Design and Impact of an Undergraduate Civic Science Course

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An interdisciplinary group of faculty members from Tufts University developed an undergraduate civic science course designed to help students better understand and interpret the broad, sociocultural impacts of science. The course teaches principles of civic science and was designed around four facets of learning. These facets lay groundwork for students to fully explore, through dialogue and writing, connections between science, personal values, and civic life. We present an overview of the course structure, challenges and goals, and student feedback from surveys and focus groups about the impact of the course. Students developed an appreciation that science is accessible, personal, relevant, and indispensable to their civic lives—especially those with interests in the humanities and social sciences. Students also learned a "working language" of a science issue and an understanding of the personal relevance of an issue in ways that informed their personal and professional lives. The approach frames science learning around real-world issues of personal relevance that challenge students to find personal and civic solutions to society's most daunting problems that exist at the nexus of science, technology, and society.

The educational goal of civic science is to ensure that students understand the often controversial societal, political, and ethical issues grounded in science in ways that will help them make well-informed personal and civic choices (Garlick & Levine, 2016). Civic science creates opportunities to engage in controversial and complex public issues at the intersection of science and civic life such as the Planned Parenthood debate, the Flint Michigan water crisis, and the opioid crisis. This is a particularly compelling time to create more inclusive public discourse and civic engagement to increase understanding of the relevance of scientific research in ways that can bridge different perspectives on complex, science-based issues (Liu, 2009). As denial of widely accepted scientific evidence grows (Achenbach, 2015) and public misconceptions are fueled, science research faces opposition that undermines its public value (Leif, 2017). The consequences of these challenges that are widening the gap in public understanding of the relevance of science to our everyday lives is increasingly important. The college classroom is an important place for connecting science-based concepts and processes with civic, sociocultural, or economic perspectives (e.g., Marks & Eilks, 2009; SENCER, 2017). Particularly in the first year of college, the classroom is a logical place to cultivate an understanding of science practice and knowledge as accessible and relevant to students' civic lives through civic science.

Tufts University is a private, competitive, predominantly white institution in the Boston area, enrolling about 11,000 students, about half of whom are undergraduates. Offered each spring since 2011, the 25-student first-year seminar, Science and the Human Experience, provides students from various disciplinary backgrounds opportunities to explore the personal, interpersonal, and societal impacts of contemporary and divisive science issues. The interdisciplinary nature of the course was intentional to highlight alternative ways of thinking and framing issues (Klein, 2006). The seminar is a nonrequired course that qualifies for natural science distribution credit, thus providing additional incentive for students from the humanities and social sciences to participate in the course. The course focuses on contemporary and often controversial science topics, and students can suggest topics to cover that arise from current events and are not originally part of the syllabus. The course's team of faculty are from the university's health profession schools and departments, social sciences, and humanities, and faculty from outside the university are invited to speak on topics ranging from the opioid crisis to the role of the media in science.

The seminar was designed with a civic science lens to teach foundational scientific literacy (Roberts, 2007) as a basis for interpreting the impact of science on students' civic lives and values. The course has the dual aim of developing students' ability, whether they become scientists or not, to critically evaluate policy and consume science media as informed, active, and engaged citizens. Students from various disciplinary backgrounds build science knowledge, engage peers in a values-based discussion of science issues, and explore the idea of science issues as relevant, personal, and accessible. Course design is also guided by principles of socioscientific issues pedagogy, which focuses on developing character through moral sensitivity, empathy and reflective judgment, and constructing alternative perceptions in science (Zeidler, Applebaum, & Sadler, 2011). As discussed later in this paper, many students left the course with changed views about science, an enhanced ability to participate in scientific discussions, and a better understanding of the relationship between science and civic life.

Course design

The course, Science and the Human Experience, is meant to teach principles of civic science and was designed around four facets of learning (Table 1). These facets lay groundwork for students to fully explore, through dialogue and writing, connections between science, personal values, and civic life. In the first facet, students developed foundational science literacy and a level of comfort discussing scientific topics. Science content areas were selected only if the teaching team believed them to have complexity, potential personal relevance, broad impacts, and clear interpersonal dimensions. In the second facet, students reflected on the personal relevance and impact of science topics on their lives. The third facet required connecting the societal relevance of a given science issue and its broader economic, moral, religious, biopolitical, civic, legal, or social impacts. The fourth facet, necessary for deep thinking, was understanding the foundations of varied and deeply held perspectives on science issues.

Three specific challenges/goals of the course were for students to (1) develop sufficient scientific literacy in short periods of time, (2) develop the necessary dialogic skills to openly explore alternative perspectives and effectively communicate their own perspectives, and (3) demonstrate development along the four facets outlined in Table 1 in a culminating assignment. Table 2 outlines how we addressed each of these challenges/goals and how they were assessed.

TABLE 1

Four facets of learning in the course.

Facet 1: Developing foundational science literacy	A brief overview of scientific principles on different topics at different points in the semester gave students foundational literacy in select science content areas. Science topics selected were chosen if they were *complex*, held inherent uncertainty, (e.g., personhood, epigenetics) have led to divisive public debate (value of the embryo, pain, addiction, genomics), and could be linked to students' life experience and values.
Facet 2: Understanding personal relevance and impact of science topics on own life	Once students acquired a foundational scientific literacy on the selected topics, they reflected on the *personal relevance* of a topic and how it informed and impacted their lives. This included personal values and beliefs (bioethics, race and privilege, personhood), health-related issues (health consumerism, social determinants of health, emergent biomedical enterprise) and personal choices (right to privacy, reproductive choice).
Facet 3: Understanding societal relevance and broader impacts of science issues	Students gained appreciation of the range of broad societal impacts that link science issues to the world around them. Students acquired an *awareness of the scope* of the societal issues that illustrated their relevance and importance in their lives. The science issues were selected based on whether they influenced or engendered broad economic, moral, religious, biopolitical, civic, legal, and social justice impacts.
Facet 4: Valuing diverse perspectives on science issues through interpersonal engagement	Students engaged in *inclusive discussions* about contentious science issues by learning to respectfully share points of view across a spectrum values and beliefs. This interpersonal learning was situated within conversations about challenges that guided students to value points of view that were initially distant from their own. For example, the realization by students that issues were more nuanced than first imagined led to a more open-minded discussion as it became clear that there may not be a right or wrong answer to the questions raised by a particular science issue (e.g., personhood or when life begins).

Challenge/goal 1: Develop sufficient scientific literacy in short periods of time

Science topics were selected based on specific criteria. The teaching team chose evidence-based science issues linked to a high degree of uncertainty to help students think critically about the "gray areas" that exist. For example, this included questions related to when life begins, how to define personhood and the value of the human embryo, the role of the state in end-of-life questions, and the uncertainty of harms that may be linked to epigenetic changes. Topics were also selected based on their potential relevance to students' life experiences, and whether issues were likely to inform new personal and interpersonal perspectives when studied.

A brief overview of scientific principles was sufficient to give students a foundational literacy in contemporary science issues. Each topic was introduced with a concise background lecture on the terminology needed to develop sufficient "working literacy" for student enagement with the science content. These foundations in science literacy ensured that students of all disciplinary backgrounds had the tools to understand, analyze, and evaluate the social, moral, philosophical, political, and ethical issues that were embedded in this scientific information. Students were asked to take quizzes about the scientific topics discussed, and these were worth 15% of their final grade. As the intent was for students to learn the foundational, working scientific concepts in several science topics (e.g., stem cells, gene editing, ancestry testing, embryo cloning, epigenetics), course faculty viewed these as "proficiency quizzes." Students were required to score at least seven out of ten points on the quizzes, and students who scored below seven were required to review this content and retake the quiz.

Challenge/goal 2: Develop the necessary dialogic skills to openly explore alternative perspectives and effectively communicate one's own perspectives

Students were coached to create guidelines for inclusive participation in classroom conversations. The guidelines helped students understand how to participate in discourse that avoided dogmatic approaches or staking claims to particular viewpoints, a process that we called "inclusive participation." We created a grading rubric for inclusive student participation in both classroom and online discussions, emphasizing the importance for all voices to be heard, and shared commitments to listening and considering multiple perspectives. As many science issues discussed were linked to polarizing public debate, the use of these guidelines in their conversations encouraged students to value alternative points of view that at first seemed distant from their own, and to seriously consider their worth and the broader implications in the world.

At the mid-point of the course, students met individually with the instructor for a conversation through which they could assess how effectively their class participation, both online and in class, had contributed to the spirit of an inclusive conversation. Students assessed their participation by rating themselves on a scale of 1 to 5 on the the items listed in Table 3, where 5 is strongest and 1 is weakest. Effective engagement in dialogue consisted of 10% of the student's grade, emphasizing this approach as an essential learning outcome of the course.

TABLE 2

Course components.

Challenges/goals for learning	Teaching strategies	Assessment
1. Develop sufficient scientific literacy in a short period of time	One to two lectures per topic providing an overview of scientific principles by instructor and guests	Science literacy quizzes
2. Develop the necessary dialogic skills to openly explore alternative perspectives and communicate their own perspectives	Class participation through inclusive dialogue and online discussions	Self-assessed using list of items on inclusive participation (Table 3)
3. Demonstrate development along each of the four facets in a culminating assignment	Op-ed writing assignment connecting science to civic life	Instructor graded using rubric

Getting all members of the class to embrace and practice this set of values and skills was integral in supporting rich, open classroom and online dialogue about several potentially divisive science topics in the course. Through cultivating students' ability to remain in difficult conversations with the intent of deep interpersonal understanding of other perspectives, the complexity of issues was surfaced, and students were able to begin to develop more nuanced and informed views. Course faculty guided in-class discussions that helped students develop a deeper understanding of aspects of their own identities by reflecting on how science issues connect to their core values and beliefs, especially those that touch on their race, gender, cultural heritage, and ethnicity. For example, the Flint, Michigan, water crisis is closely tied to issues of racial discrimination and inequalities (Michigan Civil Rights Commission, 2017). Following the guidelines, students invited other students to reflect on and share their lived experience in ways that could break down stereotypes and inspire empathy and understanding. In addition to classroom discussions, faculty created an online discussion site. This allowed for continued connection between face-to-face classes, and for students to have time to reflect and respond at their own pace (Boud, Keogh, & Walker, 1985). Course faculty posted reflection questions related to a weekly article that presented a critical analysis of or commentary on the science issue to be discussed in class that week. Students often shared personal reflections that revealed the values and beliefs that informed their opinions on the science issues in ways that built curiosity. For instance, during the week on epigenetics, one student wrote:

> Reading the Kahn article, I was struck by the example of asthma in the children of low-income urbanites. I am the child of a father from poor Dorchester, Massachusetts. Both my sister and I have asthma. I can't say for certain that epigenetics are to blame for this, but I can't help but think it.

Students were encouraged to ask questions to better understand their peers' experiences and responses. The face-to-face discussions allowed students to further engage each other, to each find their voice and listen to others with empathy on contentious science issues. Through these online and in-class discussions, students respectfully shared what they cared about on science issues, while learning to entertain a spectrum of values and beliefs that were different from their own.

Challenge/goal 3: Demonstrate development along each of the four facets in a culminating assignment

In the culminating assignment, students were asked to write an op-ed essay. They were expected to demonstrate learning along the four facets in the course: developing sci-

TABLE 3

Items for student self-assessment of class participation for inclusive discussions.

Asked questions of genuine curiosity that deepened an understanding of other's ideas in ways that built interest, trust, dignity, and value into our conversations.
Asked questions/made comments that indicated a degree of comfort with complex scientific information allowing you to contribute to the conversation on your own terms.
Asked questions/made comments that brought out diverse sides of an issue (i.e., hopes versus fears) to help see difference where you only saw commonality and see commonality where you only saw difference.
Shared your personal narrative and insights about something meaningful in your life that supported and deepened an understanding of the issue and gently encouraged others to delve deeper into their worlds.
Shared aspects of your identity that could be understood by others, so they could meet you where you are "coming from" with empathy and curiosity.
Shared your perspective with humility, by balancing principled commitments to your beliefs with an openness to new ideas, contradictory information, or being wrong.
Shared your personal narrative with a relatively low self-focus while maintaining an accurate assessment of your abilities and accomplishments.
Expressed views about the intellect of others without feeling entitled to the intellectual privilege of your own accomplishments, so you are better able to give your peers the credit they deserve.
Asked questions/made comments that indicated a degree of comfort with complex scientific information, allowing you to contribute to the conversation on your own terms.
Able to consider complaints and criticisms seriously by being willing to "own" your intellectual limitations by not dismissing criticism, but rather by being responsive to it.

entific literacy, understanding the relevance of science in their own lives, understanding broader social impacts of science, and valuing diverse perspectives on science issues (Table 1). The exercise of writing an op-ed fostered critical evaluation and reflection skills on science-based topics that mattered to students. It required students to provide an argument supported by carefully chosen science data or evidence, present views with a critical viewpoint, and make a case that would leave readers feeling that there was a way out of the quandary being addressed. The assignment was scaffolded through an in-class workshop with science journalists from Tufts Office of Public Relations to make sure that the op-ed topic would be timely and suitable for publication.

There were three distinct stages in the writing of the op-ed that guided students to understand op-ed structure and intention. Students first submitted a one-page outline of their op-ed that included references they expected to use to support the position they took in their op-ed. This outline was graded using a rubric, and students received written feedback from the instructor. The second step was a class to workshop op-eds where students had an opportunity to share their "work in progress" with the class and faculty who offered feedback. The third step was for students to write the op-ed. A separate rubric was given to students to clarify expectations for the written op-eds. This rubric provided guidance along several criteria, such as the degree to which the op-end is clear and convincing, supported by evidence, and timely and relevant.

Student feedback

Across three semesters, all students enrolled in the course were invited to complete pre- and postsurveys on their beliefs about science literacy, their interest in science as a field of study, the relevance and importance of science, the importance of connecting science to civic life, and the importance of hearing diverse viewpoints on divisive science issues. We used paired *t*-tests to identify statistically significant changes in students' self assessments. The pre- and postsurveys indicated notable changes in students' perceptions of their scientific literacy, importance of connecting science and civic life, and importance of hearing diverse viewpoints. Table 4 shows how students rated themselves on selected items at the beginning and end of the course. The largest pre-/postchanges were in their views of their own scientific literacy. After the course, on average students reported feeling more able to understand science-based articles in popular media and more confident that they have the tools needed to form opinions about the impact of science on their lives.

In addition to surveys, three focus groups were held: one with students who were finishing the course at the time of the focus group (six students), and two with course alumni who were still students at the university (four students in each group). The instructor (Garlick) was not present at the focus groups, which were facilitated by an education researcher (Bergom). The instructor and facilitator worked together to develop guiding questions for the focus groups. The discussions centered around aspects of the course that most affected students' learning, how the course changed students' thinking about science, how the course changed students' views of the relationship between science and society, and what students learned that they plan to apply going forward. Student reflections in the focus groups are summarized below.

Developing foundational science literacy

The course was designed to teach science literacy, which includes feeling comfortable reading and understanding popular scientific publications and engaging in well-informed conversation about specific topics in science. One student explained, "We can…engage with the [science-related] conversation, take it upon ourselves to read more and educate ourselves more, now that we know the foundation." Another student reported feeling a sense that barriers to engaging with science were reduced, commenting, "I think it was reaffirming for me to be in a space that was like, 'Yes, you can do science and you don't need to be a scientist.'"

Guest lecturers with science expertise from experts in industry and academia taught basic scientific concepts such as epigenetics, genetics, and stem cell biology. They presented points of view that expanded or challenged students' thinking, either about a scientific topic or about how we can use classroom dialogues to speak across difference on divisive science issues. A student commented that the guest lecturers "always expanded my understanding of science in some way while also testing what I believed." Another said that the different viewpoints of guest lecturers "showed us that a dialogue isn't one side just yelling and the other side just yelling theirs." In this respect, two main course components converged—overview of scientific principles and inclusive dialogue and conversation—to create a cohesive learning experience for students.

Understanding personal and societal relevance of science issues

Many students reported that the course helped them to see connections between science and social and economic issues that they had not seen before. Understanding these connections was eye-opening for science majors and nonmajors alike. Most students in the course identified as having strongest interests in the humanities or social sciences, and were eager to fuse these interests with a deeper appreciation of issues based in the natural and life sciences. A first-year student majoring in sociology explained:

> After this class… I see how sociology and science have all these intersections…Now as a sociologist, I am capable of bringing science into the way I think about social change and it has really profoundly changed how I conduct activism and it's changed how I view interdisciplinary studies.

Students with little background in the natural and life sciences reported that they were motivated to acquire science literacy and quickly became conversant in the scientific topics discussed. They gained confidence in their abilities to understand and process scientific information that applied to contemporary issues they cared deeply about.

At the same time, students with a natural and life sciences orientation said they deepened their connection to these disciplines as they developed new perspectives on science issues by grappling with personal and moral dimensions of the issue. A student majoring in biology with plans to practice medicine commented:

> The big thing for me was seeing that connection between science and the world around in more than just a physical or chemical way. Seeing the connections in a very social way. For example, I remember talking about health and healthcare and access and I thought, "Oh I'm going to be a

TABLE 4

Comparison of pre/post survey feedback about student perceptions of their learning.[1]

	Mean PRE[2]	Mean POST	Difference	Significance[3]
I am "scientifically literate" and am able to understand articles in popular scientific publications such as *Scientific American* or the science section of the *New York Times*.	3.11	4.26	1.15	***
I have the tools that I need to form my own opinions about the impact of science in my life.	3.18	4.29	1.11	***
I usually feel very comfortable in the conversation when I am discussing a topic in science.	2.62	3.49	0.87	***
I feel that science is personal and very relevant to me and my daily life.	3.60	4.11	0.51	*
I feel that science is of great importance to our country's future growth and development.	4.69	4.85	0.16	*
Being scientifically literate is an important part of responsible citizenship.	4.06	4.66	0.60	***
It is important to know where political leaders stand on scientific issues such as global warming and stem cell research.	4.51	4.8	0.29	*
I think people with expertise in the humanities and social sciences increase their understanding of the impact of science from discussing scientific topics with scientists.	4.26	4.61	0.35	**
Being in a class with people with different points of view furthers my learning about complex issues.	4.60	4.83	0.23	*

[1] Sixty-one students responded to both the pre- and postsurveys. However, some items were not included in the first administration of the survey and were added later, so the number of responses collected for those items is fewer.

[2] 1 = Strongly disagree and 5 = Strongly agree.

[3] *p < .05, **p < .01, **p < .001

> doctor and I'll treat people, and it's simple." And it was a super naïve view because it is not simple at all, and people's access to health care and so many things impact the kind of doctors they can see and the kind of treatment they can get.

Science-oriented students found value in developing science communication skills needed to explain complex, scientific jargon to their fellow students who were less conversant on science topics.

Considering interpersonal perspectives on science issues

Intentional, sustained discussion was frequently mentioned by students as a key aspect of the course that influenced their learning. Discussions provided opportunities for students to talk about their own—and hear about others'—experiences, beliefs, and "truths" on complex, uncertain, or divisive science issues, as some students said. In these conversations, students felt that they did not have to be experts on a topic to have on opinion or to engage in conversation about the topic.

> I think that learning facts that conflict with your experience or your opinions [and] hearing about someone else's life and their experiences and how their experiences have shaped their views are totally different things. It allows you to be more open and even if you aren't going to change sides it lets you think about your supposed "enemy" in a different way and shows you that there are no enemies in this kind of dialogue. [There are] different opinions, and you can be open to at least understanding if not supporting that other opinion.

In the discussions, students were challenged to reflect on and articulate their own opinions and beliefs, but they also were challenged to consider other opinions related to controversial science-related topics—such as stem-cell research, the value of the human embryo, or epigenetics—that may differ from their own. Several students reported that the discussions deepened their ability to be empathic listeners.

> This class has really helped [me] realize that everyone has their own truth … I think that what this class has helped me do is to find empathy. To hear what someone is saying and actually listen to it and try to figure out where that comes from and how you're situated in that other truth.

Another student expanded on the idea of empathy as an outcome of the class discussions, saying, "I think this class teaches empathy more than anything else. The ability to connect with a human on a very basic level, that we all have these pasts, these histories, that inform how we view the world." A student in one of the focus groups reflected that this ability to listen to opposing viewpoints is especially important in the current sociopolitical climate in the United States. The student commented:

> Frankly I think that is something that has been lost a little bit on college campuses these days is the ability to have dissenting opinions and the ability to listen to someone who has viewpoints you disagree with. And be able to calmly disagree and not disagree with them as a person. I think those are all skills that this class has reinforced.

It is important to note that the level of ideological diversity of students in the class or on the campus may affect the perspectives that they hear from one another and, thus, the learning experience. An ideologically diverse group of students means that students are more likely to face dissent on their core political values, while an ideologically uniform group could mean that students are not forced to question their underlying beliefs because students agree on them. On some topics in this course, such as when life begins, students were squarely on opposing sides of the issue in discussions. Other times, though, they tended to be in agreement, such as on the topic of social determinants of health (e.g., systematic injustice based on race and class versus genetics and life choices).

Related to ideological diversity, campus climate for sharing political beliefs may affect how open students feel they can be in these class discussions. In one informal survey of Tufts students, most respondents identifying as conservative indicated that they rarely or never feel that the campus climate allows students to openly share their political beliefs, while only a small minority of students identifying as liberal felt this way (Joung & Foster, 2016). It may be the case that the Tufts campus is a particularly homogenous one in terms of political ideology, and on other campuses disagreement in course discussions could more deeply challenge students' underlying assumptions or worldviews.

During the course, the instructor strove to create an inclusive classroom environment in which all students were comfortable participating. Students reported feeling that the sense of community in the class was important for creating supportive, inclusive spaces where students were comfortable sharing viewpoints and engaging with others who disagreed with them. One student commented, "We all cared about each other and wanted to foster a dialogue and wanted to really be invested in what each other was saying and invested in each other's projects." The inclusive environment contributed to the success of the dialogues.

Conclusion

Through the lens of civic science, students developed science literacy in ways that were as much about understanding scientific facts as they were about appreciating the humanizing principles underlying these concepts. Students developed an appreciation that science was accessible, personal, relevant, and indispensable to their civic lives—especially those with disciplinary interests in the humanities and social sciences. Students learned a "working language" of a science issue and an understanding of the personal relevance of an issue in ways that informed their personal lives and professional growth. This lays the groundwork to further develop civic science learning approaches for training students in civic capacities that include public and collective evaluation, strategic thinking, and one-on-one organizing (Gastil & Levine, 2005).

The course also provides new opportunities to advance intercultural competence, diversity, equity, and community engagement initiatives through science education that invite groups that have been traditionally underrepresented in higher education (Sturm, Eatman, Saltmarsh, & Bush, 2011). The science-based, dialogic pedagogy we developed promotes an inclusive classroom climate in which a diverse spectrum of opinions and beliefs are discussed that inspires curiosity and empathy for diverse points of view. Such inclusive conversations ask students to reflect on and share questions that break down stereotypes and lead to a greater understanding of how individuals acquire particular perspectives on science issues. In this way, students deepen their understanding of both themselves and divisive science issues by encouraging others to elaborate on their formative, lived experiences to build mutual trust. In this way, it becomes possible for students to gain a sense of wonder not only about science, but about each other.

In summary, our approaches frame science learning around real-world issues that challenge students to find personal meaning and civic solutions to society's most daunting problems that exist at the nexus of science, technology, and society. The approach encourages students to ask questions such as: What does it mean for a scientist to be an active citizen? Which aspects of science issues are authentically scientific as opposed to those that are normative, involving clause or ethical principles? How should science education be institutionally organized in relation to civic practices and governance? Teaching civic science through these questions offers a path forward by modeling civil, inclusive discourse on science-related, pubic issues within a safe and respectful classroom environment that informs ways to bring civility into our daily lives. By using the classroom to build open-minded discourse, we can begin to leave science dogmatism and polarization behind and work together to find compassion and common grounding on issues we care about to improve the quality of our national science conversation and our lives. ■

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