant increase in Social Justice from pre (mean = 3.410, SD = 0.612) to post (mean = 3.502, SD = 0.590; $t(173) = -7.857$, $p < 0.0001$) at a significance level of $p < 0.05$. Cohen’s effect size value ($d = 0.15$) suggested a potentially small practical significance. There were increases in Interpersonal and Problem Solving Skills from pre (mean = 4.225, SD = 0.454) to post (mean = 4.316, SD = 0.446; $t(173) = -1.817$, $p = 0.071$), and in Political Awareness from pre (mean = 3.684, SD = 0.724) to post (mean = 3.808, SD = 0.684; $t(178) = -1.678$, $p = 0.095$) at a significance level of $p < 0.1$. Cohen’s effect size value were small ($d = 0.20$ and $d = 0.18$, respectively) suggested small practical significance. The other three CASQ scales (Civil Action, Leadership, and Diversity) did not show significant differences pre-to-post. Within the three scales with significant changes pre-to-post, statements on the assessment that had the largest magnitude change in student responses are displayed in the Supplement.

DISCUSSION

Student responses about their view of the importance of an issue, actions that might be taken to impact and issue and whether these actions will be effectual, gave insight into how students situate the action and self-efficacy of individuals within societal systems. Our research most importantly demonstrates that students’ ideas for action were more focused on personal choices over advocacy or political action, and that students’ perception of individuals (or themselves) within social systems as capable actors depends on the SSI context. We also documented that we found increased civic engagement attitudes and skills post-instruction in our

course focused on policy-level decision making about SSIs. In our discussion that follows we unpack these findings and also consider instructional and research implications that stem from our analysis.

Students Ideas for Action do not Often Include Advocacy or Political Action

The majority of students were able to suggest specific actions individuals could take across the four SSIs, although students' ideas for behaviors tended to be narrow in scope. The actions students cited varied by topic, but for three out of the four SSIs the majority of students emphasized direct actions such as their consumer action, behavior and career choices over indirect actions such as petitions, raising money, contacting government officials or voting. This finding is supported by other studies that found that individuals age 15–25 do participate in community-related and volunteer activities yet tend to be disengaged in electoral participation (Keeter et al., 2002). Additionally, other studies of voting behavior have found that voting turnout of young adults has decreased over time, whereas turnout of older adults has increased (Levine and Lopez 2002; File 2014; Galston and Hendrickson, 2016). Therefore, the low number of students reporting political or electoral actions in our study is perhaps not surprising given the broader trend of civic engagement in the general public.

On the other hand, we expected students to suggest actions that have a closer connection to policy changes, such as voting and advocacy, because our classroom activities were oriented around completing a structured decision-making exercise that compared “Options” or alternative solutions that were all at the policy level. Some examples of these policy-level alternatives we investigated included increasing water restrictions for farmers to resolve water conservation issues, changing the status of prairie dogs from “vermin” to a game species or protected species to conserve prairie dogs, or increasing the minimum wage to ameliorate food insecurity. In contrast, the responses we received from students suggested that they see themselves in a system where their primary levers of change are their own personal choices and educating people in their proximity. This suggests a need to go further in intentional instruction, about of the potential impact of individual actions, particularly political and electoral actions, in forming the policy changes we investigated in the course. Similarly, others have reported that youth and college students in particular, do not see political action as a mechanism for change and do not have a clear understanding of the functions of a political system nor competencies for engagement (Andolina et al., 2002; Beaumont et al., 2006). Unfortunately, current educational opportunities at the K-12 and postsecondary levels (in the United States) often do not provide sufficient learning opportunities for political engagement and understanding (Colby et al., 2007; Shapiro and Brown, 2018). In response, many have argued for explicit instruction around political engagement at all levels Bloch-Shulman and Jovanovic (2010), The National Task Force on Civic Learning and Democratic Engagement (2012), Shapiro and Brown (2018)

including in science classrooms (Rudolph and Horibe, 2016). An SSI-based science course such as the one described here may be a starting point in develop students' ability to connect individual civic engagement to policy-level decision-making and while making explicit connections to science evidence. Although, we found through this study that while the structured-decision making framework used in our SSI-based course may help students understand the impact of different policy solutions, it may still fall short in elucidating how individual actions, including political, would help to actualize different solutions.

Students Views of the Efficacy of Actions Varied by Socioscientific Issues Topic

When asked if they thought if their actions would make a difference in the SSIs studied in the course, about half of the students in the context of prairie dogs and biofuels and one-third in the students in the context of water conservation, thought their actions would *not* make a difference. The reasons for fewer students having a sense of self-efficacy varied by issue—with prairie dogs due to a lack of personal connection to the issue (i.e., they were not ranchers in the region where prairie dogs lived), and with biofuels and water conservation due to the large scope of the issue (i.e., noting that change would need to happen at the societal level or through policy interventions, which their individual actions could not influence). In contrast for the food insecurity SSI, which had the highest percentage of students who felt their actions would make a difference, students cited direct individual actions such as volunteering at a food bank or donating food. This resonates with findings of other studies of college students who, despite feelings that issues like climate change are important and action should be taken, disengage because of feelings of powerlessness due to the large scale and complexity of the problem (Kenis and Mathijs, 2012). These responses suggest that the perception of whether the SSI is a local or global issue, and at what scale actions can have an impact, influences student perception of their efficacy.

Taken all together, our data may suggest that students' sense of self-efficacy may be related to their notion of the societal system and what levers are available to individuals. For example, if students were only able to conceive of direct actions to influence the issue (i.e., consumer choice and volunteerism), then issues that are very large in scope (biofuels), or outside of the interests of their local community (prairie dogs), are not ones that they could influence as an individual. This tension of individual efficacy and scale/location of solution was also manifested in the number of students who said their individual actions may not (or may) make a difference, but that the collective action of many people *would* make a difference. These findings align with other's work on student perceptions of environmental issues. One such study of undergraduate students in Australia found students perceived that people, including themselves, pose a threat to the environment but that environmental issues such as climate change, endangered

species and pollution were beyond their personal control and solutions to these environmental issues is the responsibility of others (Eagle et al., 2015). In the Eagle study and ours, it appears that large-scale issues are daunting to students, leaving them unclear ideas about pathways for their individual actions to effect a change.

Self-efficacy for civic engagement may also be due to students' motivation toward an issue. Of the four SSIs, only the prairie dog's topic was ranked as less important by students; students saw the issue as less significant despite current ongoing debate about prairie dog conservation in the state legislature. Anecdotally, instructor experiences found that many students in the course conformed to the general public perception in the region of prairie dogs as competing with cattle for rangeland and harming the ranching industry, therefore discussing conservation of prairie dogs in class was unfounded. Students may have felt less motivated for civic engagement if they had these beliefs, or many may simply not have seen the personal or societal relevance of the module. Personal and/or societal relevance of the focal topic is key to the SSI-based educational framework Zeidler and Nichols (2009), without which interest and perceptions of importance are reduced. The lack of importance placed on the issue as well as the distance to the issue for many students may have resulted in a sense of apathy that translated into few students conceiving of actions that could impact the issue.

Self-efficacy for engagement in an issue may ultimately impact the way classroom activities influence the development of students' civic engagement skills. Our classroom model was designed with the idea that students would engage in decision-making as a way of practicing and gaining proficiency in their emergent science literacy and civic engagement skills. However, if students do not clearly see themselves as part of the mechanism for change for these issues, there may be a disconnect between the students' classroom experiences and the hoped-for learning outcomes. People's beliefs about what they are capable of accomplishing is an important predictor of actions and behavior (Bandura, 1997). Indeed, this relationship bears out in practice in non-classroom settings, for example, the willingness to engage in community actions for environmental stewardship have been found to be related to high levels of self-efficacy (Sorensen et al., 2018). Additionally, pro-environmental behavior can be determined by the interplay between attitudes, personal capabilities, habit and routines, and the contextual factors surrounding an individual (Stern, 2000). These internal and external factors influencing public civic and environmental behavior also likely come into play in the context of SSI-based classroom instruction. From an instructional design context, it is important to note that the connection between SSI instruction and civic engagement is complex and the student perceptions of the issue will likely impact the focus of civic engagement. It is clear from our data, that looking across all four SSI topics used in the course, students considered some issues of more or less importance or more or less within their scope of influence, and this may have resulted in variable patterns in student perceptions of their own actions in terms of efficacy and

potential impact. Further work investigating the connection between student attitudes, prior knowledge and perception of an SSI, SSI-based instruction, and broader civic engagement outcomes is needed to understand these relationships.

Students' Civic Engagement Attitudes and Skills Change as a Result of Course Participation

From this work we see clear opportunities for SSI-based instruction to influence students' civic engagement. In support of this connection, we detected an increase in some aspects of students' civic attitudes and skills after our science literacy course focused on decision-making about locally relevant SSIs (Figure 1). Our effect sizes are small, yet small effects are common in education research and could potentially still represent an impact on students. Importantly, there are limitations to the pre and post-approach to studying increased learning gains without a controlled comparison, including that we cannot necessarily attribute these learning gains to any specific aspect of the course. More research is necessary to understand the role of the course in general, and the SDM approach specifically, in cultivating civic engagement attitudes and skills. Notwithstanding, we see connections between specific content of the course and gains that were detected using the CASQ instrument, which we further detail in order to more fully consider the potential impact of the course on students' civic engagement.

In particular, we saw significant increases using a social justice attitudes scale on the CASQ instrument, which measured attitudes about the causes of poverty and misfortune and how social problems can be solved. More students disagreed with statements about poverty including "I don't understand why some people are poor when there are boundless opportunities available to them" and "people are poor because they choose to be poor" (Supplement), which resonated with content associated with the food insecurity module related to current social conditions regarding poverty. Misconceptions and stereotypes around poverty are common (e.g., Gorski 2008; Shuffelton, 2013; Gorski, 2014; Gorski, 2018). Our module helped to frame those living in poverty as not unlike the student population of their own class via learning about the cycle of poverty (people may work extremely hard but are unable to sustain life above the poverty level due to societal structures) and examining demographic data on food insecurity (which includes children with working parents, rural populations and college students). We will also note that, while the food insecurity SSI topic may not be a mainstream topic used in science classrooms, it afforded an opportunity to examine scientific research that bridged sociology, psychology, engineering, agriculture, health, geography and economics (for example, data from Hill et al. (2016) that show the psychological impact of growing up hungry has a long-term impact on eating behavior). This interdisciplinary SSI simultaneously allowed students to learn science concepts, apply scientific evidence to an issue and examine their attitudes and views regarding societal elements.

We also found learning gains in Interpersonal and Problem-Solving Skills as well as Political Awareness (**Figure 1**). Interpersonal and problem-solving skills such as listening to others, working cooperatively, communicating, and making friends were ingrained in the mechanics of the course, and hence, practiced throughout the semester. In particular, the course required group work including think-pair-share and active learning exercises in lecture and required group research projects including a final project working through a decision-making process on a new SSI topic in recitation (Dauer et al., 2021). Additionally, interpersonal and problem-solving skills including taking on the role of another and thinking logically and analytically solving problems, were practiced throughout each SSI topic as a result of the use of the SDM framework. For example, the SDM framework required students to consider various stakeholders and their values as well as work through a process of using scientific evidence to determine the potential consequences of an alternative solution to the issue and considering tradeoffs for each alternative. Additionally, for skills around political awareness of local and national events, there was no one particular SSI topic that encapsulated this focus, however, students understanding and awareness of local events and issues may have been amplified through place-based instruction.

Our study is among few that have sought to document a connection between SSI instruction and increased motivation or self-efficacy toward civic engagement. Some notable examples are Lee et al. (2013) who demonstrated that ninth grade students who learned about genetic modification technology became more sensitive to moral and ethical aspects of the issue, yet still struggled to demonstrate willingness and efficacy to participate in action toward resolution of the issue; and Herman (2018) who found increased intentions to engage in environmental actions in 7–11th graders who participated in SSI instruction and a field trip to Yellowstone National Park to understand wolf reintroduction. It is acknowledged throughout the SSI literature that SSI-based instruction arose in part out of an interest in building student competencies and practices that would support active and socially responsible civic engagement (for example, Ratcliffe and Grace, 2003; Sadler and Zeidler, 2005; Sadler et al., 2007; Sadler et al., 2007). Given the oft stated assumption that SSI instruction will encourage civic participation and action, more studies of this nature should be conducted to further explore the strength of this connection.

Implications for Socioscientific Issues Instruction to Support Civic Engagement

It is challenging to develop curriculum and teaching strategies to address the abstract qualities that we desire in students that may lead to civic engagement. A direct service-learning opportunity as part of the course may have the potential for the greatest impact on students. Unfortunately, service-learning experiences are difficult to achieve at the scale of most large-enrollment introductory courses. We propose that SSI instruction holds promise as an alternative model for introductory science classrooms. However, commonly used models that describe SSI instruction vary in their explicit connection to the second component of civic engagement using Rudolph and Horibe (2016) definition based on Levine (2007): engagement should focus on setting general policies or rules for society, for example, around

questions of how goods are distributed in society (who gets what) and what behaviors should be promoted and which discouraged (who should be allowed to do what).

SSIs are defined as beyond the context of personal choices, instead they focus on contexts that are of importance to society generally, thus connecting to the first part of Levine's definition of civic engagement. The second aspect of Levine's definition of civic engagement (i.e., explicitly connecting content to policy choices with broad societal impact) is less uniformly a focus of SSI interventions. For example, SSI instruction as described by Zeidler (2014), include the idea of teaching to bolster students' ability to "make informed decisions, analyze, synthesize and evaluate varied sources of data and information, use moral reasoning to attend sensibly to ethical issues, and understand the complexity of connections inherent in SSIs." The explicit hope is that this type of instruction would serve as a type of springboard into social action, yet the characteristic of the SSI model that entails using reasoning to inform civic decisions may be enacted to different degrees. In another example, the SSI instructional model proposed by Sadler (2011), Sadler et al. (2007) focuses on "design elements" including providing a culminating experience, and "learner experiences" including negotiating the social dimensions of the issue. Learning objectives include "awareness of the issue," which just stops short of including learning objectives around student practices and skills of civic engagement. Therefore, under the general SSI instructional model, students may make connections to the broader societal context through a culminating activities that have fewer connections to civic engagement (such as activities where students write about their own stance or explain the issue via a mock newspaper article), or the instruction may build on civic engagement skills directly (such as an activity where students develop policy recommendations). The former activities allow students to make interdisciplinary connections and raise self-awareness, but they do not allow students to consider power-dynamics and policies that dictate who gets what and who should be allowed to do what. Nor do they consider the mechanisms by which these social rules and policies get set. As a result, in the typical SSI instructional model, students may or may not have the opportunity to truly practice civic engagement skills in terms of the second component of Levine's definition of civic engagement. They may or may not be asked to make connections to policy-level decisions about political or economic structures that should or could be changed to ameliorate the issue, and the individuals' role instigating change.

Jensen, (2004) work is useful in laying out dimensions of educational activities that are important in developing students' civic engagement behaviors and action-competence in science courses. Namely, Jensen advocates for incorporation of the following elements in lessons addressing civic engagement:

- (1) What kind of problem is it? Knowledge about effects,
- (2) Why do we have the problems we have? Knowledge about root causes,
- (3) How do we change things? Knowledge about change strategies, and
- (4) Where do we want to go? Knowledge about alternatives and visions.

Traditional science instruction more often focuses on the first two dimensions rather than the second two. Our instructional design using an SDM framework included a focus on the first, second and fourth dimensions, and interestingly our results highlighted that our students were particularly lacking in the third dimension; knowledge about *how* to make a change. This dimension may be an area of greater focus in future iterations of the course. Using the SDM model is one way that science courses, even large introductory college courses, can be built to teach science literacy understanding and skills while simultaneously being framed around civic action in a way that supports students' civic engagement and self-efficacy. Incorporating civic self-efficacy, knowledge and skills into science courses at all levels may be important at a time when civics are less frequently a focus in primary and secondary public schools (The National Task Force on Civic Learning and Democratic Engagement, 2012; Shapiro and Brown, 2018).

In summary, our findings support the idea that, in the absence of an ability to engage students in civics through service or experiential learning, it is possible to support students' civic engagement in science classes by intentionally designing curriculum around supporting students' understanding of civic systems, including the role of scientific evidence and the role of individual actions. We found that foregrounding a structured decision-making framework aimed at policy-level solutions, such as that used in this study, provides a useful opportunity to focus science classroom activity around policy-level decisions. The SDM framework we used engages students in using scientific evidence to understand the potential consequences of various policy-level decisions, and understand the important role of stakeholder values as appropriate leverage points in an issue for decision-making. This curriculum framework has the potential to support connections between individual actions that directly and indirectly support policy changes that have societal relevance, but would be strengthened by clearer instruction about the role individuals can play in supporting policy-level changes.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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ETHICS STATEMENT

The studies involving human participants were reviewed and approved by all research was conducted with University of Nebraska-Lincoln Institutional Review Board approval (20140813907 EP). Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

JD developed the conceptual framework and research design. JD and JW worked collaboratively to collect data, develop a coding framework and preliminarily analyze the data. AS finalized the analyses and wrote the initial draft of the paper. JD wrote and revised the manuscript.

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SUPPLEMENTARY MATERIAL

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