Secondary Science Teacher Beliefs about Science Education for Citizenship

By

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Abstract

This study examined secondary science teachers' conceptions of democratic citizenship and their beliefs about how citizenship relates to science education. These beliefs and conceptions were studied through a framework comprised of theories of belief, citizenship education, and civic engagement with science. Data were collected from 10 working teachers representing all kinds of high school science courses in the form of two one-on-one semi-structured interviews. Relevant documentation of their teaching (e.g., syllabi, student handouts, lesson plans, assessments) was also collected and analyzed.

The first key finding of this study was that participants think of citizenship as an obvious and uncontroversial goal for their teaching. However, citizenship was found to be a nominal concern, named only after specific prompting, while college and career readiness were the main justifications given for science education. Participants believed that citizenship and career aims were both met simultaneously by science education as currently practiced.

The second but primary finding indicated that participants worked from a model of "well-informed" citizenship. In this model, the role of science is to supply reliable knowledge, while the role of citizens is to adopt and integrate this knowledge into their civic discourse. These representations flattened the reality of both how scientific knowledge is produced as well as used. Participants framed public-science dysfunction as a knowledge deficit problem that should be remedied by more effective means of top-down communication of facts.

The third and final set of findings related to what participants felt were appropriate and effective ways for their teaching to address citizenship goals. Most participants sought to limit the presence of sociopolitical issues in their teaching. Such issues were sometimes mentioned as external points of reference meant to increase students' motivation to learn traditional science content. Relatedly, participants also sought to maintain a professional border between science and the humanities or social studies. This mirrored the strict separation between science and politics they thought not only existed but served as a source of credibility for science. For the minority of participants who did feel it was appropriate to cross disciplinary borders to achieve civic aims, school structures and external mandates on their curriculum and instruction were serious impediments.

This study adds to research on science education for citizenship. Most work in this field attend to science education for citizenship by making theoretical arguments for reform. Many others serve as models of practice that demonstrate the effectiveness of a chosen reform. However, little is previously known about how science teachers who are not already involved in those specific reform efforts think about citizenship and how to teach science toward it. The implication for teacher educators is that a deep belief in the power of traditional science teaching to overcome misinformation and citizens' lack of trust in scientific experts must be addressed. Additionally, for those arguing for interdisciplinary teaching, attention must be paid not only to limitations imposed from outside the science classroom, but to the science teacher's full range of commitments to remain within their discipline.

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Chapter 1: Introduction

Justifications for science education have long been steeped in the language of democratic virtue. According to the landmark report *Science for All Americans*, we should expect science courses, among other things, to equip citizens "to participate thoughtfully with fellow citizens" (Rutherford & Ahlgren, 1990, p. *xiii*). Science education for those authors is a crucial component of our attainment of an "open" and "truly just society" (p. *xiii*). The intervening decades have only cemented the presumption of a connection between science education and citizenship. Presently the *Framework for K-12 Science Education* (NRC, 2012) holds a prominent place of influence for science teachers. That document—which set the stage for the Next Generation Science Standards (NGSS)—puts forth, among aims like personal enrichment and helping students make "informed everyday decisions" (p. 7), the learning goal that science courses should improve the "civic decision making [that] is critical to good decisions about the nation's future" (p. *x*). It goes on to say that citizens need to learn science so they can "engage with the major public policy issues of today," such as "determining how to invest public funds for water supply options" (p. 7). The most recent iteration of this rhetoric is found in the National Academies of Science's *Call to Action for Science Education* (NAS, 2021). The authors there firmly state in the opening pages that "knowledge of science and the practice of scientific thinking are essential components of a fully functioning democracy" (p. 7). Indeed, it seems de rigueur at this point to invoke civic purpose as a fundamental reason for school science.

Yet as much as it is routine to link science education with improved democratic decision-making, this rhetoric is not matched with strong or clear guidance for practitioners as to exactly what such an education would look like in real classrooms. The Academies' *Call*, for example, implies that knowing science content knowledge coupled with thinking as scientists do will improve students' abilities to engage with public issues that involve science. They tuck "how science can be used to solve local and global problems" among their list of learning goals (p. 8). However, the big "Action Areas" they advocate for seem to set an entirely different agenda. The report's core aim is to "elevate the status of science education" through standardization and accountability regimes, to broaden "STEM opportunity" to be more inclusive by leveraging partnerships outside of formal schooling, and to document the effectiveness of actions seeking to expand opportunity (pp. 9-10). I highlight these not to refute the value of extending professional opportunities to a wider range of students and improving the quality of science education for all, but to lodge my skepticism that any of these action items will have anything to do with the specific problem of science education *for citizenship*. That is, I would assert that our current public-science dysfunction has less to do with the lack of scientific knowledge or economic opportunity than we might think.

For its part, the broad strategy that *Science for All Americans* advised was to pare down ballooning esoteric content to make room for focusing on learning about the nature of science as well as its social purposes (Rutherford & Ahlgren, 1990). This is an amplification of Dewey's directive from over a century ago to favor science as a method over the uptake of facts as most beneficial to "the masses" (Feinstein, 2015; Rudolph, 2014). The newer Next Generation Science Standards (NGSS) seeks to advance the nature-of-science argument as well but has dispensed with the nod to educating about the social purposes of science. While the terms "citizenship" and "citizen" appear a handful of times, they are only used in passages meant to justify the revamping of the standards to teach the "cross-cutting concepts" and "practices" *of* science (NRC, 2013). There is no weaving together of democratic citizenship and science to be found there.

The fundamental problem with this kind of rhetoric is that the meaning of citizenship, and its connections to science, are left implicit. The link between learning science and citizenship is easy to claim, and it would seem foolish to argue against it. Yet it still requires a firm theoretical grounding that is sorely lacking in the policy documents or the relevant literature (Rudolph & Horibe, 2016). The citizenship education scholar Ian Davies critiqued this kind of tacit presumption, writing that "some science educators who claim to be interested in citizenship education are in fact doing little more than justifying their own subject area. The understanding *of* science is the focus; 'citizen' is used as a slogan, or instead of 'person'" (2004, p. 1757, emphasis added). Thus, the usefulness of citizenship as a guiding principle for science education is diminished.

While theories of democracy and citizenship defy neat summation, some basic definitions can be made here at the outset. The social studies scholar Walter Parker describes a citizen as a "public actor" which he contrasts with a state of "idiocy" that is marked by a "self- and familial-indulgence at the expense of the common good" (2003, p. 33). He writes that "democratic citizens" are "people who are capable of democratic living, who want it, and who are determined to achieve it—to work toward the fuller realization of democratic ideals" (p. 1).

But what is this kind of living? What are these ideals that rise to the vaunted status of democracy? Political theorist Robert Dahl answers this by setting forth a few criteria for democratic life. For an association to be democratic, all members must enjoy *effective participation*, *voting equality*, *enlightened understanding*, *control of the agenda*, and *inclusion of adults* (1998, pp. 37-8). These labels on their own are opaque. They are broad enough to describe how both a bowling league and a nation-state may be governed. But these basic parameters allow one to imagine a tangible way to achieve Dewey's oft-cited idea of democracy: "a mode of associated living, of conjoint communicated experience" (1931, p. 101). The point of citizenship is to be involved in collective self-rule. Democracy at its core is a way to decide together across differences. I join with Hess and McAvoy in saying that we are fulfilling our role as citizens "when we are democratically making decisions about questions that ask, 'How should we live together?'" (2015, p. 4).

Science educators—or at least those who wrote the policies cited above—seem to take it as an article of faith that good science teaching (by which they mean science teaching that instills an understanding of the canonical ideas of the scientific disciplines) cannot help but increase students' capacities to engage with these normative questions about how we live. From their perspective, school science is essentially already aligned with the citizenship goal; we merely need more of it or for it to be more effective in its current form (Rudolph, 2023). This position assumes that students will elsewhere and by other means learn how to use the science knowledge they learn in civic venues that lie beyond the four walls of the science classroom.

Educating citizens for the duties of citizenship however requires a different path. Citizenship entails a particular set of learning outcomes that can only be achieved through explicit schooling (Castro, 2013; Gutmann, 1999). Furthermore, scholars argue that citizenship education should be distributed throughout the curriculum—ideally that an entire school is infused with it (McCowan, 2009; Syed, 2013). In other words, the science teacher needs to be included in the goal of making citizens as well. This is a challenge to the notion that civic engagement with science ought to be kept to the margins in a science classroom or left out altogether. Such challenges have routinely been made in recent decades, and calls to undertake reform in order to firm up science education's claim to citizenship education are now voluminous (e.g., Davies, 2004; Millar & Osborne, 1998; Osborne, 2010; Sadler, 2011). They all share in observing that science education has so far not adequately addressed students' understanding of science as an integral part of their role as citizens.

What is to be done? What kind of science teaching is *for* citizenship? Two kinds of answers emerge from the science education literature. The first idea for how to make science education support citizenship has to do with teaching what science is. If students could come away with an understanding of the social character of science and its epistemology, according to this reasoning, then they would have a better sense of the value of scientific expertise and how to engage with it in civic contexts (Collins & Evans, 2017; Hodson, 2011; Kind & Osborne, 2017; Kolstø, 2001; Ryder, 2002). An attractive feature of this strategy is that it should already have buy-in among science teachers. It seems eminently sensible on its face that a science teacher should teach an authentic version of how science produces knowledge (Chinn & Malhotra, 2002). However, success in this domain—teaching students how scientific knowledge is produced in schools with the teachers we have—has consistently proven to be an elusive goal (Collins, 2015; Millar, 2006; Rudolph, 2019).

The second common approach has been for science teachers to bring sociopolitical issues that involve science into the science curriculum. Proponents of employing salient issues that necessitate learning both scientific and non-scientific dimensions in the classroom—often coming under the heading of *socioscientific issues* (SSI) teaching (Levinson, 2007; Zeidler et al., 2005)—argue that deliberating such issues is well-aligned to citizenship education (Ratcliffe & Grace, 2003; Sadler, 2011). A reform of this kind, however, invites a host of problems for science educators. Even when teachers are convinced of the value of SSIs, they are typically ill-prepared to carry out SSI instruction (Amos et al., 2020; Lee & Yang, 2019; Macalalag et al., 2020). This is not surprising considering that it requires science teachers to step outside of their traditional disciplinary bounds. This move would invite a *political* discourse alongside a scientific one (Raveendran, 2021). Studies of teachers attempting SSI teaching often find that science teachers are at least uncomfortable and at most unwilling to teach SSIs in ways that give students opportunities to engage as democratic citizens (e.g., Harris & Ratcliffe, 2005; Levinson, 2004, 2010). While SSIs would seem to offer a clear connection to student engagement with matters of justice and equity in the context of resolving a political issue, teachers tend to avoid the political aspects in favor of teaching only the science involved (Ratcliffe & Millar, 2009; Wong et al., 2011).

Understanding the difficulties associated with implementing a particular educational reform in context is surely critical. But the problem of aligning science education to citizenship is not limited to a teacher's skillset or the hospitality of the school environment. The more fundamental problem is the slipperiness of the term citizenship coupled with vague and implicit ideas about *how* science education can also be citizenship education. Science teachers are not to be singled out here; this is a pervasive problem throughout society. Many Americans, though proud of their status as citizens in a democracy and reverent of the rights and freedoms they proclaim to enjoy because of it, move through the world with largely inconsistent and incoherent conceptions of democracy (Taylor, 2018, 2019). Dahl has argued that democratic citizenship has become "not so much a term of restricted and specific meaning as a vague endorsement of a popular idea" (2008, p. 2). We tend to be sentimental about citizenship without being able to articulate what it means or how to develop it. There is little reason to think that science teachers are more precise in this regard (Davies, 2004).

This lack of specificity in what we mean by citizenship is a problem because how teachers conceptualize learning goals is of central importance for understanding how they teach.

In considering the difficulties of a different kind of reform trend, constructivism, Windschitl writes: “One of the most powerful determinants of whether constructivist approaches flourish or flounder in classrooms is the degree to which individual teachers understand the concept of constructivism.” He goes on to warn against the harm done by misconceptions taking root: “Fragmented teaching strategies based on superficial understandings of the reform literatures have mutated into the pernicious, now-predictable mythology that has attached itself to constructivism. A list of common pseudoprinciples has distorted the very concept of constructivist teaching” (2002, p. 138-139). The same is true for the idea of citizenship. In a study of 16 middle schools’ resistance to democratic reform, Oakes and colleagues found that “the superficial attention paid to the foundational theories of learning and citizenship guaranteed that many of the changes in school would remain superficial” (Oakes et al., 2000, p. 70). If science education for citizenship is to be successful, the teachers we rely on to carry it out will need the opposite of mythology; they will need to understand and commit to a justified, articulate model of science education for citizenship.

Educating citizens in school science is spoken of as an unambiguous priority. At the same time, science educators perennially struggle to address it. What science teachers mean by citizenship and the character of their commitment to that goal remains unclear. Few if any studies are found in the literature that explore science teachers’ views on citizenship education. This dissertation, therefore, focuses on two related problems: (1) how science teachers conceptualize citizenship as a goal of instruction, and (2) what they believe their role is in educating students for citizenship. This study aims to move beyond sunny platitudes—the slogans and vague endorsements—and more closely examine how science teachers are thinking about citizenship as part of their work. To that end, I pose three Research Questions:

RQ 1: How are secondary science teachers interpreting and responding to calls to teach science for citizenship?

RQ 2: How are secondary science teachers conceptualizing citizenship and how do they relate this vision of citizenship to science?

RQ 3: What kinds of curriculum and instruction do secondary science teachers view as being appropriate and aligned to democratic citizenship education?

These questions were addressed through a qualitative interview study of ten secondary science teachers across a diversity of science subjects and school sites. The bulk of the data came through two semi-structured, individual interviews with each participant, totaling approximately 20 hours. I also collected and examined relevant syllabi, student handouts, lesson plans, and other relevant materials. Interviews were conducted remotely, over Zoom, out of necessary precautions due to the COVID-19 pandemic. The study took place during the winter and spring of 2021, a time of political and scientific tumult with few available comparisons. We had just witnessed a non-peaceful transfer of power in the executive branch of the national government and were amid the main thrust of vaccination efforts to stanch the spread of a virulent disease that had wrought so much havoc. Participants were still working in remote or hybrid teaching situations. A sense of instability and importance was always palpable during our conversations. But how science teachers ought to respond to such moments—how best to prepare their students for a democratic life destined to bring them into routine confrontation with murky scientific issues—was anything but clear.

Overview

In this introductory chapter, I have argued that science teachers' thinking about citizenship as a concept and a goal for science education is significant for achieving science education for citizenship. While policy documents and scholars have long been quite vocal that citizenship should be or already is a goal that drives science teaching, the voices of teachers are remarkably silent in the literature.

In Chapter Two, I examine various arguments and trends found in the science education literature for kinds of science teaching that are thought to support citizenship goals. This review is grounded in relevant work coming from outside of science education: research in citizenship education as well as science studies literature about civic engagement with science. I conclude the chapter by situating this study within a theory of teacher beliefs and reviewing literature about teachers' beliefs about science education for citizenship.

In Chapter Three I explain and justify the data collection and analysis methods. The fourth chapter is devoted to the findings of the study. I discuss how these findings relate to other similar works and conclude with reflections on some implications of this study in Chapter Five.

Chapter 2: Conceptual Framework

In this chapter, I explore connections between citizenship and school science. A goal of this chapter is to make explicit what so many policy statements leave as implicit: to establish a grounded framework for science education for citizenship. My assumption in doing this review work is that teachers cannot teach toward a citizenship goal that they (1) are unclear about and (2) are not committed to. To address how science teachers may be conceptualizing citizenship, I begin by outlining influential contemporary discourses of citizenship education and show how these are tied to underlying democratic theories. I follow this with a discussion of research on civic engagement with science. In that section, I engage primarily with science studies literature that examines the relationships between science and democratic citizenship. With those two conceptual frames in place—citizenship education and civic engagement with science—I discuss two main ways that science education is thought, by scholars, to align with citizenship goals. In the final part of this chapter, I introduce the theoretical lens of *teacher beliefs* and review research that suggests ways that science teachers' beliefs may constrain or afford science education for citizenship.

A point about terminology is in order here. I do not say "citizen" to mean that only people with legal status in the eyes of the State should be allowed entry into collective decision-making or be extended civil rights. For some, the term may be irredeemable due to its employment in defense of nationalism. It is certainly true that American public schools were enlisted in racist and colonial assimilation projects under the banner of "citizenship education" (Stratton, 2016). Perhaps "social justice" or "anti-racist" education is a better choice of words. Whatever we call it, we need ways of thinking about the civic and political agency that are critical of Eurocentric and assimilationist notions of citizenship identity (Knight Abowitz and Harnish, 2006). The framework outlined below is attendant to this issue.

I still opt to make this study about “citizenship” for two reasons. First, the research objective is to explore in an open-ended fashion how teachers conceptualize citizenship. I therefore cannot foreclose on any meanings they might align to—conservative or protectionist forms included. A premise of the study is that “citizenship” is the word so commonly used yet so rarely clarified. The culture and politics of schooling make “citizenship” central and thus unavoidable despite its potentially negative connotations. If a teacher were to focus on citizenship as a legal status, then that would be a significant finding. Second, I join with recent education scholars who advocate for a more inclusive meaning of citizenship (e.g., Banks, 2009). Exclusive, nationalistic concepts of citizenship are thought to be perversions of the idea of democratic citizenship that are unworthy of that label. That is, when “citizenship” refers to something other than a broadly inclusive notion of equality, this constitutes a misuse of the term (Allen, 2004; Barber, 2003; Dahl, 1998). When I say “citizenship” I mean to focus attention on the agency people should be granted and taught to exercise for bringing about change in their communities by democratic means (Levine, 2014). As much as possible, I employ “democratic citizenship” as Parker (2003) does to highlight these aspects.

Various Renderings of Citizenship Education in Contemporary American Schooling

There has never been wide agreement about how best to organize teaching for the deliberate pursuit of citizenship (Castro & Knowles, 2017; Parker, 1996; Westheimer, 2015). In this section, I map out the varied conceptions of citizenship education likely to have a bearing and influence on contemporary educators. To do so I utilize a framework of citizenship education from Knight Abowitz and Harnish (2006). This is an appropriate lens because, rather than offering an abstract philosophical study of the meaning of citizenship, Knight Abowitz and Harnish built their framework from the more everyday milieu of the schoolteacher. In doing so, they relied on a discourse analysis of the relevant civic education policies, curricula, and scholarship pertaining to schools in Western liberal democracies, particularly the United States. This is the context in which the participants in this study were currently teaching.

Knight Abowitz and Harnish's framework maps out the multiple citizenship discourses likely giving shape to how teachers conceptualize citizenship education. They found that two discourses—*civic republican* and *liberal* citizenships—were prevalent and thus the more influential perspectives. A third type, a *critical* discourse (which includes emergent theoretical and scholarly discourses with such labels as feminist, cultural, reconstructionist, and transnational citizenships) was found to be nascent and marginal in educational practice.

Civic Republican Citizenship

What Knight Abowitz and Harnish categorize as education for civic republican citizenship is an education aimed at strengthening political communities. They found that "cooperative participation in pro-government activities (voting, involvement with political parties, and civic activities) is stressed in civic republican texts" (p. 657). They also note that this discourse of citizenship carried a meaning of exclusivity of membership that other discourses did not. They argue that "the nationalistic meanings of citizenship found in civic republican discourse pose a direct challenge to the more cosmopolitan and transnational perspectives" (p. 658). That is, American schools tend to focus on citizenship as a set of special privileges non-US citizens do not enjoy.

Knight Abowitz and Harnish's findings about how civic republican ideals are represented in education draw attention to a central tension in how we conceptualize citizenship. On the one hand, it is seen as the proper role of education to engender a commitment to democracy among students (Gutmann, 1999; Parker, 2003). From this vantage point, “habitually express[ing] the values of love and service to one’s political community” can be taken as a virtue (p. 657). But on the other hand, civic republican educators may adhere to a notion of political community so narrow as to be out of step with democratic ideals of inclusivity and equality (Dahl, 1982, 1998). How we resolve this tension comes down to whether we view democracy as an accomplishment or a path (Parker, 2003). Seeing democracy as a prior accomplishment leads one to take on a custodial view of citizenship—to be a citizen is to maintain and conserve a hard-won democratic state. This is contrasted with a democracy-as-path perspective, which would have citizens work at nurturing a body politic that is both diverse *and* unified in its commitment to democratic ideals (Parker, 2003).

It is precisely this custodial notion of citizenship that Knight Abowitz and Harnish found to be so prevalent in civic education. The texts they analyzed tended to emphasize learning US history as a democratic success story. Procedural knowledge of how existing political and civic institutions—elections, judicial systems, government structure, and the like—were of primary importance in the civic republican discourse. At the same time, the “civic virtues of central concern are self-sacrifice, patriotism, loyalty, and respect” (p. 659). They furthermore found that educational texts in the civic republican discourse conveyed a distinct tone of American exceptionalism. The superiority of the U.S. democratic system, as dreamed up and established by heroic figures of American history, is taken for granted rather than critically assessed against other political systems, real or imagined. There is a tendency in US citizenship education to prioritize patriotism in a way that simultaneously suppresses dissent and activism.

Liberal Citizenship

A liberal discourse of citizenship, according to Knight Abowitz and Harnish, highlights two primary values: the “freedom from the tyranny of authority” and “the deliberative values of discussion, disagreement, and consensus building” (p. 663). Liberalism rejects the inherent authority of institutions like monarchies or organized religion and therefore seeks to consciously redistribute power and make it accountable to citizens. From the liberal perspective, citizens are primarily viewed as rights-bearing individuals who are also expected to make decisions as a collective. Which rights, how far they extend, and how to conceive of and achieve equal treatment are sources of endless and complex disagreements in a liberal democracy (Bohman, 1996; Gutmann & Thompson, 1996). This is resonant with political theorist Robert Dahl’s argument that the tension between autonomy and control is the fundamental dilemma underlying a pluralistic society (1982). Educators who conceptualize citizenship as *liberal*, as Knight Abowitz and Harnish define it here, are concerned with preparing students to navigate the political spaces where individual rights will occasionally lead to conflict.

Perhaps the central responsibility of liberal citizenship is participation—directly or through elected, accountable representatives—in the making of just laws and policies based on reason. Scholars Amy Gutmann and Dennis Thompson, in their explanation of deliberative democratic theory (2004), argue that the legitimacy of a democratic decision hinges on the reasons given for the various proposed courses of action. For them, a key activity of deliberative democratic citizenship is “presenting and responding to reasons…with the aim of justifying the laws under which they must live together” (pp. 3-4). One criterion for democratic deliberation is that the reasons must be publicly accessible, both in the sense that the reasons are understandable and that the process is conducted in the open so that those reasons can be understood, and the associated proposal judged as warranted or not. Another criterion is that the outcome of a deliberative democratic process is binding for some time—that it matters and has an effect outside of the act of deciding. Democratic deliberations are therefore not merely academic exercises for displaying participants' argumentation skills. They are not a collection of individual speeches given to persuade someone to vote a certain way. They are rather a process for stakeholders of differing morals to work toward mutually acceptable decisions (Bohman, 1996; Gutmann & Thompson, 1996, 2004).

Deliberation, as a central activity of ideal liberal democratic citizens, is therefore also a classroom practice commonly advocated for, particularly in the social studies (Fallace, 2016; Pace, 2015; Parker & Hess, 2001; Simon, 2005). Walter Parker argued that political dialog among students is a necessary part of their democratic education. He wrote, "This interaction in schools can help children develop the habits of thinking and caring necessary for public life—the courtesies, tolerance, respect, the sense of justice and knack for forging public policy with others *whether they like them or not*" (2003, p. 78, emphasis in original). Deliberations primarily deal with open questions that require the exploration of multiple ideas and viewpoints. In this sense, the deliberation is educative because the participants seek to know what they and, crucially, what their fellow deliberators value and how they are thinking about a political issue (Hess, 2009; Parker, 2003, 2011). The classroom, as a public space meant for learning, is thought to be a potentially good site for deliberation, even when the wider world lacks such forums (McAvoy & Hess, 2013). Citizens need spaces where they practice developing ideas "by trying them out in their own mouths" (Simon, 2001, p 171). Interactions can be facilitated in the classroom, difficult as it may be, where citizens can begin to think of each other less as rivals and adversaries than as political equals (Allen, 2004; Mansbridge, 1983; Sandel, 2022).

Critical Citizenship

Knight Abowitz and Harnish (2006) note that civic republican and liberal conceptions of citizenship, firmly rooted in the Western European Enlightenment tradition, dominate citizenship education in society and schools in the United States. While those discourses highlight essential aspects of democratic citizenship—membership in a political community (civic republicanism) and the public resolution of issues (liberalism)—they tend to be interpreted narrowly by educators. A civic republican ideal gets flattened into symbolic gestures of patriotism like reciting the pledge of allegiance. Texts like the Declaration of Independence and Bill of Rights are meant to be taken for granted and revered rather than subjected to a careful, values-based assessment.

Educators who advance a critical discourse of citizenship, by contrast, lead students to ask challenging questions fundamental to the idea of democracy: Who has political power, who does not, and why? How do we distribute power and resources in ways that are just and equitable? Who is "illegal" and why? Scholar Joe Kincheloe captured the need for critical pedagogy particularly well, writing:

> Often, when I observe middle school civics teachers lecturing their students about how a bill becomes a law, never referring to lobbyists and economic power wielders' role in the process, I wonder about the future of participatory democracy. If students are to learn how power actually operates and how governing takes place in a privatized twenty-first century, they will have to unlearn the fairy-tale civics lessons they learn in many schools. (2001, p. 721).

The concern Kincheloe points to is that when teachers ignore injustice and the systems that reinforce it, they imply that democratic citizenship characterized by a weak, hands-off approach to change already works well enough. Critical discourses of citizenship are important because they work against these assumptions by validating dissenting views on membership, identity, and engagement (Knight Abowitz & Harnish, 2006). From a critical perspective, political communities cannot gain strength through the exclusivity of membership. They go beyond an attitude of tolerance to one of active inclusion. In the same vein, the critical discourse accommodates protest and civil disobedience, thus expanding notions of participation beyond signing petitions, talking at meetings, and voting.

Extending the Framework to Science Education

Current perspectives on citizenship education are a useful lens for identifying similar discourses in the science education community. Science educators commonly name citizenship as a goal of theirs. They do so however without making explicit references to meanings that might be contained within a concept of democratic citizenship (Rudolph & Horibe, 2016). Inherent in arguments that science education does or should fulfill a civic purpose is that knowing science will help you perform some special activities associated with citizenship. But have we thought carefully about what these activities are or how science relates to them? Available evidence suggests that science education done in the name of functional literacy is typically untethered to any empirically sound notion of how people use science in civic and political venues (Aikenhead, 2006; Feinstein, 2011). One goal of the present study is to address this blind spot.

The more proximate reason to use a framework like this is to enable data analysis. One of this study's Research Questions asks, *How are science teachers conceptualizing citizenship*? The above review outlines several potential lines of thought science teachers might have about citizenship. For research purposes, the civic republican, liberal, and critical discourses serve in this study as initial deductive codes against which data will be interpreted.

Civic Engagement with Science

> *A popular Government, without popular information, or the means of acquiring it, is but a Prologue to a Farce or a Tragedy; or, perhaps both. Knowledge will forever govern ignorance: And a people who mean to be their own Governors, must arm themselves with the power which knowledge gives.*
>
> —James Madison (letter to W. T. Barry, 4 August 1822)

The fourth US president's words, penned to explain his support for a general system of education, feel decidedly out of touch with the present day. The Oxford English Dictionary in 2016 made "post-truth" their word of the year. There the term is defined as an adjective that denotes "circumstances in which objective facts are less influential in shaping public opinion than appeals to emotion and personal belief." In Madison's formulation, the power to govern well flows from the acquisition of knowledge. But this vague assertion about how citizens use knowledge seems to be an oversimplification. Political actors have proven quite willing to ignore or misrepresent scientific knowledge when it clashes with their desired outcomes. Science deniers shamelessly cherry-pick evidence and weave elaborate conspiracy theories to muddy the waters of a political issue (McIntyre, 2021). In one of the more important and fascinating case studies of our time, Oreskes and Conway (2010) reveal how political action to address climate change has been stymied by "an organized campaign of denial" that sought to actively undermine public acceptance of the scientific consensus (p. 183). Obfuscations of this kind continue because they work. A broad dissemination of "popular information" about science, through schooling and various media, has not prevented the coming of “post-truth” politics nor is it likely to undo it (Chinn et al., 2021; Feinstein & Waddington, 2020).

Yet a notion of remedying ignorance with factual knowledge about science is deeply ingrained in how we conceptualize the role of science in a democracy. This is the perspective that has animated a multitude of survey-based research studies aimed at measuring what the public knows—or rather, does not know—about science (Bauer, 2009; Bodmer, 1985; Durant et al., 1989). Political scientist Jon Miller, in his seminal NSF-funded research (Miller et al., 1980), found a “deplorably low” level of “scientific literacy” and argued that raising this level would “improve the quality of…our political life” (Miller, 1983, p. 29). It is important to examine what “literacy” means in this context: an ability to recall basic, well-established facts that science has produced. Miller’s work relies heavily on true/false items such as “all radioactivity is man-made” and whether respondents “provide a correct open-ended definition of a molecule,” as two examples (1998). Elsewhere Miller laments that “only 28 percent of American adults have sufficient understanding of basic scientific ideas to be able to read the Science section of the Tuesday *New York Time*s” (2010, p. 241). Such admonitions are routine and reinforce the commonsense idea that if only the public could read the newspaper without having to reach for their science textbook, then they would take more reasoned political stances.

But focusing on what citizens know about the content of science alone is misguided. This deficit perspective, as it is called, ignores the complexity of how people come to trust science (Wynne, 1992a) as well as how people gather relevant science knowledge (Irwin & Wynne, 1996). For adherents to the deficit mindset, instances of public disbelief or non-use of science advice can be fixed by broader and more effective means of top-down science communication (Lewenstein, 1992; Simis et al., 2016). It is easy to imagine science teachers being thoroughly committed to a deficit framing of public ignorance of science. Their jobs, after all, are all about providing students with relevant scientific facts. Unfortunately, writes Sheila Jasanoff, "there is little evidence that public ignorance of specific scientific facts correlates in any meaningful ways with collective responses to science and technology" (2005, p. 250). In other words, the yearly reminders from the NSF *Indicators* that Americans simply do not know the science are beside the point. Such measures do not help us to address citizens' rejections and misuses of science.

The point here is not that ignorance of science is good or that facts do not matter. They do. Government and political science scholars Hochschild and Einstein (2015) lay out several cases where being misinformed about science or failing to act on available scientific evidence can have dire consequences. Two of their primary examples include denial of climate change and strongly held beliefs that childhood vaccination can cause autism. Both involve a rejection of scientific knowledge to maintain a political preference or identity (Kahan, 2013). It is plain that scientific findings have saved and extended lives (Johnson, 2022). Superficial measures of factual uptake out of context, however, do nothing to explain how it is that people *become* informed and how they *use* that information in a democratic context, or how they come to believe in and trust scientific evidence.

One key problem is the assumption that scientific explanations can be easily implemented in sociopolitical contexts. The scientific community, including science educators, commonly point out that scientific knowledge is universal, referring to one of Robert Merton's influential norms of science (1942). This idealized notion of objective and reproducible knowledge about the world has a powerful hold on our common conception of science (Douglas, 2009). Sociologist and historian Thomas Gieryn points out, however, that "factual explanations or predictions about nature do not move naked from lab or scientific journal into courtrooms, boardrooms, newsrooms, or living rooms" (1999, p. 4). Scientific knowledge is always drawn upon and applied in a particular context. The deficit model ignores this crucial point about context dependence (Feinstein & Waddington, 2020; Sturgis & Allum, 2004).

Toward a Relational Model of Civic Engagement with Science

To recapitulate, the issue at hand is the apparent failure on the part of citizens to use scientific knowledge in their daily lives. Science is without question the place we should look for reliable knowledge to guide our actions (Longino, 2002; Waddington & Weeth Feinstein, 2016). The knowledge deficit, or public ignorance model, however, assumes that if citizens have access to understandable scientific facts, then they will incorporate those facts in their deliberations or other political activities as a matter of course. It is an alluring idea. It is also a convenient way for scientists, science communicators, and science educators to frame the problem because it ensures support for each of their professional roles (Simis et al., 2016). But the deficit model fails to account for the complicated ways scientific experts and lay citizens relate to each other.

Science educators wanting to align their practice to citizenship education can find guidance in empirical studies of lay publics engaging with science for specific social purposes (Gehrke, 2014; Layton et al., 1993). What they will see there are citizens often engaged with science through issues that are not easily resolved by quickly looking up information. Some of our most pressing political issues are often what some call "wicked problems"—which are those marked by layers of uncertainty and that affect a variety of stakeholders simultaneously (Head, 2019). Policymakers often expect a straightforward answer from science when it cannot provide one (Mitchell, 2009). Teachers do students no favors when they focus on only the most certain scientific knowledge. Nonscientists often find themselves grappling with issues or controversies that will turn on scientific evidence that is not quite settled (Feinstein et al., 2013; Herman et al., 2022). In such cases, different citizens will interpret evidence and risk differently (Hollander, 1991). Citizens will find Wikipedia and Google—or their internalized content knowledge of science—to be no help when it comes time to make decisions when the relevant knowledge is contested or incomplete.

A common sort of scientific issue that students should learn to thoughtfully engage as citizens involves determinations of environmental safety. Emergent questions of whether the air, water, and soil are safe, rely on technical measurements that have far-reaching effects on the public. In the Flint water crisis, for example, agents of the state fought to suppress the findings of a medical doctor conducting research along with residents that exposed high levels of lead among children (Hanna-Attisha, 2018). In the end, the Flint water crisis became a well-known scandal, and the hazardous water pipes were ultimately remediated. The citizens' trust in their technological water system and the expert assurances that the water is safe to drink, however, are proving much harder to repair (Clark, 2018). In another case of citizens challenging deficit assumptions, Gwen Ottinger (2010) studied the efforts of a community adjacent to a Shell Chemical plant to demonstrate that the air was unsafe by performing their own air quality measurements. Residents collected data showing that acute events like accidents or "flare-ups" produced toxins at unhealthy levels in the short term. The official, standard method of determining unhealthy exposure however depended on an ambient level as determined by long-term averaging. The lay citizens in that case, despite producing evidence that would meet scientific standards of validity, were unable to get the relevant governmental, legal, and scientific institutions to accept and interpret that evidence in a way that would force Shell to buy their homes and help them relocate.

Most often we expect and rely on experts to act in good faith on our behalf. However, particularly when the stakes are high, authority is not necessarily assumed (e.g., Epstein, 1996). Instead, citizen stakeholders will question experts and try to re-open and examine their knowledge production process. Brian Wynne's case study (1992b) of how sheep farmers responded to government regulations in the wake of the Chernobyl nuclear disaster was an early and now famous example of this. At issue was the safe marketability of sheep that grazed on lands exposed to nuclear fallout. Local farmers, frustrated by experts' predictions about which fields would be edible and when, were presumed to have failed to accept official measures because they were motivated to ignore science by the disruption of their livelihood. Wynne provided a contrary explanation. He demonstrated how the farmers instead drew on their local knowledge of the soil and growing conditions to question the fundamental basis of the expert scientific advice. What was true in the laboratory turned out not to be true in the field. Relations could be improved, according to Wynne, if scientific institutions were seen as being "reflexive" in their knowledge-making and attentive to the contributions of local knowledge.

Cases like these demonstrate how typical school science can be irrelevant when it comes to civic concerns. The Flint water crisis, Shell chemical, and sheep farmers examples are not about knowledge in some abstract, pure sense (Kleinman, 2003)—i.e., textbook science. They are more accurately framed as credibility contests where actors work to persuade specific audiences that *their* knowledge is *better* than some alternative (Gieryn, 1999). Are students learning how to assess credibility within problems like these? Is there room for practicing it in school science?

Posing questions of credibility and assessing the usefulness of science is not the same as rejecting expertise out of hand. It would be a mistake to overcompensate for a knowledge-deficit mindset and suggest that all science is worth questioning all the time. Modern life is in large part marked by specialization. The auto mechanic can unravel the mysteries under the hood of my car; I cannot. The plumber can safely bring waste to the sewer and potable water to the faucet; I cannot. Scientists can be seen in much the same way: as people we rely on to know things on our behalf (Collins & Pinch, 1998; Collins, 2014). The complexity of our society makes us epistemically dependent on the knowledge and expertise of others (Osborne, 2023). Where the analogy of the plumber breaks down, however, is that the role of the plumber in society is stable and well-known. We may dislike a high estimate for repairs and seek a second opinion, but in the end, plumbers are not controversial figures. Citizens need experts, but they need not blindly accept their wisdom (Epstein, 1996; Moore, 2017, 2021; Turner, 2001). While citizenship could be improved by a more down-to-earth, demystified conception of expertise, it is inappropriate to take the extreme view that all views are equally well-founded and matter equally (Collins, 2014). The point at present is neither to prioritize local knowledge as a general principle nor give cover to immovable skepticism, but to further highlight that science experts and citizens have a more complicated relationship than science teachers might assume. That is, one goal of this study is to explore how teachers are thinking about scientific expertise as it relates to their job in teaching lay citizens.

In this section, I have reviewed scholarship that argues we must move away from framing lay citizens as passive, empty vessels in need of scientific enlightenment and toward viewing them as actors who make sense of science in sociopolitical contexts. Considering all this, educators must reframe the citizen’s relationship with science. Contrary to what frequently gets implied as commonsense intuition, untutored citizens are not passive recipients of inherently valuable science. The task of the citizen is not so much to acquire the facts of science but rather to assess advice being made in the name of science (Bijker et al., 2009). This involves asking new kinds of questions in addition to "What is known?" Is the knowledge being shared with me credible? And, if it is credible, does this knowledge warrant the proposal being made? In other words, is it a good reason? A purpose of this study is to inquire as to how attuned practicing science teachers are to this kind of perspective.

Science Education for Citizenship

In this section I explore how science education scholarship has addressed the civic aim for science education. To guide this review, I begin by summarizing two important concepts discusses so far in this chapter. That is, statements of what we mean by *citizenship education* and *civic engagement with science* will serve as criteria for reviewing research that shows *science education for citizenship*.

Education for democratic citizenship prepares students for public life and collective self-rule. According to Hess and McAvoy (2014) and Parker (2003), some version of "How should we live together?" is the main question facing citizens. There are numerous tensions and different possible emphases within that simply worded question that I will not fully address here. In this chapter I have highlighted, after Knight Abowitz and Harnish (2006), three aspects of citizenship found to be influential in education. A civic republican citizenship education has the potential to emphasize collaboration on public works and the building of civil society. A liberal citizenship education emphasizes deliberation on public issues. A notion of critical citizenship education emphasizes justice and equity as guiding principles. Citizenship is not an all-or-nothing prospect. Integration of all three may be ideal—a stronger kind of citizenship—but any number of these aspects of citizenship may be displayed in different circumstances.

Civic engagement with science, therefore, means the ways that lay citizens interact with science to help them achieve civic and political ends. Citizenship activities of all kinds—those fitting within civic republican, liberal, and critical citizenship discourses—will lead citizens to draw upon science to fulfill specific social purposes (Layton et al., 1993; Ryder, 2001). The main point relevant to this study is that a knowledge-deficit model of how citizens use science is inadequate. A more accurate model, according to the scholars referenced above, would focus on how scientific expertise and lay citizens can find correspondence with each other. To understand how citizens relate to science, in other words, one must adopt a dialogic rather than a deficit perspective (Stilgoe et al., 2014).

Science education scholars, for their part, have conceptualized science education for citizenship in two main ways. One of these is based on the argument that citizens need to know about science itself, particularly its epistemology and social processes of knowledge production. I call this the *fundamentalist perspective* because it seeks to teach things that are fundamental to the discipline(s) of science.[1] *Fundamentalist* science teaching is contrasted with traditional content-focused instruction. It prioritizes seeing into the processes of science to understand what undergirds experts' beliefs in what they know.

The *expansionist perspective* is different in that it aims to explicitly support students to use science in their civic and political affairs. This approach is based on the argument that the use of science cannot be divorced from the context of that use. In the expansionist perspective,

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[1] At first glance, my choice of terms—fundamentalist, and expansionist—would appear to resemble Norris and Phillips' notions of fundamental and derived science literacy (2003). However, their meanings and mine are different. I use fundamentalist and expansionist as descriptions of how the science teacher views their curriculum and instruction. To be a fundamentalist teacher is to focus on the world *of* science to learn how knowledge is made. Norris and Phillips categorize this as "derived" science literacy. By fundamental science literacy, Norris and Phillips refer to how authors and readers construct meaning via text.

we see science teachers stepping outside of what is typically expected in science class, thus taking a more expansive view of what is appropriate for them to teach. Students in expansionist science classrooms are acting like citizens as part of their learning, whereas those in fundamentalist classrooms are focused intently on science while a practice *in* citizenship is kept at the periphery.

The Fundamentalist Perspective: Citizens Learning About Science

Any one program in science education cannot fulfill every aim at once, and so teachers must naturally choose some ways of teaching over others to work toward a particular aim (Aikenhead, 2006; Rudolph, 2019). This task is complicated by a tendency to use “citizen” as a slogan meant to justify a way of teaching as useful for every student—we say citizen where person or nonscientist would be the more appropriate term (Davies, 2004). The first step, then, is to clarify what civic engagement with science means, which I have attempted to do above.

In that review, I highlighted the inadequacy of the deficit model in explaining how it is that citizens engage with science. Science educators can have a hard time rejecting the notion that scientific facts have a special power to improve democratic decision-making (or indeed any sort of activity a person might engage in). Physicist James Trefil for example has been an unwavering proponent of a “cultural literacy” theory of general science education, which holds that what is important for all citizens to know is a predetermined body of knowledge that other “literate” people will assume you know (Hirsch, 1987; Trefil, 2008). The role of science education, in this view, is to ensure that citizens acquire the relevant content knowledge they will presumably need at some point in the future. Advocates of this sort of “literacy” frame prioritize an ability to have conversations that reference science without getting tripped up on a lack of common language.

One implicit assumption in this conception of educating the scientifically literate citizen is that the basic truths of science will be enough to disallow certain political arguments (Kitcher, 2001). Except time and time again empirical studies show that textbook science is not what gets referenced when citizens act (Ryder, 2001). What we can count on instead is that citizens will deconstruct, reconstruct, and translate scientific knowledge to turn it into useful information in specific sociopolitical contexts (Layton, et al., 1993). What is more, citizens have shown a degree of resourcefulness to go learn about science when they needed to (Kleinman, 2005; e.g., Epstein, 1996).

Other science education scholars have focused not on content mastery but on knowledge about the scientific enterprise itself. Because citizens are not passive recipients of science, and because the science they need is often unsettled or contested, what citizens need is a way to assess the credibility of a source of knowledge. Historian of science Naomi Oreskes writes that determinations of trust in science can be made by looking at its social processes of vetting claims through critique and peer review (2019). A piece of her argument not to be overlooked is that citizens are not expected to judge a scientific claim *as a scientist would*, but rather to see whether the relevant experts were able to arrive at a consensus by their methods. The educational question, therefore, is what every citizen should know about science that will help them recognize those kinds of processes. John Dewey addressed this more than a century ago, noting that every citizen needs to learn how to sort reliable knowledge out from “mere opinion or guess-work or dogma” (1910, p. 125). He was adamant that school science must therefore focus on the epistemology of science—what counts as knowing for scientists (Rudolph, 2005). In a content mastery form of science teaching, the value of science is taken for granted; facts are ahistorical. An argument for science education focusing on the epistemology and social processes of science is not meant to undermine science or imply that science is not special. It is based on the view that science *is* effective at making reliable knowledge, but we tend not to give students an effective way of understanding *why*.

Several strands of science education scholarship have focused on looking beyond what scientists know and into how they come to know. We see the citizenship argument by turns being used to support teaching the *nature of science* (e.g., Bell & Lederman, 2003; Rutherford & Ahlgren, 1990), scientific *inquiry* (e.g., Millar & Osborne, 1998), *science practices* (Ford, 2008), and scientific *argumentation* (Duschl & Osborne, 2002; e.g., Murphy et al., 2018). An analysis of how each of these kinds of literature portrays civic engagement is far beyond the scope of this review. Also necessary, though not directly tied to the aim of the present study, is an examination of the myriad reasons this kind of teaching has proven difficult to enact (e.g., Ratcliffe & Millar, 2009). Nevertheless, there is reason to think that fundamentalist science teaching can support citizenship (Ford, 2008). Below I highlight two promising frameworks. Each finds its strength by being grounded in the science needs of citizens.

British scholar Jim Ryder (2001) identified the science understanding citizens need to be "functional." This work stands out from the crowd because of its rigorous methodology. Ryder's approach was to review 31 published case studies of nonscientists interacting with science knowledge and/or professionals. The studies analyzed involved scientific knowledge as tentative or disputed as well as well-established. Several showed experts giving advice, such as in court cases. Many involved citizens making assessments of risk. Ryder found that the lay citizens he studied were better able to engage, or would have been better able when they could understand how scientists:

- assess the quality of data,

- design studies with varying methods to meet specific needs,
- assess validity and interpretations in science,
- use knowledge sources other than data (experience, theoretical models, reputation of other scientists) in their interpretations,
- legitimately disagree and work to resolve disagreements,
- utilize models with limitations and built-in assumptions,
- seek to minimize uncertainty (within reason) while never being able to eradicate it,
- and communicate in the public domain.

Ryder also compared the science knowledge that was or should have been drawn upon to what is usually taught in most school curricula. He found that in most cases the science needed was too specialized or too new (often not yet settled) to be something that could have been covered in school. In the minority of cases where the relevant knowledge could be thought of as school subject knowledge, Ryder observed that the nonscientists did not recall it.

Kolstø (2001) similarly puts forth topics for citizens to know about science that "transcend" the content knowledge of traditional science curricula. He argues that knowledge of each of these can be used as a *tool* for citizens who must judge the trustworthiness and applicability of scientific claims. In Kolstø's framework, the difference between "ready-made-science" (textbook science knowledge) and "science in the making" (Latour, 1987) figures prominently. In his paper Kolstø agrees with the idea, referenced above, that citizens need awareness of the social processes by which scientific knowledge is made—that consensus evolves through criticism, argumentation, and peer review. He, therefore, posits that citizens must understand something of the *limitations of science*, within which Kolstø lists four learning areas:

- science is one of several social domains that have a bearing on issues,
- how to recognize descriptive and normative statements (knowing that they are not always clear-cut),
- how demands for underpinning evidence will vary based on interest, and
- how scientific models are context-bound.

Kolstø then discusses *values in science*, where he lists two more topics:

- what counts as scientific evidence, and
- how scientists tend to require more evidence than other domains—it takes time.

Finally, the framework is rounded out by saying that it is appropriate for citizens to have a *critical attitude* toward science-related knowledge claims and therefore learn how to scrutinize them. Kolstø's framework resonates with Ryder and the other scholars discussed here because it takes as its premise that citizens need to make sense of how best to use science in a sociopolitical context.

The picture that Ryder and Kolstø paint reflects the complicated and nuanced activities of science. This is a far cry from the simplistic portrayals of science students typically receive (Chinn & Malhotra, 2002; Rudolph, 2000, 2005). The reason to teach differently, according to Ryder, is to "give individuals the opportunity to engage critically with science by enabling them to frame meaningful questions, even in contexts in which relevant science concepts are highly technical and therefore inaccessible to most non-scientists" (2001, p. 40). Ryder quickly followed this publication with another (2002) aimed specifically at science educators where he suggests several pedagogical strategies that align with the above framework. Among them is the study of data sources not generated by the students themselves, historical studies of science, contemporary issues involving science—especially those involving uncertain risks, and the use of media reports of science, to name a few.

It should be noted that top policies guiding science education in Western democracies show a clear appetite, at least nominally, for this kind of science teaching. In the UK, where the aftermath of the bovine spongiform encephalopathy (BSE) or “mad cow disease” episode intersected with a renewed national effort to revamp citizenship education (see Crick, 1998), the *21st Century Science* curriculum was developed. Millar and Osborne, editors of the academic report (1998) that presaged that national curriculum, held that “to use [science] in interpreting everyday decisions and media reports, young people also require an understanding of the scientific approach to inquiry” (p. 2019). Here in the US, the Next Generation Science Standards seek to elevate the learning of science practices because, the *Framework* authors argue, “any education that focuses predominantly on the detailed products of scientific labor—the facts of science—without developing an understanding of how those facts were established… misrepresents science” (NRC, 2012, p. 43). While policy documents like these may not forcefully tie fundamentalist science education to citizenship, at the very least they give teachers political cover. In other words, it is readily seen as completely appropriate to teach about scientific practices in science class. An expansionist approach, however, may be a tougher sell.

The Expansionist Perspective: Engaging with Science as Citizens

It has been argued that science becomes salient to citizens most often, or most urgently when they need to resolve a political issue. Deciding what to do about anthropogenic climate change, artificial intelligence, public health, national energy policy, and any number of environmental problems requires us to think about what those things mean and what the potential impacts of various courses of action or inaction might be. These issues are both scientific and political. From an education standpoint, learning to engage productively in political issues that involve science requires an interdisciplinary approach that accommodates not only what is known and how it is known, but also what citizens and governments can and should do about it. In other words, teaching citizens to engage with science means exploring the relationship between science and political power. Choosing a pedagogy that centers on sociopolitical issues—taking an expansionist perspective as it is called here—invites moral and political classroom discourses alongside a scientific one that science teachers may be uncomfortable with (Levinson, 2010).

Setting aside for the moment teachers' possible reservations, science education researchers have described and advocated for nontraditional forms like issues-based science teaching. Scholarly calls to teach science in ways that overtly include citizenship have come under headings such as *socioscientific issues* teaching (e.g., Ratcliffe & Grace, 2003), *social justice science education* (Dimick, 2012), *community*- or *place-based science education* (e.g., Lee & Roth, 2003), and science education *for political activism* (e.g., Birmingham & Calabrese Barton, 2014). In defining socioscientific issues (SSI), Troy Sadler writes,

> They are open-ended problems without clear-cut solutions; in fact, they tend to have multiple plausible solutions. These solutions can be informed by scientific principles, theories, and data, but the solutions cannot be fully determined by scientific considerations. The issues and potential courses of action associated with the issues are influenced by a variety of social factors including politics, economics, and ethics. (2011, p. 4)

In this description, we can hear several notes of conceptual resonance with the notion of civic engagement with science explored above. It evokes an image of students deliberating about gene therapy, a proposed carbon tax, or the like. The presence of an issue implies that some decision must be made and/or action taken, therefore opening the door to a normative dimension that science educators usually leave closed. Whether the emphasis is on justice, community engagement, or activism, the common feature at the core of these expansionist forms is that they involve considerations of what should be done.

Recall that liberal citizenship, one of the three discourses highlighted in this chapter, is about the resolution of disagreements and deliberation as a means of doing so. Levinson (2006) presents a framework for SSI teaching that attends to this aspect of citizenship. His work, grounded in a close examination of conflict in liberal democracy, yields a typology of reasonable disagreement and "communicative virtues" for successful deliberators to embody. Levinson also draws a distinction between narrative and "logico-scientific" modes of thought. This framework gives teachers and students an in-road for contentious dialog because it enables them to identify exactly how citizens are disagreeing on an issue. It serves as an analytical tool, helping users to recognize the sources of their conflict as well as how to behave when in conflict. Levinson's communicative virtues, which include things like tolerance, respect, and attentive and thoughtful listening, among others (Table 2, p. 1218), reads like a list of classroom norms a social studies teacher would readily recognize but would likely be seen as a novel inclusion in a science classroom. Another contribution Levinson makes is to highlight the role of personal narrative alongside scientific logic. He writes, "In the telling of a story within a socio-scientific issue, the authoritative expert science becomes displaced or marginalized, the context of a lived experience becomes the central focus" (p. 1219). Here we see a line that a science teacher may not be willing to cross. Yet learning to engage with science as citizens would require students to see how science matters in real human contexts (Zeidler & Sadler, 2007). Levinson argues that without uncovering narratives of how people are interpreting and being affected by science, citizens cannot hope to proceed with specificity, and thus more thoughtfully and carefully, toward finding agreement within a socio-scientific issue.

Ratcliffe and Grace (2003) equate teaching science for citizenship with the teaching of socio-scientific issues. They raise several essential characteristics of SSIs that have pedagogical implications. For instance, SSIs frequently involve knowledge at the frontiers of science or conflicting/incomplete evidence whereas school science typically only deals with canonical, well-established science. Also, in school, unquestionable science content is delivered by authoritative sources (textbooks and teachers), but SSIs outside of school "are frequently media-reported, with attendant issues of presentation based on the purposes of the communicator" (p. 2). SSIs are pressing societal concerns that involve values, ethical reasoning, risk, and often cost-benefit analyses—all of which the public accesses through diverse forms of media rather than a standardized, sanitized representation. SSI teaching affords citizenship education, according to Ratcliffe and Grace, because they place an expectation upon students to engage in "clarifying values, evaluating information and viewpoints, discussion, decision-making and action" (p. 23).

Socioscientific issues teaching, as theorized by Levinson (2006) and other influential scholars in the field (e.g., Zeidler et al., 2005), is rooted in a predominantly liberal conception of citizenship. Other styles of expansionist science teaching do align with critical and civic republican discourses of citizenship. For instance, Alexa Dimick's framework for *social justice science education* is an example of critical pedagogy in science education (2012, 2016). There student empowerment is pursued along social, academic, and political dimensions. *Social* empowerment is achieved when students participate equitably in the science classroom, which is a question of "whether all students' voices are valued in just ways" (p. 1002). This dimension is concerned with making the learning environment nondiscriminatory and creating a sense of belonging for all students. *Academic* empowerment, in Dimick's framework, draws attention to the student's relationship to the science curriculum. Students are not simply acquiring knowledge from science but accessing science knowledge as part of their critical analysis *of* science. Social justice science education is therefore a way to disrupt deficit narratives of ignorance by positioning students not as passive adopters of a scientific worldview but as critical actors who can use science for their own ends. Social justice science education is part of students' citizenship[2] education because it is attentive to how science has been and can be a source of power (Hodson, 2011).

It is the political dimension in Dimick's framework that is most relevant to this study. *Political* empowerment for her refers to "students' recognition and intentional, critical examination of the structures and forces that establish and maintain power inequities" (p. 995). Dimick points out that this can happen both inside and outside of school. Students' political empowerment in a school context was illustrated by Ira Shor's study (1996) wherein he as a teacher shared power with his students and made them partly responsible for making course design decisions. Several other studies that seek to "democratize" science education work primarily within this same vein of political empowerment *within* school science (e.g., Basu et al., 2011). A tenet of critical pedagogy is that all social sites, whatever else they are, are also political sites (Apple, 2014) and are therefore potentially unjust. Scholars like Basu, Dimick, and others seek to work against the historical marginalization students have incurred relative to

[2] This is my word, not Dimick's. See her thorough note (2012, p. 994) on her apprehension for using this term.

school science and the cultural, political, and professional standing that knowing science can grant them. It contributes to citizenship in the sense that knowing science increases one's access to spaces where important matters are discussed (e.g., Epstein, 1996).

It is when these efforts at social justice science education cross over into the political world beyond the school that they fit the expansionist label as I use it here. Dimick writes, "When participation extends outside a school's walls, it can provide students with first-hand experience in civic processes and help them understand the ways that youth can (or perhaps cannot) influence political structures" (p. 996). This can be seen in several case studies that take an explicit social justice and/or community engagement approach. Calabrese Barton presents a study (2003) in which youth used science as a tool for change. They worked collaboratively both to decide what project to pursue that would improve their neighborhood and then to gain enough scientific knowledge and skill to carry out the improvement. Similarly, Roth and Lee (2004), in a project typical of the genre, report on middle schoolers' science education within the context of a creek revitalization effort. The authors there argue that the students displayed empowered citizenship when they exchanged scientific knowledge with and produced knowledge for, the community. In a final example, Dimick (2016) showed how, by focusing on the ecology of a local place that students knew and eventually cared for, students in an urban park restoration project gained insights into how environmental degradation and restoration are coproduced by science and politics.

A pedagogy in search of a home. Issues-based or place-based science teaching implies that the curriculum includes more than science. Learning to make decisions on a socioscientific issue involves discussing values and ethical reasoning (Saunders & Rennie, 2013; Ratcliffe & Grace, 2003). They put students in a position of needing to interpret scientific evidence in good faith as moral citizens who must judge between right and wrong (Zeidler & Sadler, 2007; Zeidler et al., 2009). It is fair to ask, who should be teaching this? Where in school does such a thing belong?

It is often shown that science teachers are not especially skilled at facilitating the kinds of dialog that citizenship entails. Levinson (2004) described how a teacher who intended open dialog in a bioethics debate fell short of that aim. Instead, she inhibited student debate by devoting most of the class time to her teacher-centered explanatory narratives. Levinson also noted that what little debating did take place was not connected to the science lessons that were supposed to be relevant. Levinson, therefore, argues in that paper and elsewhere (2001) that humanities teachers ought to be enlisted to handle what science teachers cannot effectively teach. Dawson (2000) similarly argued that teaching essential elements of citizenship is an unrealistic expectation to place upon science teachers. His main reason was that they are unprepared to guide students in expressing their views and critically analyzing the views of others. Findings from a study by Siegner and Stapert (2019) add merit to this perspective. There, climate change was taught in a middle school within its humanities department, and students "demonstrated much higher levels of knowledge and engagement around climate change than the average American teenager or adult" (p. 11). Science teachers will likely need to expand their repertoire if they are to facilitate civil discourse involving disagreement and clarification of values.

The main difficulty of expansionist science education for citizenship is that it necessarily draws upon several disciplines. Opportunities for interdisciplinary learning are rare in most school structures (Mehta & Fine, 2019). At the end of their book, Ratcliffe and Grace (2003) raise the question of whether effective SSI teaching is achievable given its complex nature. While they acknowledge the reform burden put upon science educators as well as the relative skill of humanities teachers in key respects, they insist that science teachers have a unique role to play and should be supported in dealing with controversial issues based on contemporary science. Recent literature on science teachers learning to teach SSI is mixed, however. A review by Jan Nielsen (2020) covering an international breadth of studies since 2016 confirms that engaging with political issues for science teachers remains a difficult prospect. While there are occasional bright spots for teachers learning to teach SSI, it is always due to intensive support (e.g., Leung et al., 2020; Macalalag et al., 2020). Most often, science teachers fail to adequately engage with the social and political aspects of issues within school science (Nielsen, 2020).

Theoretical Framework: Teacher Beliefs

The purpose of this study was to explore how secondary science teachers conceptualize citizenship and how they think learning science aligns with that conception. To guide this investigation into how teachers were thinking about citizenship as a goal for science education, I utilized the theoretical lens of *teacher beliefs*. Specifically, I designed the study to focus on two sorts of beliefs: (1) what teachers believe citizenship means and (2) how they believe citizenship can and should be addressed in science class. Conceptual beliefs were studied to understand how teachers viewed the goal of science education for citizenship while beliefs about appropriate curriculum and instruction illuminated the likely prospects for science teachers addressing citizenship in their classrooms.

Beliefs are philosophical and phycological constructs comprised of peoples' personal epistemology and their epistemic cognition (Jones & Leagon, 2014). They lie at the intersection of what is known, how well something is thought to be known, and how influential one judges that knowledge should be. While there are competing notions on the proper use of the term epistemic cognition, I take it to mean a mental process by which one comes to accept knowledge

(Greene et al., 2016). This notion is part of Schommer-Aikens' (2004) definition of belief, where she argues that beliefs have a nonconscious, tacit, affective nature that makes them resistant to change. This comports with Nespor's work on teacher beliefs (1987) where he argued that beliefs are fundamentally different from knowledge because they do not require consensus and are rooted in existential presumptions shaped by an individual teacher's episodic memory. That is, teachers often let intuition about what works, built upon their experiences, be their guide, even in the face of conflicting social trends or evidence. There is a distinct value component to a belief, in addition to an acceptance of declarative knowledge. In an influential theoretical work on teacher beliefs, Parajes (1992) described them as deeply personal and resistant to persuasion. In this study, I employ teacher beliefs to mean *a personal philosophy that guides thinking about the kinds of teaching they ought to pursue*.

Previous science education research has focused on the explanatory power of teacher beliefs. In this literature, beliefs are taken to be fundamental to how teachers understand their role. Researchers have consistently found that what science teachers believe about how students learn, how science works, and their efficacy holds sway over the teaching they seek to enact (e.g., Bryan, 2012; Crawford, 2007). Jones and Leagon (2014) provided an expansive framework of science teacher beliefs comprised of at least six kinds of beliefs working dynamically across four phases of planning, enacting, and evaluating their teaching. The crux of their theory is in how teachers' beliefs about knowledge, learning, self-efficacy, and their prior knowledge combine as well as the social and political context in which their teaching is embedded to establish a teacher's motivation for how they decide to teach. Their framework also highlights the metacognitive dimension of beliefs as guides for action. That is, teachers are also aware of their thought processes and values as well as the thoughts and values of the relevant stakeholders in their science teaching.

A theory of teacher beliefs is therefore appropriate for an inquiry into how teachers conceptualize citizenship and the kinds of teaching they subsequently see as appropriate. For instance, in one empirical study of social studies teachers' beliefs, Rapoport (2010) found that, because they did not yet have a solid concept of global citizenship, teachers fell back on their existing knowledge and teaching methods. In that case, this meant that "global citizenship" was interpreted to mean global phenomena of economics and environmentalism, not citizenship in a civic or political sense. This work supports the notion that teachers cannot teach toward a goal they cannot articulate—a key premise for the present study. There is more at play, however than a simple determination of whether a teacher understands a goal accurately or not. Exactly what a teacher takes citizenship to mean will shape their commitment to that goal or even certain aspects of that goal. For instance, as Kincheloe observed (2001), it is easier to teach fairy tale civics than the upsetting reality.

Of course, teachers do not work in isolation. How science teachers think about their own teaching goals is important for understanding how they teach, but how teachers perceive the educational expectations of others does too (Windschitl, 2002). In other words, when everyone's goals align, the going is easier, but if goals conflict, a resolution must be sought (Hutner et al., 2022). Jones and Leagon (2014) demonstrated how reforms are successful to the extent that teachers' internal beliefs and their external beliefs (beliefs about other relevant stakeholders, i.e., students, parents, and administrators) are aligned. For instance, a theory of beliefs can show why a teacher may avoid teaching part of the biology standards if they perceive that certain parents will be upset by including evolution in the school curriculum. Such an analysis, in research, would lead to teachers' perceptions of their students (will they tell their parents?) and their principal (will my job be protected?).

Literature Review: Science Teacher Beliefs About Science Education for Citizenship

Science teachers' conceptions of and commitments to a citizenship goal is an underexplored area in the literature. In my review, only a handful of pieces were gathered that utilized a conceptual frame like the one presented above. Instead, different strands of literature were uncovered that deal with different aspects of the science education for citizenship concept utilized in the present study. Meaning, a search for "citizenship" beliefs was not fruitful; I first had to break the concept of "science education for citizenship" into smaller conceptual pieces associated with the fundamentalist and expansionist concepts outlined above. In this section—the final of this chapter—I highlight some of the literature that can serve to situate this study's findings.

As has been noted, the literature provides a steadily growing body of empirical work that demonstrate the effectiveness of an *expansionist* approach. Owens, Sadler, and Friedrichsen (2021) for example provide a case study in which an experienced biology teacher was successful at contextualizing the relevant scientific knowledge within an issue, having students understand multiple perspectives, and analyzing sources of information for potential bias. Similarly, in a design-based research study, Zeidler, Applebaum, and Sadler (2011) illustrated how deep structural change of a science course was accomplished in the service of meeting SSI and nature-of-science learning goals. Both studies provide models of success and are therefore important exemplars. They show what is possible when a committed classroom teacher has the right support. The baseline assumption, or starting point, in studies like these, is that the teachers believe in the teaching methods—or at least in the guidance of the academics they are working with.

Another common approach in this area of research is to report on the teacher learning outcomes of an SSI or science-and-society course that aims specifically to develop teachers' pedagogy in that direction (e.g., Macalalag et al., 2020). Studies like these, however, do not typically engage with the deeper question of why teachers think such teaching is a good idea. It is rare to find a discussion of those underlying reasons being tied, in the teachers' minds, to a citizenship goal. This is notable, especially considering the strong citizenship arguments being made among scholars for SSI teaching. There are however two recent exceptions found in work by Leung, Wong, and Chan (2020) and Leung (2022). In their research, Leung and colleagues focused on pre-service teachers' (PSTs) beliefs about teaching socio-scientific issues. Both studies were conducted in Hong Kong, and both examined the effects of an intervention in the form of a science teaching methods course. Though they did not explicitly seek to investigate participants' beliefs about citizenship education, they did find that a few PSTs named citizenship as a reason to enact SSI teaching. Before the methods course, no teachers were conceptualizing issues-based science teaching as a means of fulfilling a civic aim of their teaching. Leung and colleagues' studies are a modest demonstration that PSTs can learn to think of SSI teaching as citizenship teaching, and that this connection made their commitment to SSI teaching stronger.

Issues-based science teaching enacted for citizenship seems to have made much more headway outside of the US. For instance, Barrue and Albe (2013) provide a rare example of a study that did investigate science teachers' views on citizenship. Those researchers examined the French middle school science curriculum and used open-ended survey questions to elicit teachers' views on citizenship education. They found that those teachers conceptualized citizenship in two ways that are in tension. For the first and most common categorization of teacher views on citizenship, the researchers used the term “virtuous citizenship” to denote teachers promoting civil behavior and respect for rules. This concept of virtuous citizenship is synonymous with the version of civic republican citizenship most found in US civics curricula (Knight Abowitz & Harnish, 2006). Barrue and Albe found that these teachers conceptualized citizenship as character development and *not* related to understanding science. The minority of participants, in contrast to the first group, envisaged citizenship as supported by school science through sociopolitical issues that involve science. These are teachers who “have the will to develop skills to enable pupils to [practice] debates and political decisions about society goals in their adult life” (p. 1102). In France, the context of that study, “convergence topics”—essentially SSIs—have been mandated by the national curriculum and explicitly tied to citizenship education since 2006. This is a marked difference from the US context of the present study.

In a study that is relevant to the US context, Pedersen and Totten (2001) sought to understand the lack of engagement with social issues by science teachers. They developed and administered a survey of attitudes and beliefs to 37 teachers who participated in a summer workshop. It is critical to note that Pedersen and Totten chose not to select teachers who had experienced any kind of specific advocacy for issues-based science teaching, only that they attended the workshop with an intent to improve their practice generally. The researchers found that most teachers felt that teaching social issues were important and that they felt competent to teach social issues. However, over 68% felt that they bear too much responsibility for teaching social issues, and that their appropriate role was to teach science content *instead* of engaging with social issues.

As one reads more literature on teachers' beliefs about issues-based science teaching, a clear pattern emerges: the social and political aspects of an issue consistently take a back seat to science. A study by Tideman and Nielsen (2017) illustrates this phenomenon. Tidemand and Nielsen conducted in-depth group interviews with Danish biology teachers to investigate how they were interpreting the purpose of SSI teaching. They found that teachers generally harbor a content-centered view, made evident by how they instructed and assessed student learning related to SSIs. The researchers found that teachers had reduced the complexity of the issues and predominantly used SSI as a compelling hook to drive science learning. The issue was not made to be the central focus but only positioned as an interesting introduction to the important science content. Teachers justified this by thinking of *all* their content as potentially useful in some hypothetical issue students might face someday.

A final example from the literature is offered here that addresses research goals like those of the present study. Sadler, Amirshokoohi, Kazempour, and Allspaw (2006) aimed to gather US in-service teachers' perspectives on the place of ethics in their science teaching. Those researchers utilized semi-structured interviews with a broad sample of teachers. The interview protocol used terms such as "values", "ethics", "value-laden issues" and "controversial scientific issues" to inquire as to the current usage and beliefs about the place of those ideas in their science courses (p. 374). As has been found in other studies highlighted here (Barrue & Albe, 2012; Leung et al., 2020), a minority of the 22 participants in Sadler et al. (2006) believe it is both appropriate and that they are comfortable teaching ethics. Moreover, some in that minority group, without intervention, give democratic citizenship as a reason for holding that view. But Sadler and colleagues also add to previous findings that teachers have a broad diversity of beliefs about whether and how to enact issues-based science teaching. It is equally likely to find teachers who are ambivalent about the value of SSIs, that their school context presents too much difficulty for teaching them or feel that it is simply inappropriate to cross a normative line in science class.

While studies exploring the viability of expansionist science teaching contribute to our understanding of how appropriate science teachers believe that approach to be, work that addresses fundamentalist science teaching as a means of supporting citizenship tends to focus on teachers' conceptions of scientific inquiry and the nature of science. For instance, Liu and Roehrig (2019) studied science teachers' scientific arguments related to climate science. Although the teachers were involved in a 3-year professional development program on climate change education, examinations of their arguments revealed that these teachers made claims that were not justified by the evidence they were naming. Liu and Roehrig concluded that those teachers held a personal epistemology of science that was generic and that did not match that of climate science.

Shifting focus from scientific claim-making to teachers' conception of a practice of scientific inquiry yields essentially the same results. Windschitl (2004) conducted a study of US pre-service teachers attempting to plan inquiry lessons. Their reflections on their plans and their critiques of their classmates' lessons showed they relied on a tacit framework of what it meant to do science. The main failing among those teachers was that they portrayed inquiries as individual knowledge-making projects that can stand apart from a larger body of knowledge and theories. Windschitl argued that this constituted a "folk theory" of scientific inquiry that resembled common notions of science promoted throughout the culture generally but not one that had fidelity to the work of scientists. The danger in such inaccurate portrayals is that citizens will not recognize science when they need it for civic purposes and therefore will reject science that is deserving of their trust.

There are a few takeaways from this review of literature that help justify the present study. In looking at work on teacher beliefs related to citizenship, researchers seem to be concerned with two different kinds of beliefs and therefore two different root issues that constrain or support enactment. Furthermore, the two research trends that I discerned in my review could be separated into those that addressed expansionist teaching or those that addressed fundamentalist teaching, but not both.

Considering science education for citizenship that seeks to be expansive (e.g., socioscientific issues teaching), research in this camp seems to focus mostly on instruction. The consensus here is that teacher education serves as an important and effective intervention for expanding the teacher's repertoire. In terms of teacher beliefs, this approach has therefore been found to influence teachers' self-efficacy beliefs (Blonder et al., 2014). In a theory of teacher beliefs affecting the enactment of a teaching reform like SSI, a major concern is how well the teacher expects they will be able to do. Additionally, there is an emerging trend of research that addresses how teachers perceive the value of SSI teaching—what they believe it is for. The relevant finding here is that they most often believe that SSI serves as a rich context where important science content can be positioned as more interesting or relevant, thus sustaining student interest. Only one study was found (Leung et al., 2020) that showed science teachers beginning to see, and be guided by, a civic value in the SSI approach.

Meanwhile, research on how teacher beliefs influence the enactment of a fundamentalist perspective (e.g., inquiry, argumentation, and other approaches) has shown a propensity for focusing on the conceptual underpinnings of enactment. These contribute to an argument that a teacher cannot teach toward a goal that is not clear. The consensus on this count is that teachers seem to work toward a vision of science that does not resemble authentic science. No studies were found that attempted to link a teacher's belief in the value of (for example) inquiry to democratic citizenship. Research that has explored how science teachers think about the value of fundamentalist science teaching tends to find that goals are left implicit and, where they are addressed, vague notions of general literacy are often supplied (Friedrichsen et al., 2011; Olafson & Schaw, 2006).

Chapter 3: Methods

This study explored how science teachers are conceptualizing citizenship and their beliefs about science teaching for citizenship. I employed in-depth interviews and qualitative analytic techniques to better understand how secondary science teachers thought about their role in educating citizens. The basic design of the research was built around the core method of in-depth, semi-structured interviewing (Ravitch & Carl, 2016; Rubin & Rubin, 2011). I took what participants said to signify their espoused beliefs, which Bryan defines as "self-reported claims about the way things are or should be" (2012, p. 479). To add depth to the data—to push participants beyond their initial thoughts and into a more contemplative mood—I utilized a technique of critical incidents. These are incidents that put respondents in a decision situation (Watts et al., 1997). The prompts, then, were a mix of questions that created space for open-ended thinking as well as more pointed responses to specific ideas participants were confronted with. In the remainder of this chapter, I explain and justify the methods of participant recruitment, data collection, and analysis in further detail.

Participant Recruitment and Selection

Participants were recruited through a purposeful sampling scheme to seek a diversity of perspectives (Creswell, 2007). An online survey was developed to gather demographic information as well baseline data about potential participants' general curriculum and instruction (Appendix A). This survey was distributed to everyone in my network who currently worked in high schools or knew people that did. The attached description of the study was purposefully vague. It did not mention "citizenship", only that I sought to study their thoughts about the purposes of science education as well as their classroom practice. This was necessary to ensure that I was not over-sampling a population that felt they already teach in alignment with explicitly civic aims. The survey invited respondents to pass it along to colleagues or anyone they thought might want to participate.

Within a few weeks, 53 science teachers had filled out the survey. However, only 26 of these indicated that they were willing to be interviewed and thus move ahead with full participation. Considering my capacity as a single researcher intending to handle all the data analysis, it was decided that a final cohort of 8-10 participants would be selected for the study. To narrow the field down to 10, I constructed a spreadsheet that assigned a random number to stand in for each respondent's name. I kept visible their school type (public, charter, parochial, private), geographic context (rural, exurban, suburban, urban), years of experience, subjects taught, as well as self-indicated gender and racial identity. Selection was also informed by responses to four survey items asking how often the teacher included "sociopolitical issues", "discussion of current events", "news media", and "taking a position on a normative question" in their science teaching. I then randomized the order of the rows in this table and began to move down the list blindly selecting participants until a diverse cohort was constructed.

In the end, five women and five men were selected who represented a balance of school types, subjects taught, and levels of experience. Unfortunately, only two people of color responded and they both taught chemistry in urban schools and identified as women. One of them was selected. The disproportionate Whiteness of the sample population is a limitation of the study. Also unfortunate was that no teachers in rural settings responded. Table 1 presents a summary of pertinent demographic information.

Table 1: Participant Background Information

Name (pseudonym)	Subjects currently teaching	Self-identified gender	Self-identified race	School type (enrollment)	Years of experience
Lydia	IB Biology	Female	White	Suburban charter (400)	17
Tom	Physics & environmental science	Male	White	Suburban public (1400)	15
Alex	Environmental science, physical science	Female	White	Suburban public (1400)	1
Nel	Biology & IB chemistry	Female	White	Suburban charter (350)	8
Trent	“Science & Technology”	Male	White	Suburban public (1200)	34
Elaine	AP Physics	Female	White	Suburban public (2900)	21
Glen	Biology & physics	Male	White	Urban public (1100)	26
Abby	Biology & chemistry	Female	Non-white (declined to specify)	Urban public magnet (500)	6
Neal	Engineering – intro & CTE	Male	White	Urban public magnet (500)	7
Leah	Physics – ninth grade and “advanced”	Female	White	Urban private (600)	15

Data Collection

Data for this study came from four main sources: initial interviews, documents, written responses to assigned readings, and follow-up interviews. I also retained email communications that were part of the recruitment and enrollment process. In two instances I posed follow-up questions through email when setting up a third Zoom meeting felt onerous.

The first phase of data collection consisted of one-on-one semi-structured interviews with each of the 10 science teachers who participated in the study. Interviews were conducted over Zoom. To gain insight into teachers' thinking, a semi-structured interview protocol was utilized. Semi-structured interviews enable researchers to ask consistent questions of each participant while also following up and clarifying points as they arise (Brenner, 2006). Interviewing in a semi-structured manner enables the discussants to achieve greater clarity and depth (Rubin & Rubin, 2011). But they demand of the interviewer that they make real-time judgments about whether to go off-script. They thus require close, attentive listening and some measure of live analysis to ensure that the data can ultimately address the stated research objectives.

Initial interviews lasted approximately one hour and were recorded and stored in a password-protected Zoom account. The goal of this opening phase was to collect data pertaining to the teachers' reasoning for why they taught as they did. The protocol for interview one (Appendix C) was therefore designed to explore at the outset the participant's curriculum and instruction. Participant responses that described their teaching were leveraged to open up the interview to the reasons these teachers taught in the ways they described. The first half of interview one was intentionally general in how it asked about the purposes and usefulness of their science teaching for all students. It was not until prompts seven and eight that "democracy" and "citizenship" appeared.

For the second half of interview one, participants were invited to elaborate on their responses to the recruitment survey items. Those questions invited teachers to reflect on their decisions (and/or the limitations imposed upon them) to include current events, news media, sociopolitical issues, and students taking a position on a normative question in their science teaching.

After the first interview, and at least two weeks prior to a second scheduled interview, I supplied each participant with two documents and instructed them to analyze and respond to them by annotating them and writing out their thoughts. The first was a single paragraph from the *Framework for K-12 Science Education* (NRC, 2012; see Appendix D) that described reasons for science education. This passage mainly focused on careers and citizenship.

The other document was a 3-4-page vignette that showed how a fictional teacher, Ms. Franklin, went about teaching an interdisciplinary unit that blended science with political deliberation. I adapted these narratives from published units in a socio-scientific issues teaching book by Zeidler and Kahn (2014; Appendices E-G). These vignettes were constructed to serve two research purposes. First, on the one hand, they involved science content that was part of any standard biology, chemistry, or physics curriculum. On this count, they would be appropriate inclusions in a traditional science course and therefore could offer science teachers an in-road. Second, and on the other hand, they portrayed significant class time devoted to deliberation, which could be seen as a more controversial design choice. These vignettes prompted participants to reckon with the notion of crossing a normative line in their teaching. They served as a model that gave us something to talk about. Interview two protocols were tailored to each vignette (see again Appendices E-G). These vignettes did two things that added to the quality of the data. First, they made a merger between science and issues-based citizenship teaching tangible rather than abstract. None of the participants had prior familiarity with the term socio-scientific issues, and most had never entertained the possibility of doing something like what they saw in the Ms. Franklin vignette. Second, they created a critical distance between the participants, me the researcher, and the version of science education for citizenship shown. I found that the invention of a fictional third party as the proponent of SSI instruction enabled participants to be more forthright and honest in their assessment of how appropriate or effective her teaching was.

This prompting of direct responses to a given situation represented by a text passage or vignette is in line with the qualitative research technique of critical incidents. These are examples of practice or depictions of situations that are deliberately chosen by researchers to elicit a response (Butterfield et al., 2005). Nott and Wellington (1995) used critical incidents to explore science teachers' understanding of the nature of science as well as to study their justifications for adapting scientific processes in the classroom. The Ms. Franklin vignette was supplied to get teachers thinking about the appropriateness of her technique, which was drawn up deliberately to represent an expansionist perspective on science education for citizenship. "Her" practice pushed participants to decide whether certain aspects of SSI teaching seemed appropriate to them.

Another piece of the design of interview two was to follow up on ideas raised during interview one. Time was built into the data collection methods for a first-pass analysis to be conducted between the two interviews. This initial phase of data analysis yielded targeted questions unique to each participant. Here I mainly sought to highlight concepts and goals raised by participants and wrote follow-up questions aimed at clarifying and deepening my understanding of the concepts they seemed to employ in making teaching decisions (Rubin & Rubin, 2011). For example, "science literacy", "science process" and "scientific inquiry" were frequent utterances but were used in many ways and thus hindered my analysis. The second interview being so responsive to earlier data—asking the participants if my takeaway from interview one was correct, often asking “Is that a fair question?”—also contributed to the trustworthiness of the study’s findings (Ravitch & Carl, 2016).

Throughout the data collection process, I repeatedly made it clear to participants that there were no favored responses, and I was not advocating any kind of teaching. Prompts commonly began with phrases like “in your own words” and “to your way of thinking”. Additionally, I intentionally began each Zoom meeting with some zero-stakes talk about how their teaching was going. I felt that my background as a secondary science teacher enabled an authentic rapport—it felt like two teachers talking. I believe that this established a level of trust that was critical to data collection.

Data Analysis

As each interview was completed, my initial steps in the analysis were to create a full transcription and to write a memo capturing my immediate reflections upon the participant encounter. The Zoom program generated an initial textual representation of the video recording. These however contained mistakes and included distracting timestamps at each moment of silence in the conversation. I, therefore, listened back to the entire recording while transforming the raw text into a legible and accurate transcript. I added marginal notes to this document as I thought to do so. My next step was to read the transcript without listening, making further marginal notes and labeling chunks of text with potential codes that could inform the research questions. Once this was done with each of the 10 participants’ first interviews, I then worked to compile a list of initial codes from the entire batch of interview data. Knight Abowitz and

Harnish's framework of civic republican, liberal, and critical citizenship (2006) served as the only a priori codes for a deductive round of analysis.

At this point, I brought all the transcript data along with their initial coded analysis into NVivo. This made it easier to assess the coding by quickly gathering each chunk of data under a common single code. In this phase of the analysis, codes were refined—either split into more than one label because the participants' ideas were different, or combined because two initially different labels, upon further consideration, had the same meaning. This process of refinement continued until each relevant piece of data could be sorted into a mutually exclusive category or sub-category (Merriam & Tisdell, 2016).

I then began a process of pattern coding in which I sought to understand the plausible explanations for recurrences I saw in the data (Miles & Huberman, 1994). This was an iterative process that involved several refinements to the code definitions driven by repeated passes back over the transcripts to verify fit (Saldaña, 2015). Consistent with Merriam and Tisdell's notion of constant comparative analysis (2016), subsequent data collection was made to be sensitive to the emergent categories the early analysis was generating. This mainly meant that ambiguities that could not be justifiably resolved with the available data led to purposeful follow-up questions to be asked in the second interview.

Another analytical tool utilized in this study was research memos. These constituted trial explanations and descriptions of initial themes found across the whole dataset. To address validity, I then compared these nascent texts once again to the data, specifically looking for evidence that could form a counterclaim. This was particularly helpful in sorting out what teachers believed was generally important for students to learn from what they felt was their specific responsibility to teach.

Limitations of Study

The primary limitation of this study is that it deals only with what teachers say and not what they do. In terms of a contribution to teacher beliefs, this closes off beliefs that can be inferred from teachers' actions and only allows insights into teachers' espoused beliefs (Bryan, 2012). A stronger set of findings could be had from a study that could compare observation data to interview data. This limitation was intentionally addressed by gathering teachers' lesson plans, assessments, and similar documents, in addition to asking them direct questions about relevant classroom phenomena that could not be corroborated through direct observation.

Another key limitation stems from the participant cohort. Enrollment was limited by a reliance on personal networks for recruitment. Given more time and effort, I could have achieved greater diversity among participants. As it happened, only one participant self-identified as a person of color (without choosing to specify their race) while the other nine of 10 participants self-identified as White. The study was also limited by having no teachers in rural settings contribute their perspectives. Balance was achieved however in gender self-identification, science subjects taught, years of experience, and teaching contexts (public/private and school size).

Researcher Positionality

In this section, I discuss my positionality as it relates to my research interests and methods. All research is inevitably shaped by, and therefore readers deserve to know, who the researcher is (Wolcott, 2008). In research utilizing qualitative interviews, this is especially true, as the interviewer is part of the data collection. For instance, while protocols were somewhat validated through critical conversations with colleagues, ultimately, they were my creation, and the wording of questions and the manner in which they are posed will influence the data

(Hammersley, 2008). I identify as and presented on the Zoom screen as, a White cis-gendered male. This alone may have influenced participants' responses in subtle ways and should be disclosed.

I believe the more salient feature of my positionality, though, is derived from my dual professional sets of commitments as both a science educator and a researcher. Early in interviews, as a deliberate part of my rapport-building with participants, I took advantage of natural openings in the conversation to disclose my identity as a science teacher. I spoke in the present tense. It was also clear, through the participant induction process, that I was definitively acting as a researcher in the context of our interviews. I, therefore, achieved a level of "insider-outsider" status (Kinloch & San Pedro, 2014). On the one hand, I believe participants felt more at ease knowing that they were talking with a fellow science teacher. On the other hand, at the end of the day, I always held a position with the agency to interpret their words. I attempted to ameliorate this power differential by tailoring follow-up questions and re-voicing some of their responses, making it clear that my goal was to hear them correctly.

My background as a science teacher and teacher-turned-researcher also informs this study. My interest in the intersections of democratic citizenship and science education began as a classroom teacher before pursuing doctoral studies (though I would not have used those words then). Early in my career as a high school physics teacher, I was drawn to what I felt were "authentic" and virtuous instructional goals like "inquiry", "student-centered" and "culturally relevant" teaching. I use quotation marks because I surely held naïve views about all those concepts. Over time I became more critical of the typical notions of "relevance" and "usefulness" proffered by science educators—myself included. (Again, I would not have put it that way then.) As it happened, I had the chance to develop a new course on science and controversial issues. This was a completely novel idea to me at the time; the administration wanted it to happen and tasked me with it. I cannot call that first iteration a success, but I knew we were onto something. While this story may indicate a bias toward issues-based science teaching, I do remain skeptical. I believe these experiences as a teacher contribute to my ability to be sensitive to the difficulties that any reform initiative presents to teachers. This is a position I tried to put across in how I interviewed participants.

Chapter 4: Findings

In this chapter, I explore how a group of secondary science teachers conceptualized the relationship between science and citizens as well as their role in mediating that relationship. The chapter is comprised of three main sections that answer each of the three Research Questions in order. In the first part, *Sense of Purpose*, I show the reasons participants give for why all students should learn science. In the next part, *School Science and the "Well-Informed Citizen,"* I present the main findings of the study which pertain to participants' beliefs about the role of school science in the more specific task of preparing citizens. Third and finally, in a section titled *Science Classrooms as Places of Citizenship Education*, I show what participants believe to be appropriate ways of teaching that they feel align with citizenship goals.

Sense of Purpose

The first Research Question guiding this study is *How are secondary science teachers interpreting and responding to calls to teach science for citizenship?* Participants were asked to consider "citizenship" as an explicitly named goal at multiple points throughout the interviewing process. However, the data-collection protocol prompted teachers early on, before the idea of "citizenship" was introduced, to respond to more open questions about any goals they had for students. It is important to look across the full range of aims these teachers identified because it will help us see how they are (and are not) prioritizing democratic citizenship.

Why Everybody Needs to Learn Science

Participants' justifications for why science should be taught to everyone—what their courses broadly have to offer students who will not go on to a career in a STEM profession—coalesce around three distinct themes: (1) it teaches generalizable thinking skills, (2) it supplies knowledge that is applicable in "everyday" concerns outside of science, and (3) it can instill a public appreciation of the achievements of science which will extend to greater trust of expertise in the present. These findings are not directly related to citizenship, and, therefore, readers may find their inclusion curious. However, examining how participants think about what their course is for (aside from and prior to an explicit invocation of "citizenship") helps understand how they think democratic citizenship does fit or could be made to fit within the bigger picture of their teaching.

Science teaches generalizable skills. Throughout this study participants routinely spoke about the useful skills that students stand to gain from their classes. Most often this meant the ability to analyze data. Participants spoke fervently about students valuing evidence as a universal benefit coming from science class.

Abby was a good example of a science teacher who centered understanding data and evidence. She stated that, when she considers learning goals, "It's not just the content, right, it's how you look at data. And I think how you look at data is important to every aspect of your life in order to know if something is true or not." Similarly, Nel said that science education helps make "an educated populace" because it instills in learners the disposition to go "looking for evidence and trying to separate fact from opinion." She went on to highlight—as happened so many times in this study—a sense of urgency around this skill brought on by our current cultural and political moment:

> …we've seen it a lot in politics this year. We've seen it a lot in debates this year and I know that does cross over to other subjects, but the "where is the evidence?" critical thinking piece…I think it can inform decisions outside of school, or your opinions, like things you might vote on.

It is worth noting here that the rhetoric of "critical thinking" was ubiquitous in the data. Nel makes an uncommon move to say what that means to her: seeking evidence. Her statement also stands out because it is a rare mention of anything related to democracy that is unprompted by the study protocols. She was not at this point asked about why science education is useful to *citizens*, yet she offers the voting booth as a place of use for science.

Participants did however frequently name the student's future workplace as a key venue in which analytical thinking skills would be highly valued. Take Neal for example. He teaches an introductory course in engineering that every ninth grader at his school is required to take, which is a requirement he fully supports. He recognizes, though, that only a fraction of his students will go on to be working engineers. He then poses a question to himself and immediately supplies his answer:

> So then why the hell am I teaching all these other kids who aren't going to do that? Well, because, engineering design process is, as one example, is extendable to if you're going to create an NGO…and to a nurse…to a wide range of careers.

When asked how he explains to parents and students why they should take his course, he says he "de-emphasizes the importance of the exact field" and highlights the fundamental skillset that is "applicable to anything you decide to do."

Tom made the same argument. He is worthy of attention on this point because he came to science teaching after a 25-year career in chemical engineering. This evidently grants him credibility with his students: "It's amazing when I say, 'Ya know, I'm gonna share with you something from my years of experience in the business world.' All of a sudden, I feel like I have every eye on me." He pitches his science course to his students via a stark reality as he sees it:

> There are two kinds of jobs in this world. You're either solving problems or you're flipping hamburgers. And I pose to them the obvious question. Which one pays more? Which one is more rewarding? And they immediately understand. Yes, being good problem solvers. And I say, "Well physics is the ultimate course to learn how to be a good problem solver. If you can learn how to solve problems, you can be successful in any career you so choose."

There is no room for interpretive ambiguity here. Throughout the interviews, Tom would often talk about things he has students do in the classroom—programming with Excel and solving open-ended problems with little guidance, among others—referring to them as marketable skills that would ingratiate students to their future employers.

Respondents often employed language meant to tie schooling in a science discipline to future endeavors at a remove from that subject. Alex said that "whether they consider themselves a science person or not, ultimately, I hope to empower them to feel comfortable and confident and more willing to take risks" which will help students "pursue goals and careers." Leah said, "Reasoning with numbers is a valuable skill—being able to take a problem, turn it into math, and find a process for solving it." She added that this is "probably going to be the only thing they retain from physics and, if I can develop that muscle for them, I think it'll be helpful."

This idea of science class as a kind of gymnasium or a proving ground—a place to exercise your mind and develop technical thinking skills—was a recurring theme amongst participants. Neal argued that his course was a place to practice problem-solving, saying this is valuable for his students because they "build not only capability but confidence. And by having confidence you decide to tackle problems that you wouldn't have before." Trent, who teaches students to reverse-engineer devices as a way to learn the physical science concepts at play within them, said:

> If you can break it down into a flow of energy, into an understanding of the types of materials that are there and the properties of those materials, and you have a little bit of an ability to read a little bit, you can figure any of this stuff out. And when you do it's like the best feeling in the world. They really need to taste that.

When asked when she feels teaching is most rewarding for her, Nel said, “In chemistry one of the things that I’ve seen be the most empowering is for kids to feel like ‘hey this was challenging but now I totally get it.’” Glen shared an anecdote as evidence of why he strives to maintain rigor in his science teaching:

> I have a former student that reached out to me…and he said that it was my class that showed him that he had the skills to compete with kids from more privilege, from a stronger background. That he knew that if he could survive my class and what I taught him that he was able to learn anything.

Many of the participants subscribed to the notion that science class is valuable *because* the subject matter is difficult, not that the subject matter itself was useful. They often expressed a hope that their students will do as Glen’s did, to look back on their science education as a place where they showed their mettle, working hard to develop the analytical thinking skills of the discipline. These teachers went out of their way to name this as an opportunity their course provides.

Supplying knowledge that is applicable to “everyday life.” Respondents spoke often about the usefulness of scientific knowledge in much the same way they spoke of the transferability of general skills. Supplying students with specific scientific explanations—the facts about how things work—is a central aim of their teaching. For them, it is of prime importance to teach the underlying principles that bring a sense of order to the world. They often spoke about science being "connected" to every facet of life.

Trent, for example, mentioned that this is something parents and caregivers respond favorably to when they come into school to meet the teacher and get oriented to their child's new science course. He described the value he sees in his course, which was how he described it to the back-to-school-night audience as well:

> I'm only partly training them in a discipline. I'm trying to make them appreciate that the discipline offers them insights into their life. So, we talked about not only you know political questions that center on science and social issues around science, but also simple consumer issues.

Lydia asserted that "people don't realize how integrated science is into their everyday lives" and spoke at length about how she sees her science classroom as a venue for correcting this. Abby said,

> I don't necessarily care if you can tell me the equation for photosynthesis or cellular respiration. I want you to be able to apply this knowledge. Especially now that we have the Internet, and you can pull up any facts, I don't care that you know a fact. I want you to be able to show how that applies, how that affects you in your everyday life.

This rationale, where acquiring science content is certainly necessary if not the primary goal, surfaced in how most participants talked about the value of their courses.

Participants readily supplied what they considered examples of applicability. Alex, illustrating why it is important for "members of your society to be knowledgeable about science," offered that it might be helpful that students "understand the phenomena that they're dealing with in their cars" such as "why you need antifreeze." Nel said that it is "very motivational" for chemistry students if they "can connect it to the real world. Like yeah, I'm using this nonstick pan, but what does that mean chemically? What does it mean if I ingest some?" Thoughts like these reflected the most common way that "connections" purportedly exist in participants' science classrooms: Now and then these teachers will briefly mention that a piece of the curriculum shows up in students' lives in a particular way. As Nel put it, "I feel a responsibility to look up pertinent examples that I can sort of dribble throughout the classes."

There were a few instances where teachers went further and sought deeper "integration" in their instruction. Glen, who said that "the most important thing is that I want them to have a layer of common sense," told a story about a key unit in his biology course in which he brought in a reading from the book *Burn: New Science Reveals How Metabolism Shapes Your Body, Health, and Longevity*:

> In the book, it talks about how all of the macronutrients, which they learned about in the first unit, plug into the Krebs cycle and where they plug into cellular respiration. So, from their diet stuff, we did earlier in the course, now they can see where it fits into how they get energy out of it. … So they can see an implication for if I eat fat…if I eat carbohydrates…if I eat protein… And the author used the [example] of eating pizza, which contains all three macronutrients and how each of them are broken down.

He went on to say he "had a student that came back, from my biology class, that lost 150 pounds because the lessons we learned in biology finally took root."

The participants here were not talking about knowledge of science as important in and of itself. They sought to connect it to students' everyday lives by mentioning applications and, in some instances, making students accountable for performing such an application. Participants, in other words, tried to arm students with an understanding of the scientific principles and facts that govern the phenomena that affect them. The teachers seem to believe that when people have this awareness of how science shows up in their lives, they will gain control—Neal used the term "agency"—derived from the predictability of nature. Science education results in, according to the respondents, an enhanced ability to plan ahead and make better decisions.

Science education fosters public appreciation of science. The third and final justification participants consistently made for why all secondary students need to learn science has to do with the authority and status of scientific expertise. These teachers were tremendously concerned with science maintaining a place of high regard in the eyes of the lay public. They wanted everyone to understand that it is the best source of reliable, credible knowledge.

This desire—or anxiety—led several participants to position scientists as objective or dispassionate reporters. In one example of this, Tom said,

> Probably the most important reason…what everyone should appreciate about science is just how different it is from a lot of other things that we experience. It strives to be as factual and well-tested a process…more so than anything else…what people need to appreciate is the fact that it is well-vetted and well-tested.

This idea about the credibility of the scientific enterprise reflected the thinking of nearly all participants in the study. They unambiguously implicated school science in the important goal of protecting or restoring the public's trust in science.

While the participants' comments pointed to the appreciation of science as a source of information as one clear theme, they also identified technology as another product of science that demands respect given its power to improve quality of life. As one example, Lydia responded to being asked how science education contributes to "the greater good" this way:

> I feel like science and technology go hand in hand, right? I mean like just thinking about medicine. Like, God, it would be awful to be living in the 1600s. I wouldn't have made it through my first birth, where I had an emergency C-section. Who knows if I would have made it out of childhood?

Participants, in other words, insisted that high school science education should be a vehicle to promote student trust and belief in science. Such trust would hopefully lead them to not reject science out of hand and to counter malicious actors who seek to misinform them. They felt, furthermore, that demonstrating or reminding students of the tangible benefits of science (which they extended to technological innovation) was the way to instill this disposition.

The STEM Pipeline Demands Attention

While participants unanimously agreed to a science "for all" mission for most courses, they simultaneously felt beholden to ensure the education they provided would support students' possible entry into a STEM field in the future. Alex thought back to her success as a college science student and wanted to prepare her current high school students so that they can find similar success: "I want them, obviously, to have like a hard skill set for science, for future science classes at the high school level, at the college level." She explained that it is her goal to make students "comfortable with their background knowledge so it doesn't feel quite as difficult once they get there." Her approach to accomplish this was to run through essentially the same material an introductory college course in chemistry would, but to go slower and provide more support and encouragement. Yet elsewhere in our talks, Alex struck a markedly different tone about the same course:

> I think that students would really engage if they felt like it wasn't being gate-kept in terms of like lifelong opportunities. That is one of the goals in the class, to make them

> interested in it, or at least make them feel like they can, are allowed to be interested in it, and are allowed to have thoughts and ask questions about it. And that it's not science people versus non-science people.

Lydia expressed a similar sense of misalignment, though more directly. After discussing how in a previous teaching position she held, she taught a course that dealt exclusively with climate change for the length of a semester, she said,

> The kids didn't know anything about the periodic table, but they knew a lot about what country was screwing things up and who was taking accountability. Which I would argue is more important. But, did I do a disservice for the kids who maybe wanted to go into the medical field or explore a science field, and maybe they didn't get a lot on the periodic table? I always kind of struggled with that.

Abby, who teaches the ninth and 10th-grade biology-chemistry sequence at her school, which every student goes through, pointed to a tension of purpose in her work as well:

> You have to teach to the students who want to become science and engineering professionals. You have to find challenging ways to keep them engaged because they might come into the classroom already loving science, but then they could get a little down if it's not challenging enough. So you have to teach to challenge them while also making sure that every other student is just science literate.

She went on to explain that this dual mandate has made it important to "differentiate" her instruction. Indeed, throughout this data there was a solid theme of teachers feeling they need to cover "both" bases—that the needs of the pipeline are different from the science education needs of the non-professional (sometimes "citizens"), yet both must be handled at once because of the nature of the course enrollment and where it fits in the overall school curriculum.

Elaine, who teaches AP and "College Prep" physics exclusively, was an outlier in the sense that her courses are not intended to give students a general education in science; they are made to funnel talented students into the professional pipeline. She has no qualms about that. When discussing how effective her teaching has been, she said that she "hear[s] back from students who've gone on to college and tell me that they were well prepared." "One of my students," she stated, "just graduated from MIT last year, and she was one who told me she felt well prepared." When Elaine responded to abstract calls for science education to address citizenship and professional training, though, she pointed out that "not everybody's going to be a STEM professional…nor should we have that." While science education meant to prepare citizens was something Elaine saw as necessary and good, it was not a kind of science teaching that falls under her purview. She felt no particular pressure to specially attend to citizenship because a professional purpose was baked into her course from the outset.

There was another sense with which the STEM pipeline was being attended to by several of these participants. Leah, Elaine, Abby, and Lydia were all especially focused on a lack of diversity in the sciences at the professional level. This meant that as high school teachers they took on the responsibility to make their curriculum and instruction more inclusive. For Elaine, this was personal. She said of her experience studying engineering in college, "I was often the only female in a class." She then related a story:

> I had a professor…probably electricity and magnetism class. We were learning about the right-hand rule, and he told us about screws or something. And he asked for an example: "Does anybody have an example of something else that works that way?" And I raised my hand, and he calls on me, and I'm like, "Well, a jar. A jar works that way." And the

> rest of the year, [when] I came into class: “So [Elaine] did you do your fall canning yet?” He would not have done that if I had been male.

She then explained that it was therefore important to her to not devalue her students’ cultural assets and to welcome all ways students had of connecting to physics. Lydia also repeatedly talked about wanting to create a welcoming environment for all, to make her classroom “a place for students to have that natural curiosity.” Lydia felt that “great scientists” are great “because they have that natural curiosity, and they were given the support to explore that.” In our conversations, Lydia shared that it has been a big shift for her to go from her previous school where she served a predominantly Black and poor student population to her current one which is by her account middle-class and majority White. She said, “I don’t feel like I’m having as much of a difference at my current school as I did at [the former school].” Lydia saw science education as a particularly powerful way to serve students of color because of its potential to change their socioeconomic status.

While Lydia was concerned with “creating that culture, creating that sense of community” where all students feel welcome to be curious about science, which she said, “snowballs into the scientific movement,” Abby and Leah were thinking of the same issue in terms of curriculum reform. Abby, when asked at the end of an interview what else she wants me to know about her teaching, was quick to share:

> For my curriculum, I’m very passionate about representation in science. So talking about under-represented minorities and women in science. That's something that I also think about every time I make my lesson is like, how can we get in diversity, and you know what role models can I show, so that students can see themselves in science. One of the

> biggest things is just—seeing someone who looks like you in science makes you think, "I can do that."

She went on to say that this was difficult to accomplish because "I don't talk about a lot of history of science. I don't talk a lot about people; I'll talk about their theories." Leah for her part spoke about a desire to build more cultural competence into her physics teaching. She described to me a moment in class that motivates her:

> At one point in the electromagnetism chapter Hewitt [the textbook author] starts talking about how the discovery of…electricity or magnetism, or like magnets moving a compass…just starts waxing eloquent about how this was the most glorious thing discovered in the 1800s, the most important development probably even surpassing the Civil War. And a Black girl is like, "Excuse me? No." I'd never seen that until somebody pointed it out to me and then you're just like 'Oh, wow, that got published.'

Our discussion of making science teaching serve all culminated in Leah saying, "You need to somehow teach the White boys that this is not just their field."

I add this finding here because, in the way these participants talk about it, being inclusive is ultimately aligned with career preparation. I was careful in data collection to ask about student empowerment in a way that left the door open to discussing political power. I found that most of the participants were concerned with equality but could not say that it was political equality they had in mind. It was rather an equality of economic opportunity that dominated their conception of what science education is for and what it can do for their students.

Nominally Prioritizing Citizenship

Up to a certain point in data collection, I did not employ the words democracy and citizenship as I sought to determine participants' sense of purpose for their science teaching. Few respondents during that initial phase brought up “citizenship” of their own accord. The protocol prompted teachers to respond to a passage from the *Framework for K-12 Science Education* that described a few central needs for science education reform (NRC, 2012). That text asserted that the “need for science and engineering professionals to keep the United States competitive in the international arena” was no doubt “genuine.” It also stated that “understanding science and engineering, now more than ever, is essential for every American citizen” (p. 7). In addition to that prompting, I directly asked, “Why do you think it is important for all citizens to learn science?” (see Interview 1 Protocol, Appendix C). I found that, once the citizenship goal was pointed out, nearly all respondents easily agreed that students’ citizenship should figure into how they teach their courses.

Leah, for example, stated, “It’s not like we have an option of whether we are trying to train people who are going to be democratic citizens.” In weighing the professional and citizenship goals described in the *Framework* passage, Nel said, “You kind of have to do both.” On the same point, Elaine observed, “I think they [professional and citizenship goals] coexist peacefully.” Not only did these teachers agree to an abstract link between science teaching and citizenship, but they also went on to say that this was likely compatible with the professional pipeline goal.

There were a few subtle forms of divergence from this unanimous consent to science education for citizenship. Tom did not disagree that citizenship should be a goal of science education writ large, but he did respond to the *Framework* passage by saying, “The idea that ‘everyone’ should have ‘some knowledge’ of science is over the top.” Yet he also said, “Everyone needs to learn to a different level of science.” Elaine made nearly the same statement:

> We need to do both [prepare scientists and citizens]. I think we need to educate every American citizen to some level of science. I don't think that every American citizen has to be educated in science to the level where they would personally be involved.

I do not interpret these comments as contradicting the overall consensus that citizenship should be thought of as something that guides science teaching. I think that Tom and Elaine here are calling attention to the struggle to realize many aims at once. They are saying that more specificity is needed to better articulate which courses, or which parts of courses, should address citizenship and which would better align with professional training. Science education, in other words, is not a monolith, which complicated their answers.

Summary: How Teachers Think About Citizenship as a Reason for Science Education

In this section, I have shown how participants were thinking about why science should be taught to all. The study was designed so that this issue was explored openly, to invite teachers to voice all the potential reasons they saw for their work. The goal of citizenship, however, did not figure prominently in teachers' initial responses to this question, while college and career preparation did. Notions of science being useful in future jobs and students being ready for college-level science were expressed often and easily. These reasons were top of mind for all participants. Citizenship, by contrast, while eventually and enthusiastically agreed to as a justification, was only seized upon once it was named explicitly, first in interview questions and then upon reading the *Framework* excerpt. Much of the participants' rhetoric—the transferability of skills, explaining everyday life through science, and appreciating science—often led up to the threshold of citizenship but stopped short. Where exactly are science skills useful? Which parts of one's "everyday life" is science applicable to? In which public activities is an appreciation of science helpful? The responses to each of these could have been connected to facets of democratic citizenship but rarely were.

School Science and the "Well-Informed Citizen"

Research Question 2 asks: *How are secondary science teachers conceptualizing citizenship and how do they relate this vision of citizenship to science?* Where the previous section dealt with teachers' overall sense of purpose for school science and how citizenship might fit into that, here the focus turns to what teaching science for citizenship means to them. Put another way, the previous section indicated *how much of a priority* citizenship might be within the overall project of science education, and now this section will seek to clarify *how* they believe citizenship is to be supported through science teaching.

The data gathered and analyzed here showed that participants, when they did envision how science education would contribute to citizenship goals, commonly relied on a narrative of what I call the "well-informed citizen." While there were nuances among teachers, their core logic remained consistent throughout. They believed that the value of school science for preparing citizens is to supply reliable scientific knowledge and, closely related, to instill a sense of trust in science so that they can and will use this knowledge to make sound decisions. This narrative rests on three subsidiary findings: (1) participants nearly exclusively invoked discourses of *civic republican* and *liberal* citizenship (Knight Abowitz & Harnish, 2006) when considering how science education prepares students for democracy; (2) participants defaulted to a portrayal of scientific facts as stable, portable, and value-free when speaking of civic and democratic contexts; and (3) participants believed that it is important for citizens to independently seek out scientific information from credible sources.

Participants' Thinking About Citizenship

One of my goals in analyzing the data was to ascertain how participants' ideas about democracy and citizenship aligned with the three-part framework of Knight Abowitz and Harnish (2006). I found that respondents reflected the *civic republican* discourse in key respects, made frequent commitments to the *liberal* discourse, and collectively made only occasional and indirect references to *critical* discourses of citizenship.

Evidence for civic republicanism: citizenship as tribute. According to Knight Abowitz and Harnish (2006), a civic republican discourse of citizenship is about maintaining or restoring civic order. In their framework, the concept of responsibility carries a lot of weight for proponents of civic republican citizenship. They write, "The civic virtues of central concern are self-sacrifice, patriotism, loyalty, and respect" (2006, p. 659). Democracy, by this way of thinking, is primarily understood as a set of existing institutions that are proper and function well, provided they have the continual support of patriotic, cooperative citizens. The main educational goal then is to produce 'good citizens' who will work to keep these democratic systems operational. Democracy is, in the civic republican view, a prior accomplishment that requires service—the energy and skills of committed volunteers.

Themes of volunteerism and service were easy to find amongst this cohort of respondents. For instance, Tom said of citizenship, "To me, it's what you contribute to making sure the democracy is sustainable." This notion of "contributing" to "sustain" democracy is indicative of civic republicanism. Furthermore, consider Lydia's overtly stated definition:

> Citizenship to me means being responsible. Having empathy for others and being able to put more good into the world than bad. Recognizing that you have a role and that part of your role as a human is to help others.

Nel echoed Lydia's sentiment, saying, "When I think of citizenship, I think of belonging to a greater whole and…your contributions to that greater group. I think with citizenship there's a sense of responsibility." These statements do not rule out other commitments to other forms of citizenship on the part of these respondents, but they are significant in that they indicate a fundamental view of a citizen as one who is helpful and giving.

Glen's comments were also well aligned with the civic republican discourse. He asserted, "Democracy is the idea that each individual has a say, and what we have is a representative republic, which is not the same. Citizenship is to be able to contribute to society as a whole." When asked to elaborate on what kinds of contributions he has in mind, Glen responded:

> Citizens will produce goods and services for other citizens. They can do things as service to the good, as in they can do public service. Citizenship would be the ability to go out and do charity work or clean up a public park.

The only political action Glen named in our conversations was voting. What I find interesting in Glen's position is that he focused on what he saw as the proper limit of self-governance. He seemed to say participatory democracy should be less of a concern for educators because the "representative republic" system is not meant to accommodate, nor does it require, forms of participation beyond those he listed.

Another aspect of the civic republican discourse Knight Abowitz and Harnish highlight are the "civic skills…enabling citizens to engage in productive dialogue around public problems" (2006, p. 659). In their analysis, they placed the Ohio State Department of Education's directive of "becoming informed on public issues" within this category (2006, p. 660). Part of being a civic republican citizen, then, is to learn skills of information gathering—to go find out.

This was, indeed, the most prevalent sort of citizen behavior that the study participants named. A key finding was that all of these teachers, across all school and subject contexts, held a strong ideal of the well-informed citizen as a guiding principle for science education. Alex displayed this view by stating, “Part of my goal is obviously trying to give them tools to be an informed citizen.” Nel offered that, in light of a compelling issue like the Flint water crisis, “I think science teachers have a responsibility to build that in…to augment existing information.” I noted in my analysis that responses in this category, those that sought to tie school science to well-informed citizenship, were delivered with confidence and clarity. Furthermore, data supporting this finding came in response to all kinds of prompts throughout the protocol.

Participants spoke about the acquisition of scientific knowledge as a civic duty. Here is one of several passages in the transcripts where Lydia spoke of citizenship as a responsibility:

> I think it’s important to be informed citizens so that when they are able to vote and make choices, and even like what social media accounts they choose to follow, I think it’s important for them to…they need to have a sense of responsibility. I think for some of them they’re like ‘Oh whatever it doesn’t matter—who cares?’ But it’s like, ‘No. You’re going to be a voter in a year. You need to appreciate the responsibility that comes with that.’ … [P]art of that is recognizing the responsibility of being well-informed, making sure you know what you’re talking about and that everything you’re talking about is based in factual information.

Leah, for her part, also made it clear that being informed is necessary for effective citizenship:

> [C]itizenship is being a participant…which in theory ought to have like an obligation to be informed about things and like weigh in on things, but obviously...you can't make

> everyone be informed. You can't restrict democracy so that people who are uninformed can't participate.

Leah's comment about the non-option to "restrict democracy" served to underscore the importance of citizens being informed. Elsewhere Leah stated, "Science education allows people to make decisions based on accurate information. So, if somebody doesn't know correct facts about, say, human reproduction, then their opinions on abortion aren't going to count for anything." Her previous statement on participation was more correct though: all citizens actually can make their opinions "count" whether based in "correct facts" or not. For Leah this reality seemed to increase the pressure on her to disseminate the "correct facts."

Indeed, most participants spoke of anxiety about citizens failing to take up and believe the truth that science had to tell. They were hyperaware of mis- and disinformation as a corrosive presence in democracy. When our interview turned to the topic of science education's response to this, Tom shared:

> If people appreciate [that science is well vetted] then we don't have the problems we're currently having, which is "well I don't want to take the vaccine because I don't know that it's safe." Or "I don't know that there is a need for the vaccine in the first place." Eliminate all those things that really just hold us back.

While this idea has broad significance in this study, it is presented here as a pattern of evidence for how participants defined citizenship. In large part, for them, it is a responsibility to be informed, to 'follow the science.' This view is aligned with a civic republican discourse of citizenship because participants talked about it as an entry-level civic duty.

Evidence for liberalism: citizenship as thoughtful engagement. A liberal discourse is the second of three elements comprising Knight Abowitz and Harnish's framework. They say of liberal citizenship, “Freedom from the tyranny of authority is one of two primary values in this discourse. The other involves the deliberative values of discussion, disagreement, and consensus building—all viewed as essential to democratic societies” (2006, p. 663). This discourse, with its focus on accommodating and working through disagreements and challenging authority, is distinct from the civic republican discourse, which focuses instead on maintaining institutions and civility. Teachers emphasize the liberal discourse when they prioritize thinking and talking as a group about what should be done. Ideas that related science to deliberation were pervasive in participant interview comments.

Like what was previously shown with civic republican citizenship, participants made frequent connections between being informed by science and the quality of democratic exchange. For instance, Lydia stated, “When you have shared discussions…it’s important to base those discussions from evidence. … It’s hard to have a discussion when there’s not like a foundational agreement of how the world works.” Tom, when talking about the failures of our national discourse on nuclear energy policy, offered his diagnosis of the challenge: “We need to have a more informed discussion.” When I asked whether he planned to create a platform for such talk as part of his class, he said, “Oh it’s a question [whether to build new nuclear power plants] I’m looking forward to discussing. I’m actually building toward that question.”

Also emerging from the data was a strong sense among participants that gaining scientific knowledge would push students to be more open-minded citizens. Alex directly stated that she intends for her teaching to support this outcome:

> Part of my goal…is trying to give them the tools to be an informed citizen and informed member of society, not just voting blindly along party lines or what their parents do. So, hoping that bringing awareness and shedding some light on maybe these issues and

maybe the political bias, the polarization…I think can only make better citizens and only improve our democracy.

Undergirding this hope was the notion that supplying scientific knowledge would supplant inferior views that rely on partisan ideology—that politically motivated reasoning could be quelled by clear scientific explanations learned in science class. Abby said that this is why she has her students debate the value of genetically modified organisms every year. She said,

…[it's] a really good topic for discussion [because] there's pros and cons to each side. Being able to talk through those but then also understanding the science behind it, because I find a lot of controversial topics are because people don't understand the science that's underlying it. So learning that background information and then having a discussion about it and coming to your own conclusion.

Getting students to be independent, rational thinkers was clearly important to respondents. What is more, though, is that they often positioned being informed, specifically bringing scientific evidence into a political dialog, as a critically important way for citizens to achieve this.

Relatedly, Glen said that science education supports students' citizenship "by widening their worldview and purview to include ideas that they might not have been exposed to just living in their bubble." He went on to say, "The curriculum is giving them more information and putting them at the point where they're forced to accept and reject ideas." However, other participants reported mixed results when it came to science education supporting democratic deliberations. In describing in-class debates about Fritz Haber and chemical weapons, Nel said,

Sometimes the discussions do go in circles a little bit and people do become a little bit more entrenched in their positions. …but I think they do elaborate on their positions. So I think they do think about it more deeply or they might concede a point or a couple points.

While she was ambivalent about how it played out, Nel nevertheless held that open-mindedness—at least approaching a deliberation with a willingness to change one's mind—was an aspect of citizenship to be pursued in class.

Some participants felt it was paramount for citizens trying to decide where they stand on issues to know that scientific knowledge is tentative. Nel said that the value of science education for citizenship "goes back to logic and evidence-based decision-making. You might have a gut impulse, but if new evidence comes up, you need to be able to look at it objectively." When asked how science education could improve political discussions, Trent offered, "I think the success of scientific thinking is looking for places where you might be wrong and finding out if you are. I think that's a hard emotional lesson to learn." This goes beyond referencing the stand-alone value of scientific facts as information. He continued:

> We have an entire political party who is absolutely willing to ignore the advice of any scientist, to almost scoff at the idea of scientists, and to take the fact that we've learned something new as evidence that we didn't know what we're talking about in the first place.

Here Trent altered his message. He began by calling scientific thinking "successful" because it is open to change, arguing that this is a good character lesson for citizens as well. He then moves on to a different point, saying that our politics suffers when citizens, particularly an association as large and consequential as a bloc within a party, fail to understand a core epistemological component of science. Trent and the participants quoted above were aligned with a liberal citizenship discourse because they referred to the potential for science education to improve dialog.

Supporting democratic deliberation, though, was not the only type of liberal discourse participants engaged in. Two respondents, Glen and Tom, showed commitment to a neoliberal discourse as well. Of this discourse, Knight Abowitz and Harnish write,

> most political and educational theorists…largely reject neoliberalism as a civic discourse, in part because its model of *homo economicus*—the human being as an essentially economic animal—reflects an individualism so severe as to be incompatible with the civic ideals long associated with democratic public life and common schooling. (2006, p. 662)

Glen and Tom, however, embraced this model; they insisted that economic contributions *are* civic contributions. When asked how science education supports citizenship, Tom was direct:

> Citizenship, to me, it's what do you contribute to making sure the democracy is sustainable. And that includes the economy—the economy flourishes. Are you being a net drain on the economy? Which some people are gonna be. We all have different skill levels. But hopefully finding a way that you are a contributor to the economy.

It was telling that this was Tom's initial response to the first question he fielded containing the words "democracy" or "citizenship". Glen, in the same manner, put "citizens will produce goods and services for other citizens" first on his list of activities he imagined citizens doing. Elsewhere, Glen made a different set of comments that aligned with a neoliberal discourse. He said, "All science education has the responsibility to do is inform the individuals. What they choose to do with that information we don't have control over." Glen was concerned in our talks with "the individual's free will" and referred to citizenship as an "individual contribution" that "will shape society." At one point, after explaining why he downplays the role of humans in climate change, Glen shared that when teaching climate, he is "not saying that they have to change the way they live their lives and, you know, proselytizing that whole side of climate change." It was clear that Glen had a strong commitment to not have science education infringe upon anyone's liberty, which he framed as their liberty to continue to produce and consume goods and services in the economy.

Citizenship as a kind of critical discourse. The third and final citizenship lens utilized in this analysis was that of critical discourse. According to Knight Abowitz and Harnish, "Critical discourses raise issues of membership, identity, and engagement in creative, productive ways." They add, "Critical discourses have in common the agenda of challenging liberal and civic republican notions of civic membership, civic identity, and forms of civic engagement" (2006, p. 666). In other words, critical citizenship is about expanding who counts as a citizen and what forms of participation count as citizenship.

Few respondents said much that could be squarely grouped under this heading. Some participants were vaguely attentive to a wider and more equitable distribution of political power that may be tenuously connected to critical discourse. In describing democracy, Alex said it was "obvious" that we should "want everyone to be involved." She did not however expound upon who was or was not involved or how to expand involvement. Indeed, no respondent referred to "creative, productive" forms of civic or political engagement by any heretofore-marginalized groups. Leah showed concern for the protection of voting rights and fair proportional representation. At one point she lamented, "In our country, we can't even empower everybody to vote so…voter suppression is a 'fun game', and gerrymandering is a 'fun game.' People are trying to win. They're not trying to empower everybody." This general concern for fairness and equity was as far as any participant went in discussing how political power is distributed.

Participants, thus, did not articulate criticality specific to science students' political agency. This is perhaps to be expected, for Knight Abowitz and Harnish write that critical discourses "only slightly influence K-12 curricula or standards" and call this an "omission and/or invisibility" (2006, p. 666). There was, though, a critical bent to how participants talked about making their science curriculum justice oriented. The strongest of a handful of examples came from Nel. At one point she brought up that she had recently taught how opioids were under-prescribed to Black patients with sickle cell anemia. This came about, she explained to her students and then relayed to me, because of flawed but influential studies that had convinced much of the medical community "that Black people had thinner skin and fewer pain receptors." I asked her why she had included a case like that, and she said,

> Ignoring them doesn't erase them. If we're trying to prepare kids for a world where…you're still going to come across these issues and…there's things that you can do as an individual, and I think we're seeing in recent years, a lot more students taking action if they see something they don't agree with it. But they don't always know everything that's going on. And so I think priming them to at least look for it and think critically about those topics is important.

Her goal is to raise awareness of injustice by widening the scope of her course to include, not science facts without context, but a specifically chosen science story that affects a specific group of stakeholders. But was this framed as a scientific injustice, a political one, or both? Such cases occupy an interstitial space: they could, depending on the teacher's design, lay bare an internal politics of scientific knowledge production. The key question this quote raises, for the present study, is what did Nel imagine students could then do because they learned about this? Perhaps they could exercise a political oversight of science through normal representative government or a sort of activism akin to ACT-UP. However, the data cannot show that Nel, or any of these teachers, have such outcomes in mind as they instantiate these rare bits of science instruction.

Thinking About How Science Class Contributes to Citizenship

Up to this point, I have sought to display what participants think democratic citizenship is. The main objective of the study was to connect these notions to their work as science teachers. Therefore, the focus now shifts to how participants are conceptualizing science and how they connect science to those previously highlighted notions of citizenship. The primary finding is that participants see school science's main contribution as providing the information in the "well-informed citizen" model. Participants, in the context of citizenship, routinely characterize science as stable and portable—a body of uncomplicated truths that are simply to be taken up by lay citizens. A handful of participants talked about science as a "process" being necessary for *citizens* to learn, but all available evidence suggests that, even for those respondents, content acquisition remained the most important outcome.

Science facts are immanently useful to citizens. Participants at every possible turn emphasized the usefulness of scientific facts as information citizens need. Alongside this, I also found that participants fervently held that providing good information—meaning science content knowledge—was a good antidote to the problem of disinformation. Undergirding this notion of how science is useful to citizens was that participants consistently characterized scientific knowledge as settled and stable. It was particularly notable in my analysis that scientific consensus was spoken about as a prior achievement when the context of the discussion was the civic use of science. They sometimes talked about wanting to teach that science "wasn't done yet" (Leah) or that it was the process of science that made the knowledge reliable. But by and large, when considering the citizen's needs, participants consistently defaulted to a content-delivery role for themselves.

I found that these ideas were expressed in two distinct but related ways. First, participants said that political actors must first agree to basic scientific facts. Respondents by extension spoke of their value as professionals as key providers of that foundational knowledge. Second, in instances where political discourse had been degraded because it happened without scientific grounding, participants often said such errors could be corrected through scientific enlightenment. For each, the participants' notion for remediation was the same: supply more science or maybe communicate it more effectively. The analytical cut I made was to group the more basic talk about the democratic value of scientific knowledge, which respondents talked about as a preemptive measure, apart from data that indicated a reactionary stance to what we might call 'post truth' or a politically motivated rejection or ignorance of science.

Science as apolitical foundation. The science teachers studied here felt that learning science was obviously helpful for citizens because it established an inert factual basis for any political issue one might engage in. Respondents were often concerned with enforcing a separation between science and politics. Moreover, they tended to assign a temporal progression to these two domains by asserting that one must first establish scientific facts before engaging in politics. They sometimes noted that political stances were errant or illegitimate when undermined by, in Leah's words, "incorrect facts."

An important theme was the general character all participants assigned to science. Glen described biology as more "informational" than other subjects students take. Tom used the term "instructional" to describe his environmental science course; he used this word to draw a contrast with more "hands-on" learning that involved open-ended problem-solving. In the opening phase of our interviews, where I sought to build rapport by asking teachers to describe their course, Glen, Tom, and others launched into sequential lists of what they “covered.” Trent explained that what sets science apart is that “there is a real answer key.” He added,

> In literature there's so many diverse standards of what excellence looks like, but in the science world, it's pretty simple. You learn a pattern in nature, you learn how to apply it, when to apply it, and nature tells you if you're right or not.

The notion of students applying the science content they learned, as shown early in this chapter, was particularly important to Abby. She said something that especially relates here: “In order to get to that application obviously you need that foundational knowledge. Which comes from facts.” What Trent and Abby are getting at here is that, while they elevate the “application” of science to non-scientific areas as an important part of education as a whole, they also clearly think facts and what “nature tells you” are of primary concern. What came through clearly throughout the data was that these teachers see their role first and foremost as *informing* their students.

Participants had several opportunities to address how they thought learning science and/or about science related to their students’ citizenship. Leah made a clear statement that was emblematic of my finding here: “Science education allows people to make decisions based on accurate information.” Similarly, Abby said, “I’ll talk about science citizenship. And when I’m talking about it in that sense it’s like, ‘Can you understand the basics of science?’” What begins to emerge from quotations like these, which were plentiful in the data, is that science teachers answer questions about preparing citizens in terms of how science is already being taught. Their aims of teaching “the basics of science” and giving students “accurate information” make sense to these participants both in service of learning science for its own sake *and* for citizenship.

While all participants held that their main contribution to citizenship was to tell students what is objectively true, this did not mean that they never entertained subjective topics. But their descriptions of how and why they undertook these forays beyond the facts—Lydia called them “extension activities”—only strengthened the main finding. One of my conversations with Lydia turned to the issues of people of color suffering disproportionately from Covid as well as Black women faring worse in pregnancy and childbirth. She pointed out, “So it’s not just science. It’s also the ethics that come with it. They really go hand in hand.” I asked what science and ethics being connected meant for her science class. She responded, “I think science can provide the factual backup, like the factual evidence, for these arguments. I guess that’s where I would say science holds its place. You’re going to pull from science to justify the right decision.” In a separate interview on a different day, Lydia reiterated this idea about science as a factual foundation:

> I think you have to almost like level the playing field. Because it’s hard to go into an argument—like you can have different perspectives but if you believe in different facts [laughter] you know what I mean? Then it like becomes difficult. So…let’s come to a common understanding of what the hell we’re talking about when we’re talking about stem cells. … I think from that then you can build off on your arguments.

Alex was also eager to drive home essentially the same message. She said,

> It's fine to debate the policy and debate what we're going to do about it. But, you know, understanding that the science is only saying one thing. And we can argue about how we want to fix that and address it.

Lydia and Alex’s thoughts are emblematic of what I found with most participants and which none contradicted. The main story is that the science that is useful to citizens is science that is settled—telling students, implicitly or explicitly, that scientific consensus had been achieved and that the time for *scientific* argument is done. The only thing left to do in the arena of public discourse was to let those settled facts enlighten your political thinking.

Science as a corrective for misinformation. Another place where the well-informed citizen concept shone through was when participants reflected on the implications of being uninformed or badly informed. Participants showed unanimous concern for citizens and policymakers being misinformed or referencing nefarious, purposeful misrepresentations of science. For instance, when reflecting on the *Framework* statement that "every American citizen" must learn science, Alex offered a specific example. She related how a US senator, in an official deliberation on whether to relocate a military base within Guam, meant to cast doubt on the plan by asserting that the island could tip or sink into the Pacific Ocean. Alex said that the need to educate citizens reminded her of this example because it illustrated how "it's so easy for those misconceptions and misunderstandings of how the world functions to permeate into those conversations." One would be forgiven for seeing the Guam-sinking example as benign or even silly. Most examples like these that participants raised, however, were immediately and highly consequential. It was impossible during data collection, for instance, to escape discussions of the Covid pandemic. Interviews took place as these teachers were holding online classes or doing a hybrid of both in-person and remote instruction. It was also when vaccines were first being deployed and the public debate around them as well as masking and school closures was as hot as ever. It was a charged climate that made the notion of "well-informed citizenship" vital.

While participants lamented the problem of an uninformed citizenry, most respondents envisioned a simple solution. According to Leah, "[T]hese weird conspiracy theories people have are based on the fact that they really don't understand science or technology. If people actually understood anything about 5G, there wouldn't be this whole ‘5G is causing the pandemic’ thing.” Tom was referring to vaccine hesitancy and denial of Covid’s significance when he said that knowing science would “eliminate all those things that hold us back.” Abby said that the goal is to have people “able to talk through” controversial issues. She then hastened to add,

> But then also understanding the science behind it. Because I find a lot of like controversial topics are [controversial] because people don’t understand the science that’s underlying it. So learning that background information and then having a discussion about it and coming to your own conclusion.

Nel had a unique complaint that she felt connected to this point. Namely, that “they took out the immune system [from the official state standards] as a requirement for biology.” She went on to say,

> Which explains why you hear certain things. If that's the only exposure people have to biology, now, they’re apt to believe a lot of different things. But if you understand how viruses work, and you understand how vaccines work, some of the things that we've heard this year we would not have heard. … Certain things in the news would not have persisted as they did.

These teachers were working from a common premise. That is, if people could just learn the relevant scientific knowledge that has already been established—why islands are stable, how vaccines work, how viruses spread through populations of hosts—then our politics would run smoother toward better outcomes. A large part of the problem, in other words, is that citizens simply do not know enough science or the science that matters for the issues they face. The sense I kept getting as I read and reread these transcripts was an overriding tone of simplicity: if people only knew better, they would do better.

This finding, that participating teachers thought they would successfully contradict false claims by giving students reliable scientific information, was evident from the first round of interviews. I saw this line of reasoning as a problem, however. Things were not playing out as respondents asserted. To pick just one issue, credible voices about Covid were easy to find. The information participants were referencing was readily available to the public. And yet, it was being rejected or ignored at an alarming rate. I decided to follow up on this point more explicitly in the second round of interviews.

What I found in doing so is best represented by Elaine's response. When I asked her, as I did everyone, what she thinks the science teacher's role is in addressing phenomena like anti-science or misinformation, she said:

> I don't know. It is difficult and I wish I knew the answer to that question. Very good question…one I don't have a good answer to. I think five years ago I may have thought I had an answer to that, but after everything I've seen in the past five years, I don't know what the answer is and it's scary.

I asked her to clarify what she saw as having changed in the last five years. She responded:

> I guess five years ago I just didn't realize…not so much that I'm doing anything different. It's the fact that I didn't realize there were so many people out there with these beliefs. That's what I think has changed, is my perception of how many people don't really care what science says.

What Elaine said here that was consonant with the comments of other participants was the acknowledgment that something new was happening that they did not fully understand. They were trying to come to grips with recent history: Trump had risen to power in spite of, or maybe partially *because* of, his labeling of climate change as a hoax; his people infamously asserted demonstrably false claims about inauguration crowd size then took pains to legitimize the notion of “alternative facts.” Even Tom, who disclosed to me that he was politically conservative, said of those advancing claims that the 2020 election was improper or fraudulent, that considering the evidence, “you’ve got to yield on that.” Participants were anxious about what they saw as a corrupted public image of science and evidence. What they did not say, however, was that their teaching should change in light of these worries. Indeed, the common response was to re-assert and highlight the need for teachers to be a voice for science and sound reason.

There was however one participant who gave an uncommon response: Lydia. It was not that she refuted the notion that supplying citizens with scientific facts is an approach that *should* work. Rather, what set her apart was her recognition that convincing a resistant citizen requires a nuanced approach. She said,

> Speaking the truth…it’s a struggle. Especially with the school I’m at, because I know when I start doing that, I light a fire in them because now they’re battling with their parents. … I’m starting to kind of upset something within them.

The first part of Lydia’s recognition, then, is that what she is telling students in the name of science will contradict what her students hear in their political and religious spheres outside of class. She knows that in doing so she is essentially asking them to disagree with some of their closest and most trusted people. She also shared, more to the point, how she does approach teaching students who might be primed to be skeptics:

> I don’t really want to know who in my class is supporting Trump or who doesn’t believe in science. My efforts haven’t been so much to try to convince them of the evidence, but more so like having respect for what the other person thinks is true, even if that is not based in fact. I think…for students, because they’re still young, it’s just this idea of ‘let’s

> still have a respectful conversation.’ Because I’m finding even if you do provide evidence from a valid source, they’re still gonna like wiggle out of it. So, it’s more of like let’s just kind of open up why you think the way you do…and not get hung up on the details.

The idea that she is not trying to “convince them of the evidence” and to “respect what the other person *thinks* is true” regardless of factual basis is truly unique in this data. It was common for these participants to lament the politicization of scientific facts. Lydia however stands out in her response, which is to recalibrate and take a gentler stance.

Citizens should learn to respect the source of scientific knowledge. I have shown that content acquisition was the dominant way participants explained the role of science education in preparing citizens for democracy. That is, when the questions pertained to students’ citizenship and how science mattered in a civic or political domain, teachers told me again and again that the *citizen’s* central goal is to gather relevant scientific knowledge—to listen to scientists. Most of the participants’ statements along these lines, however, did not address *how* it was that citizens would come to trust and believe the information they were to be getting from scientists. Trust was generally assumed. As I also showed in the previous section, when I prompted participants to think about contemporary evidence for a lack of trust or belief in science, they saw it as unfortunate but did not offer thought-out strategies for countering that problem. I did highlight occasional mentions of trust in science being a learned disposition. However, none of the participants made space in their teaching for a study of a trustworthy scientific consensus being formed.

The message participants wanted to convey to students was that scientific claims should not be so easily doubted because they were correspondingly not easy to come by. For instance, Alex told her students to listen to experts and not “random quacks.” She explained that students should relate to those with credentials "not necessarily [by] deferring to someone just because of their title but recognizing the effort that goes into obtaining degrees like [a Ph.D.]." Tom, when asked what he thought was important for students to learn from his class, responded,

> I want them to walk away with an appreciation for how good science has done, number one. The rigors of data collection. That you don't just stop with one or two trials or three or four runs. I love…the guy that asked the charge on the electron [Millikan]. 365 data points he collected. Think about the patience that went into that. So, the process of science for one thing.

Later in the interview Tom again reflected that "the number one [priority] is opening them up to the idea of what scientific process is…that they are able to master a basic understanding of how science works." For participants like Tom and Alex, the central reason they wanted students to have for accepting scientific claims was through an appreciation for how much diligence is required on the part of the scientists to establish those claims.

Glen and Trent echoed and deepened the idea of citizens valuing scientific work. They focused in on empirical testing as the lynchpin of theory promotion. When asked how his science class contributes to his notion of democratic citizenship, Glen stated,

> By going through the development of where ideas come from. By showing them the process of science…that there is trial and error and that there are mistakes. That we throw out the mistakes. We don't keep it because the theory's elegant. We keep it because it's the truth.

This quotation displays one of a few times Glen told me that it was important for him to teach his students, as future citizens, that a scientific theory is "not just someone's opinion" but instead the product of a careful, objective analysis of data. Trent, in considering citizens rejecting or ignoring scientific expertise, named what he thought was the “essential question” at the core of that phenomenon: “We’re talking about, ‘Why should we accept scientific consensus?’” He went on to explain,

> The answer is not because it's obviously right. It's because it's been tested and it passes every test. And if it doesn't pass tests, then scientists are more interested than anyone in getting it right. And there are people who dedicate their careers to finding a little corner of it that's been unexplored and trying to explore it. I feel like if that's controversial then that's the controversy we should be embracing. We need to model that and demonstrate that, whenever somebody raises a concern, it's really important that we test it. And we do test it, but sometimes these theories fail the test and that's when scientists sweep it into the dustbin of history. History is full of false claims and claims that are plausible but turned out not to stand up. And we don't show enough of that process of false starts and false leads and why we get rid of the ideas that we get rid of.

Trent’s thoughts here are worth seeing in full because they point out what he sees as the democratic value in centering science as a process. However, it is worth pointing out that Trent was also a key promotor of science content being important for ‘good citizenship.’ He is also continuing with Glen’s line of reasoning that what might seem to make sense intuitively is and should be dispelled through empirical study.

Yet there was also a corresponding ambivalence among these very same respondents for how best to meet the scientific process learning goals they were naming as priorities for citizenship. As forceful as Trent was that “we don’t show enough of that process,” he at the same time said, “I hesitate to even bring this up, because every time that I’ve seen a textbook or a curriculum package try and teach the scientific method it's almost always been like a two-week time suck that does absolutely nothing.” Elsewhere he voiced a pertinent struggle he feels as a science teacher:

> There are a lot of things that come out in the science teacher magazine that I look at and I’m like, ‘Okay, so they're going to spend, I mean if they're going to do this right, they're going to spend a month doing water, these water studies of this creek.’ And they'll have nothing about the electromagnetic spectrum, nothing about chemical and physical changes, nothing about alternative energy sources. A month for them to become experts on this stream. And on the other hand, that's what scientists do. So, they're seeing what scientists do, and yet they're not getting a foundation of what scientists already have tested out. And they're not getting an exposure to a wide variety of topics, and if they hate streams then they think they hate science.

Trent is therefore concerned with the opportunity cost of devoting too much time to process at the expense of content. He has conceptualized learning “what scientists do” as in tension with what is already known from science. Alex was another participant who thought citizens should know how scientific studies are done. At one point she named “peer review” as a specific scientific process that students should be at least somewhat familiar with. But she also said,

> That's kind of the hard part at the high school level I struggle with. At least one of the goals of high school, in terms of engaging with modern life and with modern public policy, is that it should give you a strong foundation for understanding data and the knowledge base to potentially interpret scientific studies and applications in everyday life, right? To a certain extent, I don't know how achievable that is at the high school level or middle school level. I’m not sure exactly how you would fit all of the knowledge that is required to have a strong enough foundation to evaluate that science.

Both Trent and Alex are citing “foundational” science content knowledge as a sacrifice ‘process learning’ would demand but they are likely unwilling to make. Trent’s worry stems from a lack of “exposure” to the wide variety of insights science had to offer. Alex is meanwhile concerned with the citizen’s inability to appreciate a contemporary scientific process, and thus judge the veracity of a related scientific claim, because they have failed to learn enough of the scientific contextual knowledge that surrounds the question at hand.

The notion that science teachers should teach students how science is done was not rare in the data. However, it was rare for respondents to connect this “process” learning outcome to citizenship. Readers will recall my finding that learning scientific process was vaguely connected to improved cognitive abilities that everyone should have. These participants—Alex, Glen, Trent, and Tom—sometimes went further and talked about the need for citizens to respect empiricism. Moreover, these rhetorical connections between citizenship and scientific knowledge production were not meant to negate content acquisition as the more necessary and attainable (from the participants’ perspectives) citizenship goal.

“TikTok is not a valid place to get your information!” During data collection and ongoing analysis, it became clear that being well-informed was fundamental to participants’ concept of science education supporting citizenship. I, therefore, approached subsequent interviews and data analysis with a new question in mind: How might these teachers be thinking about learning to *become* informed? It was clear that participants felt strongly that citizens should think of science as the most reliable source of information. During the interviews, participants often complained about people believing or repeating false claims or conspiracy theories they saw on social media or by other means. It was Lydia who most colorfully captured the collective sense of this problem when she exclaimed, “TikTok is not a valid place to get your information!" But, having named the use of trustworthy sources as central to productive engagement in civic affairs, how were Lydia and the rest proposing to respond to this need? My analysis revealed that participants were working with a diverse set of ideas about how citizens learn to become informed. There was little agreement among the interview participants on how best to approach this problem and, however, they might approach it, ambivalence as to how effective they could be at helping students identify trustworthy sources.

The primary and most basic way participants responded to this challenge, I found, was to position themselves as valid sources of information. Alex said, for example, "There's a lot of misinformation, so it's good to feel like you're combating that. Good science education should be working to combat some of those misconceptions that people have." The idea participants held was that science class is the place where you get bad information replaced by good information. To achieve this, Lydia said she wanted to provide a place where students could feel free to "ask their questions" and "get their questions answered." She said sometimes this "happens more informally" and that she prompts these sessions by asking students, "What do you know? What have you been arguing about with your friends? Let's clear up some of that information." Respondents consistently communicated that, simply by being in class, students could circumvent a fraught media landscape and avoid the difficult task of source evaluation. In other words, they believed that when you come to science class you no longer need to worry about finding the right source; you are already there. Thus, their main role was to be a voice of science—Lydia at one point referred to herself as "the lead scientist in the room"—and to provide quality information to students as an essential service.

Beyond this, however, respondents also frequently voiced concern about the ability of their students to seek out and use secondary sources of information. Elaine identified this goal when she said, “A big thing is to be able to evaluate sources.” She continued, “And that is something that we do try to teach.” When asked in which context she and her colleagues tried to teach skills of source evaluation, she clarified that it was within the ninth-grade general “scientific literacy” course housed within her science department—a course she had taught once, years ago, but did not currently teach. As to her role as an AP and honors-track physics teacher, she added, “I don’t know how much we do that in AP physics because there’s not time.” Elaine’s comments here fit a pattern that emerged throughout the analysis. Teachers expressed concern about students learning how to find, interpret, and assess sources of information that involve science. But they provided little evidence that these skills get much attention in their science classrooms beyond naming them as important.

Abby was another participant who indicated a desire to include science as it is found in the media, while at the same time acknowledging that she was rarely able to make time for that in her teaching. In her reflection on the Ms. Franklin vignette, she stated that devoting class time to secondary research was a “really good idea.” She pointed out a line of inquiry she would like to engage with: “‘What are valid sources of scientific information?’ We like touch on that, but I think posing it as a question is really great.” When I invited her to say more about why this resonated with her, she responded by expanding the scope of her thinking to her assessment of a problem outside of, but connected to, her own teaching:

> I think a lot of high school kids don’t know valid sources of information. They’re taught ‘don’t use Wikipedia’, right, but anything else is fine. I don’t know who their librarian or media specialist was if they even had one. We do not have one in [our] high school. There’s like three in the [large metropolitan school district]. I think that’s really lacking, their research ability. We sort of assume that all students know how to research and really

> they just know how to Google. Especially now, in this time, there's so much misinformation and people spouting nonsense, knowing what a valid source of scientific information [is], is super important. It's sort of one of those soft skills that we don't teach because we either assume students have it or we don't have time.

Other participants made similar statements: Citizens need to learn how to become informed, but school science does not typically meet that need consistently. A lack of time and resources were commonly identified constraints in this regard.

It might be that science teachers themselves are not conscious of their own process for finding and evaluating scientific claims encountered in the media. Some participants displayed a distinct lack of confidence on this front. Elaine told me about how she had recently wanted to figure out what a new quarry development would mean for her neighborhood, particularly how it might affect asthmatics. As much as she thought it important for citizens—herself included—to be "able to evaluate sources," she had to admit,

> Now, it's almost hard for me because I'm not always sure what's a reputable source online anymore. It's hard to keep up with that, and the more that everything goes electronically, the harder time I personally have deciding what's a reputable source.

For Elaine, it was the advent of social media and the subsequent diminished influence of traditional news outlets that screened out unreliable information that complicated matters. Still, she and other participants said that they had no other choice but to prepare students to navigate the world as it is now. Leah was in this category. She said,

> People are disagreeing on the facts, people are disagreeing on the data, and people disagree on what's a trusted source. That's a good space to have kids navigate, like learn to navigate. But I also don't know what you do when you have two kids who disagree

> about whether a source is trusted. Like when I argue with my mother about vaccines, because she doesn't believe in vaccines, I have no way of convincing her that my intuition about what's a trusted source is better than hers.

She went on to add, "I'm sure that history teachers…have solved this…they've put more time into scaffolding, like, 'what are reasonable resources?'" Leah thus attributed her misgivings as a teacher to her limited knowledge of how to assess credibility. It struck me that she thought she had "no way" to give someone what she called an "intuition" about what sources to trust while at the same time pointing to history teachers as ready and able to do so. Leah's characterization was reminiscent of Abby's labeling of this kind of research as a "soft skill." It is also again relevant here that Abby wondered about librarians and media specialists, implying that they are the ones who should fill this role. These participants, while clear on the point that citizens must learn to use secondary sources that involve science, did not embrace teaching this as part of their responsibility as science teachers.

The bottom line for most participants was that science content knowledge somehow was all that was needed to assess whether a source was credible. Alex, who described the citizen's task as "differentiat[ing] between some random quack spouting off nonsense and what the expert[s] are saying," described that process in part as "mak[ing] sure you're not misremembering your chemistry class or your environmental science class and then…do that research and then realize, 'This person doesn't know what they're talking about.'" Trent also stated that having a memory of science knowledge or some means of referencing it would grant lay people the ability to judge truth claims about science. He shared:

> My mom sends me all this stuff about whether Round Up causes cancer and I'm like, "Do you…" She doesn't know anything about the chemicals involved or what those

> chemicals do in the human body. And she might be right. You know, she might be right, but she doesn't have any sort of scientific foundation for it. All she has is the authority of the newsletters that—she gets an email [and] she feels like they're more credible than the companies.

Here we must imagine what Trent would have the citizen—in this case, his mom—do in these situations where they are faced with competing claims to credibility. The citizen's burden, according to Trent, Alex, and others here, is to either remember their high school science or to find, years later, someone who can tell them that science content. Only someone who has the relevant "scientific foundation" can be an arbiter of a source's reliability.

In sharing these ideas, however, participants failed to articulate how students could learn to do case-by-case assessments of sources. They forcefully equated "credible" with "scientific" but did not go into how one could independently tell a scientific source from a non-scientific one. For instance, Nel, in the context of how she would help students research the side effects of drugs, said that they must "figure[e] out where the useful websites are" and specifically named the Mayo Clinic because it is "more trustworthy than just some random discussion board." Telling students that a source is scientific, in this view, is not much different from telling them directly the scientific information they will find in that source. Participants believed that it is useful to model for students how we use sources, but pre-selecting the source, as was done in this instance, removes the opportunity to learn how to select from among a range of more and less reliable sources. To be clear, Nel was not herself satisfied with this aspect of the lesson. Upon reflection, she added, "I think it does need to be a more cohesive approach. It's kind of haphazard, like as you think of it."

Based on statements such as these, it was clear that study participants did not offer a coherent vision for how to teach students to judge scientific credibility 'in the wild'. They did not seem able to give students a more general sense of how to decide, in the moment, whether a source was to be trusted. If the first part of their advice was to not use TikTok or Facebook or Twitter, then their follow-up was to 'come ask the science teacher instead.' I feel compelled to state the obvious here: A vast majority of citizens are not currently enrolled in a science class. To the extent that engaging with science in the media outside of school was discussed, this was described as an "intuitive" process that was difficult to articulate. Ways of noticing markers of credibility were not offered; the teachers instead tended to simply tell students when something was credible, again positioning themselves as the trusted source of what can be trusted.

Summary: How Science Teachers Think about Their Part in Educating Citizens

In this section, I have explored what study participants consider their role to be within the overall project of educating citizens. I found that what guided most participant thinking was an image they held of a "well-informed citizen"—a person armed with scientific knowledge and thus ready to pitch in and be thoughtfully engaged in civic and political affairs. This in turn meant that making students "well-informed" was their specific responsibility as science teachers. I found a presumption of citizens' trust and belief in science to be a trouble spot for these teachers. I also found teaching students how to assess the credibility of purportedly scientific sources outside of science class to be severely lacking. Their model for how citizens become informed therefore seems fragile: it relies on citizens finding and accepting the science they need through behaviors they are unlikely to learn in these science classes.

Science Classrooms as Places of Citizenship Education

In this third and final section, I present findings in response to the third Research Question guiding this study: *What kinds of curriculum and instruction do secondary science teachers view as being appropriate and aligned to democratic citizenship education?* Here I present data that grants a window into what is happening in these teachers' classrooms that may be related to learning citizenship. At times this data took the form of a concrete representation of what the teacher currently does. Other times the data reflected a desire for a hypothetical reform the teacher was thinking of in real-time during the interview.

I found that what participants told me, and showed through planning documents, about their teaching could be sorted into three categories of relating science to citizenship: (1) Most respondents were briefly mentioning to students, in an informal and unplanned manner, ways that science was relevant to sociopolitical issues. I refer to these as marginal and ephemeral touchpoints. (2) About half of respondents described planned, formal units or lessons where they expected students to use scientific evidence to make sense of, and/or take a position on, a sociopolitical issue. Examples varied in the class time allotted and depth of study. (3) Two participants—Leah and Neal—led students through a substantial civic improvement project. I include descriptions of these along with how the teachers thought about their value as learning experiences. I conclude the section with a presentation of how participants were thinking about crafting appropriate curricula and instruction within their local contexts.

Marginal and Ephemeral Touchpoints

Study participants brought civic or political elements into their science classrooms most commonly through brief mentions of how the science being taught related to a current or historical political issue. For instance, Nel stressed that it was important to her that students saw how chemistry mattered in sociopolitical contexts. She said, “Those kinds of things [from chemistry] that can impact local and national levels of political thought, I try to integrate. I don’t know how much they walk away remembering, but we at least talk about them.” At one point she said, “We have a lot of random discussions.” When I asked Nel to explain how sociopolitical issues are typically present in her class, she put it this way:

> I don’t know about a whole unit, but lessons or the week might build up to that because the content related to it is stuff we have to cover. Maybe like Monday, Tuesday, Wednesday, Thursday we’re doing the essential information that is in the curriculum that [we] have to cover, and then Friday it’s applying it to, ‘Should we? What is your opinion, now that you have an educated opinion, on this matter?’

She also reinforced this by saying:

> It often ends up being less of an in-depth debate and more of a question or a worksheet. Even if it’s not the goal of a unit or the goal of a lesson, I try to throw it in there as at least a question, so then some of them do think about it further. I feel a responsibility to look up pertinent examples that I can sort of dribble throughout the classes.

These descriptions were borne out in the materials Nel provided that contained a treatment of Germany’s pursuit of chemical weapons during World War I and the efforts of Fritz Haber in particular. In that lesson, students were shown a documentary video, then prompted via worksheet, “What is your opinion of Fritz Haber?” What emerged from my analysis was a theme of hedging and qualifying: integration is tried, examples are dribbled, and discussions are random. Students were briefly shown a smattering of instances where science mattered in a non-science context, but they were not ultimately accountable for any knowledge or skills outside of traditional science.

I hold Nel up here as only one example of a pervasive theme. Nine of ten participants talked about something that happens in class that I labeled as a marginal and ephemeral touchpoint. (Elaine, who teaches AP and "college prep" physics, was the sole non-example.) For instance, Alex described a recent class discussion on the United States rejoining the Paris Climate Accord this way:

> I was just sort of off-handedly questioning my students, asking them what they thought. Asking what they had heard about this at home. What they thought the implications were. Asking them how they felt about the inequity between countries and the different standards for the countries. I got a little bit of feedback, but from what I remember it wasn't much, honestly.

Lydia provided another illustration of this finding. When I asked her to explain how and why she does include sociopolitical issues, she described how it typically played out:

> I look at the content and, there's the basics I need to cover, and if there's a place to extend it, I'll provide some time in class. But sometimes I don't always provide that time in class, so I will let the students know, "Hey, I found this really cool article. Check it out. I attached it in [Google] Classroom." But we just don't have a ton of time to have a ton of discussions. I will try to find some time for like debates, and that's been successful, but…it's hard to have those extension activities.

This connotation of expendability in how participants talked about stepping outside of science was found throughout the data. For instance, when I directly asked Leah what she thought the likelihood of her enacting an in-class deliberation like Ms. Franklin's example, she said, "If we weren't having this [research interview] conversation now, this [deliberation] is probably a part that I would skip. Because it feels like it's inefficient in terms of use of time." And yet, participants also desired to include them as they could. Here is Lydia again:

> I'm trying to find really interesting case studies to just kind of hook their interest—to let them know that this thing is happening. I've also been trying to really connect a lot of social justice issues to what we've been talking about. So, obviously, when we did genetics, we talked a lot about Henrietta Lacks. When we did energy pyramids we talked about transfer of mercury, the pollution of mercury, and microplastics. So, there are some places where it naturally just kind of happens on its own. … I think it happens in smaller spaces.

I found participants to be committed to two goals that seemed to be in tension. On the one hand, they felt it important to give students the impression that science matters in their lives, which included sociopolitical issues they should make sense of as citizens. But on the other hand, their science class as currently structured did not seem to accommodate this. The result was that things get "talked about" and "discussed" in "smaller spaces."

Couching Science within Sociopolitical Issues

In the prior section, the findings revealed that participants were typically unable to create much space for students to engage as citizens in science class. There were, however, a handful of isolated instances where participating teachers did seek to enact a learning experience where students could have potentially acted as citizens with respect to a scientific issue. Presented here are data that showed teachers teaching science in the context of a political issue or question that was closely related to science but could not be resolved by science alone.

The most germane of these, given the ongoing Covid pandemic, were Abby and Glen's units on viral infection and immunology. Glen's teaching of immunity and vaccination dates back about a decade. He was prompted not by the recent rise of anti-vaccination sentiment during Covid, but instead by an earlier study about a supposed link between childhood vaccination and autism that has since been debunked and retracted. Glen referred to that episode as "bogus science" and said, "I've always taught vaccines as that issue, as good science versus bad science." He went on to describe some of his aims for those lessons:

> A population that has a vaccine is less likely to have a disease spread in it. I use the measles outbreaks from San Diego [and] Jamaica New York…where we've had cases of unvaccinated populations get exposed to a disease and the disease spread, but not spread to other populations that were vaccinated. Just to say that this is what a vaccine does, not that they should be vaccinated.

In Glen's teaching on this topic, he indicated that he avoided normative statements, preferring to inform students using clear-cut scientific evidence. It is notable that, although vaccine safety may have been debatable at one point, Glen presents the case to students as a settled matter. In his words, that issue can now be declared "bogus," and he explains this designation to students with hindsight. He teaches it as a historical social controversy that was ultimately resolved by "good science."

Abby was more responsive to the present-day situation in how she taught about vaccines. She invited students to predict what sort of formulation the as-yet-developed COVID-19 vaccines would have. She then excitedly shared with them the then-breaking news that it was an entirely new form based on mRNA technology. Like Glen, she too embedded the science of vaccination in a social and political context. She attributed her "freedom" to "do what [she] feel[s] is important" to the school environment, and added, "We're so used to making our own units." In terms of the immunology unit she created, she said,

> I have always been passionate about vaccines, but it's not quite part of the [state] standards. There [are] parts of it that are in there, but the whole unit [I've made] goes into a lot more depth…because I think that it's important. Especially now, with what we're going through. I've done pieces of it before, but it is a more robust unit [now], because of what's happening.

At one point in this unit, students were prompted in an online discussion format to take a stance on whether they thought governments should mandate vaccines in the face of the pandemic. She described her expectations of this assignment:

> I showed them data of states that had exemptions for vaccines—how easy it was to get an exemption. And to think about what that might mean today if people were exempt from vaccines. They really just had to tell me, like, do they think the government [has] the right to make vaccines mandatory or should it be a parent's and student's choice?

She added:

> I want them to make evidence-based decisions. As long as they can back up their claim for 'yes' or 'no'. Can you back up your claim with evidence and have reasoning? Then it's fine with me. I'm not trying to—while I have my own beliefs and ideas—I'm not trying to push them onto the students.

Analysis of the class materials showed this piece of Abby's teaching of immunology to be relatively insignificant. In the online "discussion" format, while students had the option to respond to each other, none did. While the meaty "should" question involving government and immunology was posed and seemed to generate some interest, it was not a priority nor was it sustained.

Another example of leveraging a sociopolitical issue for science learning came from Trent, who described an in-class activity he does that aims to have students consider the wider impact of their personal choices related to energy consumption. He prompted students to decide which mode of travel they should take to a hypothetical college campus visit based on their carbon footprint. This led students to investigate and calculate greenhouse gas emissions associated with different forms of travel. In cases like this, Trent said, “When I have them do work where there are arguments to be made, I make sure that I’m grading them on the science of it.” In our interviews, it came to light that Trent saw value in getting students to explore other scientific controversies as well, for example, whether cell phones cause cancer. In that context, he made what I felt was a particularly revealing statement: “I’m sick of hearing people form compelling arguments on shaky foundations. So, I don’t really want to introduce controversial topics unless they have a foundation of clear science that they can [use to] evaluate the claims.” He was also concerned that “the science of transistors is not well established in the education community. There [are] not materials out there to use and there are very few illustrations or simulations that I find very helpful.” While he sees it as helpful to get students to a place where they can engage with controversies or sociopolitical issues, his “foundational” knowledge and curricular support hurdles are typically unmet, preventing them from becoming a prominent fixture in his teaching.

These were not the only examples of intentionally planned science units with sociopolitical dimensions. Abby had students consider whether GMOs were safe. Glen adopted a curriculum from Yale University that asked, “Should we bring back the woolly mammoth?” Across all of these, my review of the materials and transcript analysis showed these teachers rendering the sociopolitical context as a conceit intended to drive science learning. Students were given limited space to talk about their opinions or values. And, in that space, it was implied or made explicitly clear that those extra-scientific parts had no bearing on the student's grades. Talk about non-scientific ideas—what could not be "quantified" or proven, in Tom's words—were sometimes implemented as a useful way to reveal what students knew about science.

Science and Engineering as Levers for Civic Improvement

Readers will recall that inclusion of a particular kind of curriculum was not a criterion for selecting participants for this study. I did not seek out teachers who pursued a meaningful merger between science and politics or civics. As it happened, however, once the study was underway with a stable cohort of participants, I found that two of the teachers enrolled were able to enact versions of such teaching. Both Leah and Neal made a demonstrable commitment to having students learn within their respective disciplines in a way that centered a local, multi-faceted civic problem.

Leah: using physics to make streets safer. Leah teaches physics at a private school in the bustling center of a large city on the east coast of the United States. She mentioned early on that she did a "traffic safety" project with her ninth-grade physics class. During data collection, I obtained and analyzed the materials she used to teach that unit. We also talked at length about her teaching of that unit during interviews.

Leah's traffic safety unit grew out of the school's desire to institute "a capstone project with the ninth graders where they build things." She was forthright in saying, "I was hesitant about it," and added, "I'm not always good at coming up with projects." At points, she expressed disappointment that she "didn't know how" to make a good project. Additionally, although the school and her science department were overtly pushing for project-based learning, they were not in Leah's view supporting the burdensome curriculum re-design such teaching would require.

She knew that reforming her teaching in that way would take a lot of effort. The learning outcomes were important to her. She wanted to do it right and was not convinced it would be successful. Leah placed a high premium on quality science teaching and learning, and she was good at what she did. It felt risky to try this new thing.

In the end, the value Leah saw in project-based learning won out. She cited her husband being "an urbanist" as well as her own interest in city planning as a critical factor as a source of inspiration. Her school context also created an environment where she knew an engaging interdisciplinary project would not just be tolerated but welcomed—especially a project she could show being connected to a sociopolitical issue. She said,

> We've been doing a lot of trying to figure out how to be an anti-racist school. Where I've come around to on that as a physics teacher is, the way you act as an anti-racist teacher is by tackling social justice problems.

In her mind, this leads to…

> …trying to find problems in the community and finding ways to address them. … [That] really dovetails with trying to find relevant projects that have civic importance. Like, the solution to one of those is probably also the solution to the other one. Because then you're sort of making the point that you are an ally, and you want to help people change their environment.

Given all of this, she landed on unsafe intersections as a topic that was both interesting and timely. To her, this was a topic where she could justify teaching the physics she wanted to teach—namely force and motion in the form of the stopping distances and cornering abilities of cars—in a context that her students were likely to care about. Adding to the project's relevance, Leah directed students to use an interactive map of traffic incidents produced by the city police department. Students were free to analyze whichever intersections they chose. Leah made places close to where students lived, went to school, or where someone they knew had suffered in one of the mapped incidents a focus of the class.

The unit culminated in students presenting their proposed redesigns to members of the city government. Leah named access to this external, authentic audience as critical to the project's success. She said,

> I think it made the case really well [that] you need to have these measurements because you're going to have to argue with engineers, and the engineers are only going to listen to you if you have numbers. … It was a really cool experience in like, "No, you need concrete evidence because you have to make this case."

Leah was particularly proud of the fact that science was not being learned in the abstract but within a vital civic context. It was not, as she put it, "just physics for physics' sake." She viewed the teaching experience as a proof of concept that only made her want to do more and go further. She said,

> The next step is for us to actually support the work that's being done more effectively. Because when we meet with [the city officials] they're like, 'Can you please come to your community meetings? No one ever says this stuff in the community. Nobody is ever pushing for cars to go slower.' … How do I get [the students'] voices heard so that it actually helps the city become a safer place?"

She continued this line of thought by wondering whether having students attend local government meetings could be the wellspring of additional projects:

> I would probably have to help them navigate [and] figure out [how] to go to the meetings. And I'm pretty sure when you go to those meetings, they're actually all about zoning and

> housing, and someone wants to build a roof deck. But like, maybe that becomes a required component of it, and maybe it starts to have a more explicit civics part to it.

She then seamlessly began to name physics concepts already within her curriculum that could help make sense of local building ordinances. It struck me that, over the course of two interviews and a handful of emails in the space of a few weeks, Leah had gone from expressing only self-doubt about her abilities to create effective physics projects to being excited for the next iteration of one.

Neal: designing a greenhouse to improve access to local food. Neal teaches engineering in an urban setting in a major east coast city. His is a public school that was founded in the early 21st century as part of the movement toward smaller high schools that intentionally adopt a particular identity. Neal's school proudly proclaims to be project-based and is regarded as a leading institution putting reform-minded instruction into practice—they host an annual conference that attracts national attention. One of his roles there is to facilitate the Career and Technical Education (CTE) 12th-grade engineering experience. This program requires a large commitment on the part of students—considerable class time and a body of work that resembles that of a working engineer.

The salient part of the course, for this study, is the long-term capstone project that the seniors in the program must complete. Neal explained:

> The senior engineers take all the knowledge they gained over these many hundreds of hours spent with me and apply it to solving one big world problem—one big problem that they jointly want to work on as a group. Those problems have ranged from [a] water purification system for the hometown of one of those students in Cambodia to a green wall in our new school to…oh God, so many of them.

He emphasized to me that the projects were about "these kinds of solutions that very often are addressing a bigger societal need." He cited the Engineering Grand Challenges put forth by the National Academy of Engineering as a common source of inspiration for the yearly project, saying, "We usually try to bite off some corner of those Grand Challenges and grapple with them."

I noted that the process for choosing the project was itself a deliberation amongst the students and teachers in the class. Neal began by telling students they had a $5,000 budget and prompted them to suggest a range of ideas for what to do. They set about achieving "consensus"—a term Neal used with clear intent—on which problem was most worthy of their time and efforts. While he purposefully left the field somewhat open to them, he, as indicated above, guided them toward issues of deeper import. One of these that I keyed on while collecting data was their design of a local greenhouse. Neal was articulate in describing that project and how it came about:

> Two [or] three years ago, we worked with a woman who—a family actually—that were trying to build a community garden and a greenhouse in [their neighborhood], in this community rec center. And she expressed the challenges she had, mostly being [access] to water and electricity. And what that meant for her ability to be successful and for her family. It meant she was trying to have a greenhouse to support her family—two young boys.
>
> When my students were thinking about what project they wanted to work on, they looked at a wide range of them, and when they came to that one, they said, "This is a compelling project—something that we could make a change in people's lives." At [our school] a really important part of education is not [to] prepare yourself to study a thing in

> college and to be successful in your mid-terms. Instead, it's [to] make a change in the world, right now, that can affect…can bring some sort of betterment to somebody in the world. And they decided, yeah, this is the thing they wanted to work on.

Once this choice was made, the class began their engineering work in earnest. However, this did not mean that they dove in and developed a plan based only on an inert schematic of the space. Rather they engaged with people who would be affected and sought to understand their hopes and fears related to the project. Neal explained how this was a routine part of the process:

> The very first step in design is empathy. We brought this woman and her two kids into our classroom. We spent an hour with them, interviewing them and understanding their challenges. And [the students] had to prepare for that. "What kinds of questions would be appropriate here?" And we talked about empathy, compassion, and understanding. And through that listening, and then going on-site and spending time learning about the work she was doing, they were able to start ideating on designs that would help.

In other words, serious ideas about the structure to be built were not advanced by the engineering students until the contextual parameters were identified.

While the design work was to be technical, it was thoroughly embedded in a social context from the beginning. The project's guardrails were not limited to the physical reality of the job site. Neal said, "The best thing…the sweetest spot is a project that can help address social issues and get kids engaged in understanding those social issues better." He went on,

> We spent a lot of time understanding not only the science and engineering behind what's going on with respect to climate change, but also what are the societal dynamics—the financial, environmental, and geopolitical dynamics that are causing this. We spent a lot of time talking about all that.

The takeaway from Neal is that he purposefully chose *not* to confine students to a rigid conception of engineering. We can imagine others sticking to a narrower focus, thinking only of how to make a structure that "works". It is important to note that Neal intentionally opened space for thinking about the goals of an engineering project. He invited students to ponder what "works" *should* mean within context. I pressed him on why he chooses to teach this way, to cross disciplinary borders, and he explained his motivation this way:

> If we think that the important thing is to help educate students about how to affect change in the world for good, then it's incumbent upon us to teach them the complexity of issues. The reason we haven't addressed global warming isn't because we just need a smarter engineer to invent a thing. … It's not just that. It is geopolitical, and it is the financial interests. And so that discussion has to happen. Because if we don't embrace the totality and the complexity of an issue like that, they're just going to be spinning their wheels.

Neal has taken the position that the problems most worth having students think about cannot be adequately addressed through a single discipline or school subject.

Neal was not alone in this thinking. As I showed early on, several participants expressed desires to "connect" science to other areas, citing "application" as a goal. Yet these teachers' collective prospects for enacting a complex, compelling issues-based curriculum appeared in this study to be dim. In the following section—the last of this chapter—I explore the reasons participants gave for why their curricula do or do not include elements of citizenship education.

Crafting Appropriate Curriculum

The two cases described in the prior section were the only examples in this data of curriculum units that centered civic engagement in a learning space typically reserved for science or engineering. Leah and Neal, in my view, were able to embed the disciplinary knowledge and skills they sought to teach in an authentic civic context, thereby elevating the social and political dimensions of the problems the students engaged with. In each case, there was something about the teacher and the school that enabled this kind of teaching. Leah, for example, knew people in city government that she could call in to do a service for the class. She taught at a private school with small class sizes and had a clear mandate from her administration supporting project-based learning. In Neal's case, he had a deep background in professional engineering, entrepreneurship, and the Quaker decision-making process. He too was working in a context that fully supported long-term interdisciplinary projects. Most participants, however, did not have these assets.

Aside from a hospitable environment, perhaps the more crucial attribute most participants lacked was the desire to pursue reform for citizenship instruction in the first place. I found that citizenship learning activities were unlikely to occur in participants' classrooms for a host of reasons: (1) the teacher's desire to avoid controversial subjects; (2) the teachers' habit of choosing scientific topics that would reflect the students' prior interests back to them; (3) participants did not accept responsibility for directly teaching citizenship skills; and (4) reform lacked institutional support.

Avoiding controversy. Several participants talked about avoiding controversial topics because they did not want to risk the unwanted attention it would bring. For instance, while Alex was keen to help her students make sense of the Paris Climate Accord, she feared to do so. She said:

> This is something I've been struggling with. I've talked to my coworkers a little bit about sort of being uncertain. Because of Covid, because of like the crazy divides that are going on right now, they also have just been sort of avoiding it and like not really talking about

> politics, not talking about politically charged issues so much. Sort of just laying out the bare-bones science.

She also described how the virtual learning environment added to this, saying,

> I think in the classroom setting I'd be a little less nervous to sort of dive into…the more controversial aspects…but with parents and students at home, and potentially things getting misheard or misconstrued, I'm a little hesitant to do that.

For Alex, her standing as a first-year teacher added to her feeling of precarity. However, Lydia, who had several years of experience, also spoke about avoiding the same kind of risk. She lamented that "everything's politicized," and went on to explain her approach to teaching science in such an atmosphere:

> For me, instead of trying to argue one side or the other, as a scientist…I just try to push my students to seek out valid sources. "Where is your source that there's a tracking device in the vaccine? Are you getting that from a meme on Facebook? Are you getting that from a well-known media source?" That's kind of where I feel safe.

Lydia also at another point said she is "trying to not be too—like, the kids don't know what [political] side I swing—so trying to not be too political, but just capture the essence of like what happens in the world…on the cellular level." These are but a few of the moments where participants indicated they avoided controversial topics in science class because it felt risky to engage with politics in their curriculum.

I found, closely related to their risk aversion, that these teachers desired to maintain political neutrality. Lydia's comment about her students not knowing "what side I swing" was a clear example of this. In a similar vein, Glen said, "What [students] choose to do with that [scientific] information, we don't have control over, and I would hope I would never have control over." Abby gave another example of this. She explained:

> I did have some students unhappy with the nutrition unit, saying I was telling them how to eat, which I don't think I was. I was just, you know, providing evidence and then they can infer it however they want. … I explained to them, that was not my intent and I'm sorry that you thought that way. I just wanted to provide resources for you, and then you guys can make your own opinion.

I thought it notable that participants tended to imply that merely invoking a political issue would put their credibility as a non-political voice of science in doubt. They feared to disclose their positions. But it was the instantaneous leap to this fear of disclosure that struck me. Participants seemed to be saying that making the curriculum about a political issue would too easily or perhaps inevitably be construed as teachers imposing their beliefs on students. This was one of their primary concerns and it was used as a basis for avoiding politics in their classes. A delivery of stable scientific facts was consistently named the "safe" thing to do and thus the main substance of an appropriate science curriculum as it relates to political issues.

Another thematic reason participants gave for avoiding controversies was a concern for heated discussions becoming unmanageable. Alex said of Ms. Franklin's facilitation of a political discussion, "Honestly it made me a little jealous." She then added, "I could see this going very easily off the rails." Similarly, Lydia recalled times in her classroom when "the kids would get so heated. And then it would be a losing battle because no one could hear anybody." Besides fearing being seen as a political actors, these science teachers were also concerned that they would not be able to avoid dysfunction and communication breakdowns once they started down a political path. Sometimes participants mentioned giving some limited amount of time for political discussions that were understood as separate from their science teaching. Tom for example told a story about the morning after Trump was elected in 2016:

> One young girl [was] almost in tears. “What’s gonna happen now?” Which opened the door for me, and we proceeded to talk about the election: the process, the consequences, the power of the president, the democratic process. And by the end of [a] ten- or fifteen-minute discussion I actually played a snippet of his acceptance speech which, I would argue, is one of the best times he’s shown presidential-ness. And there is a young Black student in the back of the room, after hearing it, he says, “Well if he keeps talkin’ like that maybe things won’t be so bad.” And I was like, “Okay good. Can we move on and learn physics now?” And I went back in the remaining half hour of my class, and I covered everything I needed to cover.

Moments like these demonstrate that some participants saw politics and the emotions they might bring out of students as distractions from the task at hand. Most talked about being ill-equipped to manage emotionally charged discussions if they were to begin. Often this led them to avoid controversial topics altogether. Sometimes their strategy was to allow for isolated instances that could act as pressure-release valves.

Close, personal notions of relevance. Another theme that emerged from this data was that participants were especially driven to provide science instruction they felt was most relevant to their students. Very often this led participants to select topics that matched well with a prior interest their students had. I found that this had the effect of political issues being avoided that the students themselves did not *already* have an obvious stake in.

Abby was one participant who made relevance a strong criterion for her curriculum design. During a discussion about how “current events” may or may not be used in her teaching, she took that opportunity to explain what the more important deciding factor was for her:

> Is this applicable to their life? Do they care about it? The new buzzword in science is like ‘phenomena-based learning’, which I don't necessarily agree with because why do I care that this thing happened? Right? If it doesn't impact my life, then I don't care why a window was shaken because of sound waves or whatever.

She later articulated another clear choice she has made in her teaching of biology:

> Lactose intolerant people in England, we still do that because it could apply to them, because some of them are lactose intolerant, or they know people who are lactose intolerant and so they care more about it. I wouldn't talk about Tay-Sachs with my students…because the majority of them are not Jewish. I want to pick something that's more applicable to their lives. Knowing about Tay-Sachs is still important, but I would find more engagement with talking about sickle cell.

The primary concern for teachers like Abby was to find ways to ‘hook interest’ into a stable curriculum. This meant that Abby was explicitly selecting topics or examples that were localized expressions of a scientific phenomenon that could match closely to the direct experiences and prior interests of most of her students. Issues that affected other kinds of people or people in other places were acknowledged as important but did not make the cut.

Trent gave another example of this kind of curricular reasoning. When he considered the Ms. Franklin vignette, specifically whether he thought a deliberation about setting speed limits was a good context for teaching some physics concepts, he pointed to something a colleague of his did that he thought would be a better choice. He said:

> I'm thinking of the way that the guy across the hall does [friction and momentum]. We have spirit week in November, and they have the freshmen versus the seniors in tug-o-war. So, he teaches an entire lesson on the coefficient of friction of shoes. He has no problem with buy-in because he's teaching seniors who are very motivated by not getting embarrassed by the freshman and they want to know how to win.

He then added:

> Relevance doesn't come from some civic responsibility, which I think some kids roll their eyes at. So, when you argue whether that is relevant, I mean relevant to them and relevant to the grown-ups that teach them is sometimes very different.

For Trent and other respondents, "relevance" as a driver of their curricula was consistently interpreted as what students already cared about. I found that it was more common for these teachers to use benign examples like a tug-o-war instead of an issue that was more consequential or weighty. Moreover, in stark contrast to Neal's class purposefully choosing a project that would address a "societal" problem, most participants spoke of choosing topics that were personally relevant as opposed to a public concern.

Lydia supplied one final example of how participants tended to avoid thorny problems by favoring what students found interesting. She made it clear that what she was able to teach was mostly defined by the International Baccalaureate assessment as well as her local state-level subject exams. Any space left over for creativity, she said, "then I really just kind of go off of the students." She went on,

> So, my student population is like 99 percent White. And they're mostly from like high-income or middle-class homes. So, I don't think racism is like a big thing for them. I don't think Covid is like a big deal for them. I think a lot of them are just kind of like

> living in this bubble. In comparison to [my former school, where the student population was Black], it's just not like as natural of a conversation to them. It's just not as important to them. We're also like not in a big city. Like Covid hasn't really affected them too much. They're still able to drive cars and…just go over to their friend's house and hang out. I think that's still happening. It's not like there's been a big shift, the way we've seen in like the diverse cities or some other populations. You know, I don't think their parents are like losing their jobs. Like, these kids have boats. I mean, so it's just not important to them.

The point that cannot be avoided in this quotation is that, in her estimation, racism and more specifically the disproportionate effect Covid has had on people of color, is "just not important" to her students. They are not directly affected by these problems because they have White and class privileges and therefore do not need or would not be receptive to special teaching that helped them make sense of those issues. This data is important to include in this section because it is a compelling example of how teachers' ideas about what student interests are steer them away from engaging in difficult issues like those of racism—issues that would be unavoidable in an authentically democratic education. In this instance, a 'direct-effect' criterion, likely coupled with a hesitancy to engage with controversy, has led Lydia to leave students' possible assumptions about how a scientific phenomenon affects races differently untroubled.

Not my job. Another impediment to citizenship learning finding a home within these teachers' science classes was that these participants did not believe it was part of their responsibility as science teachers. I found a pervasive resistance on the part of these science teachers to integrate science with other disciplines, notwithstanding Leah and Neal's project examples.

The theme of maintaining separation between disciplines was often grounded in a teacher's sense of a professional division of labor. The data contained several instances of participants pointing to other parts of a student's education, outside of the science course, where students were meant to be getting some part of citizenship education. These were statements made by respondents during interviews that served to delineate instructional responsibilities. For instance, Nel said,

> I tried to do those things [values-based 'should' discussions], but you also, I think, have a responsibility to make sure that they get the science, and it sometimes feels like those discussions—there's built-in time and space to do that in history and in English. So, I think just because of the nature of that split you feel like, "Hey if I can only get through so much of introductory chemistry or so much of introductory biology…" What's the balance?

What leaped out of this quotation is that "the nature" of the "split" between science and not science is what pushed Nel away from a more integrated curriculum. Neal was also thinking along these lines. He said discussions of extra-scientific topics "come into the classroom all the time, because I engage my students in those discussions," adding that these were "brief" and "typically through the lens of the importance of character." Within the same response, he also said, "I mean, it's an engineering classroom. I'm not making space for the discussions that I know they're having over in history and in literature. It's obviously not the goal of what I'm trying to do."

But the most emphatic argument that science instruction should be demarcated from values-based decision-making came from Glen. When asked whether he thought it was appropriate to include deliberation on what a local speed limit should be set at, as in the Ms. Franklin vignette, he simply said “no” without hesitating. He went on to explain:

> If I was partnered with another teacher who would be able to then have a debate in a civics class, that would be their job at that point. My job would be to prepare them with the science, so that they can engage in that [civics debate]. If the language arts teacher wanted to have a debate in their class on a topic and wanted me to teach the science beforehand, that would be appropriate. But I don't think it's appropriate for me, trained in science education, to be doing the work of [for example] a world history teacher. I think I have enough to cover. I could cover the science, and make it context-rich, but having the debate in my class, I think, is inappropriate, because I’m not trained in those type of skills.

Glen impressed upon me, in various moments in our talks, that he often couched science within a “context-rich” issue or problem. But, as this quotation shows, it was equally clear to me that he had a well-developed sense of what his limits should be. He was willing to let a ‘should’ question be the reason students would learn science, but then guiding students to follow through with a decision-making process—a “debate”—to resolve that question would be someone else’s job.

Other examples were previously shown but are again relevant here. This kind of separation was also maintained when Abby named “research ability” as a skill students were “really lacking” and then named “librarian or media specialist” as professionals who should be handling that. Similarly, Elaine named a separate course from her own. Her school had a course dedicated to “science literacy” while her responsibility was to teach AP Physics, which did not have time for much if any of what happened in the “literacy” course.

I hasten to remind readers that these are teachers who also profess that a big part of STEM education's value is its ability to prepare students for anything they might want to do outside of science. The point at present is that they seemed ultimately compelled to stay in their lane. When it comes to choosing how to allocate their instructional time, they aim to stick to an acceptable notion of what courses with titles like engineering, biology, chemistry, or physics should hew to. The data showed that when participants surmised or assumed that other teachers of other subjects were handling something, this alleviated the pressure on them, as science and engineering teachers, to include those same kinds of instruction.

School hampers reform. Of course, to the extent that bringing citizenship learning into school science might necessitate reform, those reforms will be subject to institutional hurdles as all educational reforms are. That is, aside from how appropriate science teachers may feel a pedagogy of democratic citizenship may or may not be, forces that reside outside of any individual teacher are likely to hamper reform efforts. The present research participants provided ample evidence that this would be the case in their contexts.

I provided textual examples for participants of what science teaching that centered a political issue or question could look like in the form of the Ms. Franklin vignettes. Participants were then prompted, through semi-structured interviewing, how that example compared to their teaching as well as how likely they would be to implement some or all of the fictional Ms. Franklin's instruction. The following exchange featuring Alex was exemplary of most participants' situations:

> Ryan: The unit doesn't feel inappropriate to you? Is that fair to say?
>
> Alex: Are you asking from a personal perspective or from a like 'I have to follow the state curriculum mandates' perspective?

Ryan: Both.

Alex: Yeah, those are two very different answers. From a curricular, like from a state standards standpoint, I think that this would impede the goals that the standards lay out, in terms of what we have to cover. I don't think that I would be able to implement a unit or multiple units like this and also hit all of the points and goals for the students in a chemistry class.

Most participants shared that while they liked what Ms. Franklin was doing—Lydia said "She sounds like a great teacher"—they simply would not have the time to do the same. For context, each of the Ms. Franklin vignettes (each participant saw one) was slated to take between five and ten class meetings. If learning citizenship involves open-ended discussions, independent research, and whole-class deliberations, these were often seen as unjustifiable because they would not contribute to the "coverage" that was so often cited as necessary.

For participants who deemed they could eschew the standards-based expectations for their course, the demanding work of curriculum-building was cited as another critical barrier to reform. For example, Tom enthusiastically hit upon risk analysis as a thing citizens should learn to do within a scientific issue. When asked if he was able to bring that into his environmental science or physics courses, he said, "Not so much explicitly. I don't have the curriculum framework to really do it well." Similarly, when it came to engaging with whether cell phones caused cancer, Trent cited a lack of vetted teaching materials as a source for his hesitancy. He said that teaching about the technology involved "is not well established in the education community. There [are] not materials out there to use and there are very few illustrations or simulations that I find very helpful." I found that for some participants an apparent lack of already developed curricula prevented them from enacting something closer to democratic citizenship teaching in their science courses.

Other participants were not exactly daunted by a lack of existing materials, yet they made it clear that choosing to create their own has meant many long hours above and beyond their already taxing work schedules. For instance, Nel said, “It does tend to be pretty worthwhile,” but added, “It’s a lot harder to come up with those over-arching kinds of case studies. I do put a lot of time outside of school into it.” Lydia said, “I’m not, like, a chalk-and-talk teacher” but characterized that as a “struggle.” Abby was able to develop a more in-depth immunology unit in direct response to the Covid pandemic, but it took several months to do so. The salient theme among these examples is that this work was seen as extra while a more traditional “coverage” of the standards was normal. In other words, it took significant will and special effort on the part of the teacher to do that more difficult, creative work.

Ch. 5: Discussion

My study explored what a diverse group of American secondary science teachers believe about science education for citizenship. Two sorts of beliefs focused the data analysis: beliefs about how citizens relate to science and use science and beliefs about what science teachers can and/or should do in their specific roles to educate citizens. The clearest and most important finding is that participants were working from a conceptual model of well-informed citizenship that did not match how citizens use science or how scientists produce knowledge. I begin this chapter by discussing how participants think about science education's role in providing information and the citizen's role in receiving it. Here the participating teachers showed commitment to a knowledge deficit frame that is not supported by relevant research. This first set of findings discussed comes in response to Research Question 2. I begin with the second research question, rather than the first because these findings are fundamental to the overall results of the study. That is, the participants' conception of well-informed citizenship serves as a basis for their beliefs about teaching (RQ3) and their notion of how that teaching addresses educational goals (RQ1).

Following the discussion of how teachers conceptualize the relationship between citizens and science, I then discuss how the study participants view their role in science education for citizenship. This discussion forms the response to Research Question 3. The primary finding here was that participating teachers saw themselves as the voice for and providers of sound scientific evidence that citizens should use. I will also unpack findings pertinent to participants' teaching. While there were notable exceptions, almost all the classroom teaching described in the evidence gathered bore little resemblance to effective models of science education for citizenship found in the literature. In the third discussion section, I address findings that pertain to teachers' beliefs about the goals for their science teaching and thus address Research Question 1. I close out the chapter with a discussion of the study's implications.

A Model of Well-Informed Citizenship

The fundamental conceptual model that all participants in this study were working from is that, in the context of democratic participation, the proper role of science education is to provide reliable information while the role of the citizen is to take up and implement that information to make sound decisions. This thinking was revealed at multiple points throughout the interview process and was evident in multiple responses from each participant. Lydia provided a prime example, stating, "I think science can provide the factual backup, like the factual evidence, for these [political] arguments. That's where I would say science holds its place. You're going to pull from science to justify the right decision." It was common for participants to position the acquisition of science content knowledge as the essential entry point for civic and political engagement.

In this pattern of thought these participants closely echoed an Enlightenment ideal of political decision-making (Hochschild & Einstein, 2015). In their study of how information affects politics, Hochschild and Einstein's theory includes two kinds of citizens that are relevant to this discussion. The "active informed" citizen bases their political position on agreed-upon facts that have achieved consensus among the relevant experts. Hochschild and Einstein refer to this use of knowledge in democracy as the Jeffersonian ideal—a reminder that empiricism and rationality are baked into an American concept of democracy. Indeed, this is a virtuous goal to pursue—science teachers are right to want to move students into the category of an active informed citizenry. However, a problem emerges when we look closely at another of Hochschild and Einstein's categories: the "active misinformed" citizen, particularly how durable their belief in misinformation is. Hochschild and Einstein explain, “People who use falsehoods in their political activity are in an emotionally and cognitively stable position; disagreement with their stance is arguably more likely to make them dig in than to feel embarrassed” (p. 86). It is therefore problematic to assume that public ignorance of basic facts on its own is a simple deficiency with a correspondingly easy solution (Irwin & Wynne, 1996; Millar & Wynne, 1988).

Yet it was exactly this kind of assumption that I found to be so prevalent among science teachers in this study. When speaking about vaccine hesitancy, for instance, Tom asserted that if only people knew the science, this would “eliminate all those things that really just hold us back.” Similarly, Leah was forceful on the point that “if people actually understood anything about 5G, there wouldn’t be this whole ‘5G is causing the pandemic’ thing.” Statements like these indicate a naïve sense of how teaching science content held a unique power to change the misinformed citizen into an informed one.

While a preference to be informed versus uninformed may be utterly uncontroversial, citizenship education scholarship and policies do address the civic value of reliable information. Knight Abowitz and Harnish (2006) found that being informed on public issues was routinely listed among the civic competencies in social studies standards. The idea has been linked to science education as well. In discussing the potential for science education to meet civic ends, Levy, Oliveira, and Harris (2021) advance a concept of *civic science education* which they define as “educational experiences that support individuals’ ability to understand, explore, and take *informed* action on public issues related to science” (p. 1, emphasis added). Being informed is thus a widely accepted part of citizenship education. I found that this was also the primary learning goal that was readily recognized and accepted by the science teachers in this study. A comment from Alex represented this frequently voiced belief: “Part of my goal is obviously trying to give them tools to be an informed citizen." Throughout the data, interviewees routinely named being informed as a duty or responsibility of citizenship, thereby aligning their practice to a civic competency expressed in the literature.

I also found that science teachers named discussion as a democratic activity where science knowledge was especially useful. Moreover, participants articulated that political discussions are moot, errant, or nonsensical when they commence without a shared agreement on basic science facts. This popular sentiment was exemplified by Lydia: "When you have shared discussions…it's important to base those discussions from evidence. It's hard to have a discussion when there's not a foundational agreement of how the world works." This idea of a temporal progression, of first gathering facts and then doing politics, is a feature of the "cultural literacy" concept of science literacy as well (e.g., Trefil, 2008).

Therefore, the first contribution of this study is that the primary way that these science teachers approached the concept of citizenship relating to science was through a knowledge-deficit frame. Their lamentations and admonitions about public ignorance of science closely resembled those of Jon Miller (2010) and James Trefil (2008). At the heart of this conception is the belief that an a priori transmission of factual, canonical knowledge about science is an effective way to prepare citizens to engage in political and civic affairs. On this major point, however, this discussion requires precision. The problem with a deficit perspective is not that scientific knowledge is inconsequential in democracy. It is not wrong to believe that being informed is preferred to being uninformed or misinformed, as Hochschild and Einstein (2015) have aptly shown. Science teachers' deficit mindset becomes problematic for citizenship, however, when their beliefs about information (i.e., science knowledge) and its usefulness are compared to what we know about how citizens come to trust and use science in context.

One failure of a deficit model is its one-dimensional treatment of how the public understands and uses science. That is, measures of how many factual survey items lay citizens can correctly answer are insufficient to address what matters (Jasanoff, 2005). It is worth noting that the teachers' assessment documents reviewed for this study heavily favored these types of questions. What also matters for civic use of science are how information gets produced and assessments of trust regarding its source. These teachers often suggested that the citizen's agency in figuring out what science to use was limited to locating relevant facts. This thin model of science uptake was refuted by Brian Wynne, who argued that two more elements beyond the "formal contents" of science play into how citizens respond to an expert claim: the methods and processes by which the claim was formed and the "institutional embedding, patronage, organization, and control" that form the context of its making (1992a, p. 42). Citizens, in other words, also have agency in judging what information to trust and how to use it. This was a blind spot for science teachers in this study.

A richer model of civic engagement with science challenges these participants' conventional vision of the lay public as empty vessels waiting to be filled with knowledge (Simis et al., 2016; Sturgis & Allum, 2004). In the deficit frame, scientists and their boosters—here, teachers—see anything less than a full embrace of science as negligence (Lewenstein, 1992). Yet empirical research on how lay citizens engage with science has repeatedly contradicted a presumption of irrationality on the part of citizens. Layton and colleagues (1993), for example, found that stakeholders in a science issue displayed pragmatic sensemaking as they reworked and adapted science to meet their specific needs. Citizens have been shown to possess vital knowledge of their own—above and beyond basic science content knowledge—that can inform a science-related social issue (Epstein, 1996; Wynne, 1992b). This kind of two-way dialog between science and citizens was absent from the data found in this study.

While participants' model of well-informed citizenship tended to portray citizens as simple recipients of content knowledge, their conceptual model similarly oversimplified scientific knowledge as straightforward, easily implemented information. Another key finding of this study was that science teachers tended to portray science as inherently useful. They described science in monolithic terms, as a singular entity that was widely applicable in all cases. There were several instances where comments were made with the intent to flatten the complexity of citizens deciding how to use science. For instance, Trent described this by saying, "It's pretty simple…nature tells you if you're right or not." Alex said, "It's fine to debate policy" but citizens must "understand that science is only saying one thing." Statements like these do two kinds of rhetorical work. First, they indicate a belief that scientific knowledge has (or should have) a larger effect on political decisions than it does. That is, scientific facts can and should squash debate by making some choices obviously better. In the minds of these teachers, this is a key function of science. Second, these statements create a bias for textbook science knowledge. I found that these ideas voiced by the teachers work in tandem to support teaching science as content delivery. When science teachers talk about science as a singular force that shapes citizens' political thinking, they are only connecting their teaching to issues for which the relevant scientific consensus is a prior achievement that should be easy for citizens to accept.

This selective focus on stable knowledge, however, glosses over the process of scientists arriving at a consensus. If science is "only saying one thing," then the teacher's task is to revoice what science is saying for their students or to guide them to the appropriate sources of incontrovertible fact. Yet doing so omits the important cases where experts are in conflict or do not yet know—issues where no consensus can be found. Citizens often face thorny problems that are typified by uncertainty (Head, 2019; Herman, et al., 2022). Teaching science in a way that only highlights canonical knowledge likely contributes to research findings that policymakers expect simple answers that science cannot provide (Mitchell, 2009).

The alternative would be to focus on not only the facts that science produces but the processes by which knowledge is made. Oreskes (2019) has argued that this is the window through which citizens should be able to see so that they can make judgments about how much stock to put in purportedly useful knowledge. This means that being able to follow along with a consensus-forming process, as an outside observer, is a critical learning goal for citizenship. I found that participants held mixed views on this kind of teaching. The data contained only a handful of statements that seemed to indicate a recognition of a civic value in understanding scientific process. Tom, on the surface, appeared to be an adherent. He said that an important motivation for him as a science teacher was that "people need to appreciate the fact that [science] is well-vetted and well-tested." However, statements such as these were made with the intent to convince students of the authoritative position science holds. Trust in science, in other words, is not to be considered an open question. These participants were therefore not in keeping with Oreskes' frame, which treats trust in science as a problem to be solved on a case-by-case basis.

This finding is likely to point to a particular problem for science educators in the present era. As has been noted, my analysis showed early on that participants were framing informed citizenship as a knowledge-deficit problem that resides with lay citizens. In recent decades, this perspective has become increasingly unsustainable as research consistently fails to show a link between how much science content knowledge the public has and how they respond to political issues that involve science (Jasanoff, 2005). A major finding of this study nevertheless is that these science teachers are holding firm to a deficit mindset. Nine of the 10 respondents had an unqualified belief that misinformation is remedied by telling students what the relevant scientific understanding was. One participant, Lydia, was ambivalent on this point, as she displayed both a firm commitment to the deficit model of well-informed citizenship in addition to an awareness that informing science deniers was “a struggle” because “they try to wiggle out of it.”

During data collection, with analysis ongoing throughout that process, I began to suspect that participants may have been experiencing some cognitive dissonance. Their model of well-informed citizenship, from where I sat, was being tested in highly visible ways. The timing of this study’s data collection happened to coincide with the initial rollout of the COVID-19 vaccines. Participants were all too aware of vaccine hesitancy and anti-masking protests; their complaints about these positions occurred frequently in the data. Furthermore, the recent Trump presidency, during which each participant had taught, represented for them science denial and politically motivated reasoning climbing to unprecedented heights of political power. In the data, I found a keen sense of foreboding about citizens rejecting science. In other words, science teachers were worried about post-truth: the label given to this most recent and troubling new wave of science denial, where facts are subject to preference and emotion matters more than evidence (McIntyre, 2018).

How science teachers respond to post-truth thus became a research interest that the data could address. Indeed, this study was planned and carried out amid a flowering of scholarly interest in this topic (see for example a special issue of *Educational Psychologist*, 2020). In one example, Chinn, Barzilai, and Duncan (2021) are concerned with education for recognizing and acting on the best available knowledge when fake news and false claims to expertise are pervasive. Their recommendations for instruction revolve around epistemology and authentic practices. In other words, students should engage with *ways of knowing* as conceptual tools and be tasked with making real-world judgments about reliable knowledge that include all the features of the "post-truth" world they are likely to encounter (e.g., fake news). Meanwhile, in another essay, Feinstein and Waddington (2020) argue that science educators must account for the reality that people encounter science with other people of their social group and that these encounters are always contextual. It is therefore not helpful to train individual students to make private judgments about whether a scientific claim is true in isolation.

The findings in this study show dim prospects for teachers successfully countering post-truth. The best practices being advised in the literature on post-truth education are not new. In reading Chinn et al. (2021), Feinstein and Waddington (2020), and others, we find earnest repetitions of some of the arguments found in the conceptual framework of this dissertation (i.e., *fundamentalist* and *expansionist* science education for citizenship). For one example, Chinn and colleagues join with Ratcliffe and Grace (2003), Ryder (2002), and a host of other scholars in stressing the usefulness of authentic media sources in building students' capacity to assess their accuracy (see McClune & Jarman, 2012). Yet these teachers cannot and/or will not do so. One reason they give is that they are unprepared, with some even suggesting that they lack confidence in this practice themselves. Separately, in terms of how teachers represent science, Feinstein and Waddington predict that teachers are likely to respond to post-truth by "making a stronger case for the superiority of scientific practices and the robust nature of scientific findings" and add that these "well-intentioned but misdirected efforts could make things worse" (p. 3). A contribution of the present study is to affirm this worry. Participants, working from a strong belief in the well-informed citizenship model, responded to science denial by forcefully reasserting the authority of science to inform citizens through superficial references to objectivity and empiricism.

All the above findings respond to Research Question 2: *How are secondary science teachers conceptualizing citizenship and how do they relate this vision of citizenship to science?* This study found that science teachers held being informed when voting, decision-making, doing volunteer service, and having political discussions as an essential civic duty. Science education was connected to these activities as a provider of information. I found that science teachers held tightly to a simple, top-down model of well-informed citizenship. In this model, the authority of science to determine civic and political outcomes was overstated. Conversely, the agency of lay citizens in making sense of science for their own purposes was not acknowledged. Furthermore, it is argued that science teachers' commitment to a knowledge-deficit frame is ill-equipped to counteract misinformation.

The Science Teacher's Role in Educating Citizens

How does the well-informed citizenship model that these teachers hold play out in classrooms? Or perhaps the better question is, how does a model of well-informed citizenship influence teachers' instruction? The study begins to answer this by finding that science teachers seamlessly transferred the informant role they held for science to themselves as the voice of science. Lydia exemplified this by referring to herself as "the lead scientist in the room." This finding is in line with Barrett and Nieswandt's finding (2010) that chemistry and physics teachers who saw themselves as science "insiders" saw no need to teach beyond the traditional content of their course. Documents and interviews revealed that teachers in this study indeed stuck to a traditional science curriculum the vast majority of the time.

When citizenship is the goal, however, the consensus of the science education research community is that factual uptake by itself has no discernable effect on a person's ability to incorporate science in their civic affairs (Kind & Osborne, 2017). Instead, two approaches have developed from research that are thought to have more potential for preparing citizens to engage with science. These are the *fundamentalist* and *expansionist* approaches described in Chapter 2. In the following two sections, I use these two lenses to discuss what these participants believed about the appropriateness or alignment of each.

Fundamentalist Beliefs: Teaching Citizens to Recognize and Appreciate Science

It was found that the science teachers studied here believed that part of their role was to teach students that science is a reliable source of knowledge. On the surface, as a goal statement, they are well-aligned with scholarship. Recent arguments have been made that seek to refocus attention on the value of science as a source of expertise citizens can rely on (Collins & Evans, 2017; e.g., Rudolph, 2020). Sharon and Baram-Tsabari (2020) for instance highlight the critical examination of information as an intellectual virtue that scientists demonstrate and therefore science educators are well-positioned to explicitly teach. But none of this research attaches their arguments to a content-delivery approach. Rather, they advise a very different path: teach students to recognize how it is that science derives its trustworthiness and reliability.

Available evidence about how science teachers address the trustworthiness of science in their classrooms indicated a didactic approach. Several teachers thought as Tom did, who said, “The number one [priority] is opening them up to the idea of what scientific process is…that they are able to master a basic understanding of how science works.” But in looking at their curricula and hearing their descriptions of the labs they did, I found that these were algorithmic, flattened versions of science. This finding extends Windschitl’s study (2004) of preservice teachers’ beliefs about scientific inquiry. Teachers’ inaccurate and incomplete conceptions of scientific process—what Windschitl found to be their “folk theories” of inquiry—are likely rooted in their lack of experience doing science themselves. The present study also corroborates

Chinn and Malhotra's research (2002), which found that school-based portrayals of scientific epistemology fail to offer students opportunities to devise inquiries and assess varying designs for how well they meet the aims of empirical research. My findings here are qualified by my inability to observe their teaching, but the data did show a predominance of verification labs. I conclude that, while students knowing about scientific processes was named as important, this was evidently to be achieved through simply telling students that science is reliable because it vets and tests claims, and not by showing them or having them experience that process firsthand and then reflecting on its usefulness in a civic matter. Trust in science was taken for granted and not explored intellectually.

This finding constitutes a missed opportunity for citizenship education. Condon and Wichowsky (2018) for instance report on an intervention in which students developed empirical studies to compare the effectiveness of different sustainability efforts. Students judged the reliability of each other's scientific claims in the context of a civic issue. In addition to showing learning gains in all dimensions related to sustainability, student survey data also indicated an increased likelihood of future civic engagement and increased feelings of science efficacy. Allchin (2020) likens the ability to place one's trust in knowledge sources that deserve it to a social justice issue. Because an ability to direct the public's trust in science is closely related to political power, those who cannot see through the mire are more easily manipulated and thus at a political disadvantage. Allchin goes on to explain how an over-simplified, decontextualized treatment of the nature of science, like that found in the present study, is inadequate for the task. The better approach would be to "focus on the entire reach of science—from the test tubes to YouTube, from the lab bench to the judicial bench, from field site to website, from lab book to

Facebook" (p. 26). The findings of this study suggested that these teachers were not enacting this holistic approach.

Another finding related to the use of media in the classroom. Teachers believed that being informed was the central civic duty they could help with. But how did they suppose citizens access information? Scholars have long advocated that learning to engage with media representations of science is a necessary goal of citizenship education (McClune & Jarman, 2012; Ratcliffe & Grace, 2003; Ryder, 2002). In the world outside of school, science goes through secondary translations as it makes its way from laboratories and into lay peoples' lives (Gieryn, 1999; Polman & Gebre, 2015). The skill of assessing the accuracy of claims in the news is more important now than ever (Chinn et al., 2021).

The teachers in this study recognized the importance of citizens checking their sources. The data pointed to a loud and pervasive fear of students coming to rely on false claims they encounter on social media. As Lydia put it, "TikTok is not a valid place to get your information!" Alex further solidified this as an appropriate goal for science education, saying part of her role is "obviously trying to give them *tools* to be an informed citizen" (emphasis added). This common sentiment, however, did not square with how they described that teaching goal being fulfilled. Rather than giving students tools for assessing the media on their own, teachers instead saw their science classrooms as the place students should come to get their misinformation "cleared up" (Lydia). When media literacy was named as a teachable skill that was important, participants explained that they did not have the time or ability to teach those skills and indicated that such work be left instead to the librarians and humanities teachers.

Polman and Hope (2014) suggested that engaging substantively with science news stories, contrary to the reticence found in this study, should fall within the purview of science educators. They found that a necessary part of students' engaging with media was the presence of an adult broker: someone knowledgeable about both science and journalism who could help students make sense of a media piece as a boundary object that straddles both communities. The present study suggested, however, that this brokerage function is likely to be a trouble spot for science teachers. Many of the participants in this study shared that they either did not have the capacity to read the news themselves, with some even sharing that they have trouble interpreting the news and spotting false claims.

Science teachers' beliefs about science as information undergirded how they taught traditional science content in their classrooms and why they avoided media engagement. The predominant way teachers connected science teaching to citizenship was to supply that information. The role they most readily took on, which they felt contributed to citizenship, was to tell students what science says. This is a well-intentioned but incomplete effort (Feinstein & Waddington, 2020). As the literature clearly shows, the sticking point for public understanding is not the availability of information but the public's sense of trust and reliability as something scientists achieve. The main research contribution of this section, then, is that despite research that highlights the potential of the fundamentalist approach to teaching science for citizenship, science teachers tended to elide the processes by which science comes to produce reliable knowledge even as they recognized a citizen's need to understand those processes. Moreover, because these teachers positioned themselves as reliable sources of information and excluded media from their teaching in favor of traditional materials, they made students dependent upon them as the trusted source of information—an asset students would soon lose access to.

Expansionist Beliefs: Bringing Citizenship into Science Class

The other main way that science educators might address citizenship, separate from focusing solely on science, is by adopting some of the approaches of social studies educators. In other words, by achieving a level of interdisciplinarity. Centering sociopolitical issues that call upon citizens to decide what should be done is a key point of convergence between science education and citizenship education (Hodson, 2003; Ratcliffe & Grace, 2003; Sadler, 2011). One example of a best practice in citizenship education that scholars have long advocated for is a pedagogy of issues-based discussion (Bickmore & C. Parker, 2014; Hess, 2009; W. Parker, 2006, 2011). While this way of teaching does not represent the entirety of citizenship education (no one pedagogy can), discussion is a democratic activity that participants regularly claimed would be improved through science education.

But how do science teachers suppose science knowledge is to play a role in political discussions? Parker (2006) offers a model of classroom discussion that is comprised of *seminar* and *deliberation* as the two elemental classroom discourse structures that align with liberal citizenship. Seminars aim to clarify an issue by exploring meanings, while the purpose of deliberation is to decide on what should be done about a shared problem. For Parker, these two modes of discussion are inseparable; they combine to form *enlightened political engagement* (2003, 2006). We can look at the need for enlightenment—primarily achieved through the seminar discussion where public meaning and understanding are the focus—and see a connection to learning science. The purpose of the seminar is to flesh out what is going on; science teachers commonly think of their role in these terms. Moreover, considering Gutmann and Thompson's (2004) criterion for reason-giving in deliberative democracy, it becomes apparent how scientific knowledge can be a reason given to justify a decision, as participant Lydia has said.

However, my data ultimately suggested that these science teachers had at best a tenuous connection to discussion pedagogy. In Parker's frame (2006), learning democratic citizenship through a public discourse practice is a *values-driven* practice. They are open dialogs where possible meanings are explored and shaped by context rather than taken for granted. They are forms of inquiry without a priori correct answers. That is, political decisions that involve science are not one-dimensional, top-down, rational implementations of scientific advice (Bijker et al., 2009; Jasanoff, 2005). These features are anathema to the participants' model of well-informed citizenship. Science teachers tend to not address the complexity of sociopolitical issues (Kolstø, 2001). As such, they are not in agreement with findings from a large corpus of research on how citizens use science in sociopolitical contexts (e.g., Layton et al., 1993; Ryder, 2001). Deliberative pedagogy is an appropriate frame for decision-making that involves science because it creates space for interpreting scientific evidence in a sociopolitical context. The teachers studied here, however, were by and large unwilling to go there.

While participating teachers routinely avoided bringing politics into their classrooms, they felt more comfortable raising awareness of issues that involve science. A finding from this study was that science teachers cited the applicability of science in everyday life as a key justification for teaching science to all children. In doing this, participants made connections to humanistic and cultural goals for science education, which scholars have argued are aligned with citizenship (Aikenhead, 2006; Kind & Osborne, 2017). These teachers were keen to name points of relevance in their curriculum. Sometimes, though not all the time or even most times, these were examples of civic and political relevance. In my analysis, these brief mentions of applicability populated a theme I labeled marginal and ephemeral touchpoints. Looking across all the data on this theme, I came to see this teaching move as analogous to what a tour guide on a bus does. These teachers were pointing out to students interesting social and political "sites" as they passed by. The goal was not to interact with these topics substantively but to simply name them and quickly describe their connection to the content being covered.

Another interesting finding was that, in addition to the marginal and ephemeral touchpoints, teachers sometimes—on precisely three occasions in the data—entertained discussions that they represented to me as "political." I labeled these as bull sessions, which Parker describes as a type of political talk that, "though convivial, have no particular instructional purpose" (2006, p. 12). Tom and Neal were happy to entertain such talk but made it clear that they did so to build a classroom culture of openness—a community where it's okay to chat about what's on your mind. It was made explicit to me that teachers did not want these chats to be in any way part of the substance of the course. They may however offer an interesting opportunity for civic education. Boyte (2005) highlights informal talk, such as in the cafeteria at work, as a free space where political ideas can germinate.

On a few occasions, participants did go a step beyond entertaining a brief political chat. The study uncovered that about half of the participants said that they did a "topic" or "project" where students were meant to take a stance or form an opinion. Instruction of this sort has significant potential to accommodate a dual exploration of both descriptive and normative dimensions of sociopolitical issues (Kolstø, 2001). Therefore, these instructional examples, once raised, came in for closer scrutiny in follow-up interviews and subsequent data analysis. A representative example came from Abby, who undertook to rewrite her unit on immunity as an explicit response to the pandemic. This study, therefore, expands on work by Hutner and colleagues (2022) who found that science teachers, confronted with conflicting and shifting educational goals, will adapt preexisting curricula when they are committed to the value of the outcome. One of Abby’s intentions was to make students better prepared to form a political argument about whether the government should mandate vaccines or not. The data, however, revealed that student engagement on this point was nearly non-existent. In the end, the question was relegated to an optional online discussion forum that scant few students took advantage of.

Indeed, the phenomenon of stopping short of values-based reasoning in the context of a sociopolitical issue (Sadler, 2004) was a consistent theme throughout the data. Teachers who claimed to teach an issue, who were convinced that this “context-rich” (Glen) approach was aligned to citizenship, were never quite able to make space for these learning activities, or explicitly considered such activities inappropriate. Lydia called them “extension activities,” highlighting the expendability of instruction not squarely justified as science. This finding adds to numerous others found in the literature on issues-based science teaching. For instance, Wong, Wan, and Cheng (2011) described a case in which two teachers, hopeful to incorporate socio-scientific issues in their teaching, never got to the meaty discussions they planned for. Instead, they devoted class time to lecturing on the physics content they felt students would need before they could fully appreciate the issue. Similarly, Levinson’s study of a biology teacher who meant to facilitate bioethical debates (2004) found that she squashed debate instead. A close read of Levinson’s report reveals how the teacher intervened in student-to-student discussions by imposing textbook narratives of biology that had the effect of reorienting the goal of the activity to content acquisition. This finding is particularly interesting considering that it was conducted in the UK where there was a mandate to address “scientific literacy” by emphasizing socio-scientific issues. Which is to say, the teacher cited the primacy of content in opposition to the national policy she was working under.

I also found that these science teachers' beliefs about controversy informed their notion of appropriate science teaching for citizenship. Hess has argued that stopping at the level of awareness of current events deprives students of an opportunity to learn how to deliberate controversial issues (2009). Learning to be a citizen necessitates a political classroom where controversies are engaged with rather than ignored (Hess & McAvoy, 2015; Pace, 2015; Parker, 2003). Yet pointing out that an issue exists in the world and that the science being studied *could* inform it was the furthest most of these teachers got. A clear finding here was that teachers strove to avoid controversy. This apprehension was best expressed by Alex: "Because of Covid, because of like the crazy divides that are going on right now, [we're] not really talking about politics, not talking about politically charged issues so much. Sort of just laying out the bare-bones science." Many participants said that they should not disclose their own positions. This belief that it is inappropriate to disclose is seen as a best practice for facilitating political classrooms (Hess & McAvoy, 2015).

It was on this point that one of the more interesting findings emerged from the data. I compared the data related to avoiding controversial issues to those data where science was portrayed as an apolitical foundation for civic engagement. This showed that participants held two beliefs that were in tension. First, they felt that the goal of science education was to provide citizens with basic information. Part of this was the belief that science was a dispassionate, neutral provider of *uncontroversial* facts—or at least that it ought to be seen that way by the public. Second, because they saw themselves as primarily a voice for science, they held a prior commitment to remain neutral and dispassionate as classroom teachers. These core beliefs had put these teachers in a bind. They had committed to not joining in any political arguments *for* something. And yet, the emergence of post-truth had reframed scientific expertise as itself potentially controversial. The data showed a handful of teachers struggling with this new terrain in real time. Trent said,

> We have an entire political party who is absolutely willing to ignore the advice of any scientist, to almost scoff at the idea of scientists. … We're talking about, 'Why should we accept scientific consensus?' … There are people who dedicate their careers to finding a little corner of it that's been unexplored and trying to explore it. I feel like if that's controversial then that's the controversy we should be embracing.

His question, "Why should we trust scientific consensus?" captures the exact argument of the fundamentalist science education for citizenship approach. If Trent were to continue that line, he would do well to adopt frameworks like those referenced here by Ryder (2001, 2002) and Kolstø (2001). This quotation is tempered, however, by considering that Trent was also one of the primary proponents of science as a simple process that yields fundamental truth about nature (Feinstein & Waddington, 2020).

The present study contributes findings related to teachers' beliefs about expanding their practice to address citizenship. These findings extend those of previous research. For instance, Sadler and colleagues (2006) found a diversity of reasons science teachers gave for including and not including ethics in their science teaching. The researchers found that teachers' beliefs about their efficacy in teaching ethical issues and their beliefs about the appropriateness of doing values-based discussions in science class were significant factors for teachers' motivations to enact SSI teaching. Leah was the sole case in the present study of a science teacher who believed in both their efficacy and in the appropriateness of embedding her physics instruction in a thoroughly civic issue. Sadler and colleagues also found that most science teachers were ambivalent about both efficacy and appropriateness, while a significant subset felt that ethical reasoning in science class was inappropriate, making the question of efficacy moot. The remainder of the present participants, except Leah, map onto these categories as well. Glen, for instance, was emphatic that civic engagement should not be something he does, offering instead to bring students up to a point where they could have a debate by covering the relevant science beforehand, at which point another teacher could then take over.

The findings here also resonate with a study from Tidemand and Nielsen (2017). Those researchers found that Danish science teachers who professed to value socio-scientific issues as a way to support citizenship nevertheless harbored a content-centric interpretation of SSI. In other words, while teachers nominally agreed that issues-based science teaching was a good approach, in practice they relegated the political issue to the role of motivating student interest in the science content to be covered. This closely mirrors my findings here. Participants in the present study commonly led into their science teaching by naming some non-scientific issues for which the content was relevant. Resolving a political issue was never really on the agenda. But the most interesting outcome of Tidemand and Nielsen's study was how the teachers justified their adherence to content. Their rationale was that, because some political issue could hypothetically draw upon any piece of scientific knowledge at some point, they were justified in thinking that their existing curriculum was just as suited to the preparation of citizens as any other. It seems that the teachers in my study were thinking much the same way.

This study contributes to an understanding of how science teachers' beliefs influence their motivation to pursue science teaching that may address citizenship. The above findings shed light on Research Question 3: *What kinds of curriculum and instruction do secondary science teachers view as being appropriate and aligned to democratic citizenship education?* This study found that science teachers did not generally agree with approaches to science education for citizenship advocated for in the literature. There is ever wider agreement among scholars that giving students knowledge and understanding of how knowledge becomes reliable is a critical goal for citizenship. Participants here instead asserted their role as providers of settled facts without reference to where they came from. The few times participants did mention the value of knowing about scientific processes, these were overly simplistic portrayals made in the abstract.

Another approach to science education for citizenship would be to make civic engagement with science a substantive part of the course. One science teacher and one engineering teacher were found to have done this, for a total of two curriculum units. Political and civic issues were mostly absent from the participants' teaching. The main finding here is that science teachers when they did reference non-scientific contexts, tended to do so only to generate interest in the science content they needed to cover.

Weak Attachments to Citizenship

This study sought to find out how science teachers were thinking about citizenship as a goal for their teaching. It was found that participants believed that scientific knowledge and skills were generally applicable in every part of life. On the face of it, this might bode well for science education for citizenship, because democratic citizenship (as this study defines it) is a part of everyone's identity. However, as has been made evident through research by Ryder (2001) and others (e.g., Layton, et al., 1993), most often science content is not directly useable in everyday situations. Science knowledge that describes and explains a *science* problem must be transformed before it is useful in a social context, where multiple kinds of knowledge and values are also important (Aikenhead, 2006; Kolstø, 2000). The teachers in this study, in saying that science helps students in their everyday lives because it is applicable, did not show an appreciation for the complexity of “applicability”.

Aside from being unfounded, there is another aspect to teachers’ arguments about the general applicability of science that is worthy of discussion here: where in life they suppose science applies. Analysis revealed that when interviews were about a general “for all” justification, citizenship or related ideas were not spontaneously brought up. This contrasted with how participants made career and college preparation arguments for science education frequently and fluently. For example, Neal said it was appropriate for every student to take his course because it teaches skills that are “extendable to if you’re going to create an NGO…and to a nurse…to a wide range of careers.” A connection to citizenship was agreed to, once prompted, but the career- and college-readiness justifications appeared to hold sway.

These participants displayed belief in two versions of a career readiness justification for science education. First, they felt that it was important for their students to have access to the careers that school science credentials could grant them. They understood that not all would ultimately end up in a science-related career, but they did not believe it was appropriate to foreclose on that opportunity. Several thought as Nel did, that you “have to do both” citizenship and career readiness. This is admirable. In wanting their students to be empowered within science, participants were appealing to a sense of equality. This is resonant with research from Carlone and Johnson (2007), who found that women of color more easily persisted in science careers when they were recognized by others in the science community as legitimate. Some of these participants wanted to be that legitimizing force for their students. However, this position is less tenable when one considers that fewer than one-in-ten students, even by generous accounting, will go on to pursue careers in a science-related field (Rudolph, 2023).

The second version of the study participants' economic justification was that the skills and work ethic they learned in science class will be transferable to other workplaces. This belief was more prevalent than the direct pre-professional science training argument. Tom represented this perspective when he stressed to his students that his physics course would teach them how to solve difficult problems independently, then explicitly named this as a desirable characteristic in the marketplace. When science teachers employ this kind of rhetoric, they tie the purpose of their teaching to a credentialing goal. David Labaree refers to a focus on credentials as a social mobility approach to education, which "argues that education is a commodity whose only purpose is to provide individual students with a competitive advantage in the struggle for desirable social positions" (1997, p. 18). Where these participants differ from this statement is that they do not believe social mobility to be the *only* goal for their science teaching, though they do embrace it as a goal. What they say is that individual career goals and citizenship goals "coexist peacefully" (Elaine). In other words, these science teachers do not see the credentialing function of school science as a threat to the citizenship goal.

These teachers' assumption that they can address both students' civic capacities and their economic fortunes at the same time with the same kind of science teaching is problematic. For instance, in terms of democratic theory, Robert Dahl (1998) argued that our responsibilities as citizens to be moral, equitable, and just are often at cross purposes to an efficiency standard in the economic domain. Labaree (2010), working in the field of education policy, has traced how the standards-based reform movement has shifted how we think about the purpose of public education away from civic virtue and toward a private market rationale. This in turn exerts pressure on teachers away from intricate pedagogies—like those advocated for in both the *fundamentalist* and *expansionist* approaches to teaching science for citizenship—and toward the stable content that can be efficiently delivered and assessed (Schneider, 2011).

The findings discussed in this section address the first Research Question posed by this study: *How are secondary science teachers interpreting and responding to calls to teach science for citizenship?* On the surface, the answer here is simple: they are agreeable to a citizenship goal. However, when looking deeper into teachers' beliefs about the overall set of goals they hold for their teaching, it is revealed that they are happy to say their science teaching addresses all goals. Furthermore, participants were more enthusiastic and more readily supplied examples of how their teaching addressed college and career readiness.

Overall Takeaways and Implications

This study began with the observation that science education is consistently justified by its ability to improve citizens' decision-making. The study found that science teachers readily accepted this goal for their own teaching. But stated goals only go so far. A goal that demands nothing of you is easy to adopt. Teaching science for citizenship, according to the literature, would focus on the epistemology and social processes of science, centering science curriculum and instruction on an engagement with sociopolitical issues, or some combination of the two. This constitutes a significant reform burden for most of the teachers studied here—it would demand quite a lot.

And yet, every one of these teachers believed that science education *does* contribute to citizenship. When talking about citizenship as a goal, they did not use the future tense; they spoke as if science education for citizenship was already happening. This perspective is understandable considering the well-informed citizenship model. By conceptualizing citizens as in need of reliable facts and science educators as those who stand at the ready to fill that need by simply telling facts to citizens, these teachers had constructed a model of convenience. That is, the model they conjured allowed them to remain as they are. The evidence here suggests that “well-informed citizenship” was developed as a post hoc rationalization for science content delivery.

As has been indicated at several points above, the notion of well-informed citizenship found in this data is untenable from a research perspective. For a start, knowledge-deficit assumptions about the public have been thoroughly critiqued in the literature for a long time. Citizens use science, and scientists produce knowledge, in more complicated ways than these teachers understood or acknowledged them to. Rationalization is typically characterized by offering a justification for an attitude or action that differs from what really explains that action or attitude (Summers, 2017). The attitude or action, in this case, is the teachers’ adherence to their existing teaching methods. Perhaps one contribution of this study is to show that this semi-structured interview and these SSI vignettes did nothing to persuade teachers of a disconnect between the status quo and more robust science education for citizenship. It is beyond the scope of this study to explain what “really” explains this adherence, but the findings here do point to some implications.

The primary implications of this study pertain to teacher education. A good place to start might be to challenge the deficit mindset directly and explicitly. More accurate versions of citizens engaging with science should be utilized, perhaps as case studies, in teacher education programs. For example, socio-scientific issues courses at the undergraduate level are becoming more popular (e.g., Dauer & Forbes, 2016), and this is a promising site for pre-service teachers to gain some experience exploring the many dimensions of sociopolitical issues involving science (Macalalag et al., 2019). Equally important to a revised notion of civic engagement with science would be a similar project in the epistemology and social processes of science. Science teachers tend to follow a career trajectory that does not involve doing research or making knowledge. This phenomenon perhaps goes a long way to explaining teachers' resistance to abandoning a stable content-delivery pedagogy. It certainly helps explain why science teachers tend to have incomplete or errant visions of scientific inquiry. A study by Anderson and Moeed (2017) where science teachers worked alongside professional scientists is one example of an effective approach to addressing this problem.

In sharing these findings, I do not intend to give the impression that it is a deficiency among the teachers that explains why we do not adequately address citizenship through science education. It would be ironic to make several arguments against a deficit frame only to characterize teachers as merely lacking some well-defined, easily transmitted body of knowledge. First, teacher beliefs are deep and likely difficult to change. Second, teacher beliefs are not the only factor. And yet what teachers believe about what is appropriate to teach, alongside their concept of the goals they teach toward, certainly does matter. We therefore ought to try to develop with teachers a more expansive and accurate vision of what it means for their students to be educated in science for democratic citizenship.

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Appendix A: Recruitment message and survey items

Thank you for taking the time to fill out this short questionnaire. Doing so is an act of service that makes possible a growth of knowledge about science education. There are 13 items, and it takes about 5 minutes. I am seeking to ascertain in part what science instruction looks like in your room (acknowledging that many of us, sadly, are not actually teaching in rooms for now).

There are no preferred responses to any of the items. It is important that you only respond as honestly and accurately as you can.

By completing this survey you do NOT yet consent to have your responses reported on as part of a research study. Your identity and confidentiality will be protected in any event. Your responses will not be shared outside of an approved research team working under IRB oversight. If you indicate below that you are open to it, a researcher may follow up with you regarding further participation.

If you have any questions please don't hesitate to contact me at batkie@wisc.edu

With sincere thanks,
Ryan Batkie (he/him/his)

Survey consent

By completing this survey, you consent to have a University of Wisconsin researcher review your responses but not to report or present them publicly. There is a chance that, if you wish and if you undergo an informed consenting process, you could be selected for a more in-depth interview-based data collection procedure in addition to this survey. None of your survey responses or follow-up interviews could be used as data in the research study until informed consent is given by you.

Frequency of Instructional Elements

There are no preferred responses to any of the items.

Please use the "Other" option to type your own more specific response whenever you feel it is necessary.

Answer in terms of what you would be doing in a typical year (I know--if only). If the pandemic has had an effect on the presence or absence of the instructional element in question, feel free to use the "Other" space to explain.

How often are current events discussed in your science class?
Often / Sometimes / Rarely / Never / Other:

How often do you use news media intended for a general audience (articles, videos, podcasts or the like) in your science teaching?
Often / Sometimes / Rarely / Never / Other:

How often do you make sociopolitical issues part of your science teaching?
Often / Sometimes / Rarely / Never / Other:

How often are students in your science class meant to take a position on a normative question? (e.g., Should our town build a wind farm? How should we allow CRISPR gene editing technology to be used?)
Often / Sometimes / Rarely / Never / Other:

(optional) Please use this space to tell me anything else you want me to know about your science teaching. You may use this space for questions or concerns as well.

Background

What grades do you currently teach?

Please list the courses you currently teach.

How many years of science teaching experience do you have?

Which best describes the community where you currently teach?
Rural
Urban
Suburban
Exurban
Other:

Which term(s) best describe your school? (Check only one or all that apply.)
Public
Charter
Private
Parochial
Alternative
Magnet
Other:

What is the estimated number of students enrolled in your school?

Would you be willing to serve as a participant in further, more in-depth research? This would entail 1-2 hours of interviewing plus reading a few short texts in your own time.
Yes / No

Appendix B: Research Participant Information and Consent Form

Title of the Study: Secondary science teachers' conceptions of and commitments to citizenship education

DESCRIPTION

You are invited to participate in a research study about teaching science and citizenship from December 2020 to perhaps June 2021. The purpose of the study is to explore how schools might support learning science for civic purposes. Participation in the study would be completely voluntary; even if you join, you are able to exit at any time or decline to be interviewed at any time without providing reason.

If you consent, we will be collecting data from you in the form of a short questionnaire and two semi-structured interviews of about one hour each. These will be conducted and recorded over a web application such as Zoom or the like. Video and audio recordings will be deleted once transcribed—your image or voice will not be used in subsequent presentations or reporting that results from this study. Your confidentiality will be protected by use of a pseudonym as well as data always and only existing on password-protected computers. We also seek to obtain copies of your planning documents and materials you give to students. No finished student work will be collected as data. Interviews will happen at your scheduling convenience. You can decline to answer any question at any time without providing a reason. Interviews will be considered confidential between you and the researcher, and nothing learned by the researchers will be shared with any of your supervisors, colleagues, students, or their families.

BENEFITS AND RISKS

While there are no direct benefits to you for participating in this study, your participation may indirectly benefit others by enabling a growth of knowledge in the field of science education. We do not anticipate any risk or discomfort related to your participation. Every effort will be made to protect your confidentiality. No video or audio data will be published. The recordings will be used solely for this research project and will be analyzed only by approved researchers. Unrelated sensitive information will be removed either by editing or deleting the original video files. All names will be changed in the transcriptions. All recordings will be kept in a secure location on password-protected computers by the researchers and will be deleted as soon as they have been transcribed.

QUESTIONS?

You may ask any questions about the research at any time. If you have questions about the research, you should contact the Principal Investigator, John Rudolph, at (608) xxx-xxxx. If you are not satisfied with a response from the research team, have more questions, or want to talk with someone about your rights as a research participant, you should contact the University of Wisconsin-Madison Education Research and Social & Behavioral Science IRB Office at (608) xxx-xxxx.

Your participation is completely voluntary, and you can withdraw from the study at any time. If you decide not to participate or to withdraw from the study, it will have no effect on your professional standing at your school. Your signature indicates that you have read this consent form, had an opportunity to ask any questions about your participation in this research and voluntarily consent to participate. You will receive a copy of this form for your records.

To reiterate, by signing you give consent for the research team to:

- collect survey responses about your school context and some elements of your science teaching strategies;
- record audio and video of one-on-one interviews conducted over an internet conferencing application wherein your ideas about teaching and instructional practices are discussed;
- collect relevant planning documents and student handouts (in digital format).

Your name (please print): ____

Your signature: ____ Date: _______________

Please return this consent form to Ryan Batkie. Thank you!

Appendix C: Interview 1 protocol

Thank you for speaking with me today. I believe you are making a valuable contribution to science education by giving your time to this project.

What time must you end by?
Are in a place where you can speak freely?

Just a reminder that you don't have to answer anything you don't want to, and you can choose to not respond to any item or to end the interview whenever you want.

Also, none of these questions are meant to catch you off guard. I want you to answer honestly to the best of your ability. There are no right or wrong answers. If you need to clarify or add to a response because you thought differently later, then go right ahead. I really just want to know what you think. Your confidentiality will be protected. When I quote you or describe what you share here in future reporting it will be under a pseudonym.

You have read and signed the consent form, but I want to confirm: Do you consent to having this conversation recorded and used as data in a research project?

Do you have any questions before we start?

---

1. Please start by briefly describing your course.
    a. After they finish answering, if not already obvious: Is there a mandated curriculum, external exam, or standards?
    Who designs the curriculum? Assessments?

2. How do you explain the importance of your course to students and parents?

3. What stands out to you as a satisfying part of teaching this course?
    a. Maybe there is some unit or activity you are proud of or stands out as successful?

4. What are the big takeaways you want your students to get from your class?

5. How do you think learning science can be empowering for students?
    [If stuck: What skills or abilities can students learn from a science class that allows them to do more?]
    a. In what ways do you see your course contributing to your students' empowerment?

6. How does science education contribute to the greater good?
    a. How do you see your own course contributing to this?

7. What do democracy and citizenship mean to you?

[If stuck: If someone is displaying good citizenship, what might that look like?]
[If they only talk about one of the two, re-prompt them to talk about the other when they seem finished.]

8. Why do you think it is important for all citizens to learn science?
    a. In what ways might your science class help students to be better citizens?

9. What responsibility does science education have, if any, to bring about a more just and equitable society?

I'm going to switch gears a bit. We're probably half done. Would you like to take a short break?

10. On your survey you indicated that current events are (often/sometimes/rarely/never) discussed in your science class.
    If o/s/r:
    Describe a time where you made a current event part of your science class.
    What was the current event?
    How was it related to your science curriculum?
    What prompted you to include it?
    What was your desired outcome?
    Was the unit or lesson that involved the current event successful? Why/why not?
    If s/r:
    What, if anything, holds you back from doing more of this?
    If never:
    Is addressing current events something you've considered?
    Do you have a reason for not addressing them?

11. In your survey you indicated that you (often/sometimes/rarely/never) use news media intended for a general audience in your science teaching.
    If o/s/r:
    Describe how you used the news item in your science class.
    What was the topic?
    Did the news item portray the science as settled or still open?
    Did it portray conflict or disagreement among experts?
    How was it related to your science curriculum?
    What prompted you to use it?
    What was your desired outcome?
    Was your use of news media successful? Why/why not?
    If s/r:
    What, if anything, holds you back from doing more of this?
    If never:
    Is the use of news media something you've considered?
    Do you have a reason for not using it?

12. On your survey you indicated that you (often/sometimes/rarely/never) make sociopolitical issues part of your science teaching.
    If o/s/r: Describe a time where you made an issue part of your science class.
    What was the issue?
    Would you describe the issue as controversial?
    How was it related to your science curriculum?
    What prompted you to include it?
    What was the desired outcome of that unit or lesson?
    Was the unit or lesson that involved the issue successful? Why/why not?
    What is your sense of how students, parents, and colleagues feel about it?
    If s/r: What, if anything, holds you back from doing more of this?
    If never: Is inclusion of issues something you have thought about?
    Do you have a reason for not including them?

13. In your survey you indicated that you (often/sometimes/rarely/never) have your students take a position on a normative questions.
    If o/s/r:
    Describe a time where you did make a normative question part of your science class.
    What was the question?
    Would you describe the question as controversial?
    How was it related to your science curriculum?
    What prompted you to include it?
    What were your goals in having your students explore that question?
    Were your students successful in resolving the question? Why/why not?
    What is your sense of how students, parents, and colleagues feel about it?
    If s/r:
    What, if anything, holds you back from doing more of this?
    If never:
    Is having your students take a position on a "should" question something you've considered?
    Do you have a reason for not doing so?

I want to thank you very much for taking the time to speak with me today.

Is there anything else you want me to know about your work that I haven't asked about?
Or is there anything you'd like to expand on?

Do you have any questions for me at this point?

Appendix D: *Framework* prompt with relevant interview 2 protocol items

The below passage is a paragraph from *The Framework for K-12 Science Education* (National Research Council, 2012, p. 7). I have given the questions I plan to ask when we meet again (next page). I do not expect you to answer them ahead of time, just to start thinking, and maybe having these will spur thought. If you do want to write anything, even very informally, go right ahead.

> Many recent calls for improvements in K-12 science education have focused on the need for science and engineering professionals to keep the United States competitive in the international arena. Although there is little doubt that this need is genuine, a compelling case can also be made that understanding science and engineering, now more than ever, is essential for every American citizen. Science, engineering, and the technologies they influence permeate every aspect of modern life. Indeed, some knowledge of science and engineering is required to engage with the major public policy issues of today as well as to make informed everyday decisions, such as selecting among alternative medical treatments or determining how to invest public funds for water supply options. In addition, understanding science and the extraordinary insights it has produced can be meaningful and relevant on a personal level, opening new worlds to explore and offering lifelong opportunities for enriching people's lives. In these contexts, learning science is important for everyone, even those who eventually choose careers in fields other than science or engineering.

What is your general reaction to this passage?

How are you thinking about the idea that science education should "keep the United States competitive in the international arena"?

- How do you see this relating to your teaching with your students, if at all?

Now let's look at this part where they say that "every American citizen" needs to learn about science and engineering.

- How are you thinking about this idea?
- How do you see the word "citizen" being used there? What do you think they mean by it in that context?
- How do you respond to the idea that science education should help people make better "public policy" decisions?
- Is there an example in your own teaching that might be like the public water example that they raise?
- How are you thinking about their idea that science education should help people make better "everyday" decisions?
- When you think of your course, as it is currently formatted, do you see ways in which it can help fulfill the goals written about here?

Do you think science and engineering education can accomplish the things discussed in this passage? Why or why not? Are some of these goals more accessible or attainable than others? Why? How – by which pedagogical means?

As a science teacher in your school, what role do you see yourself playing in relation to this passage?

Appendix E

'Ms. Franklin's' physics vignette, adapted from Zeidler and Kahn (2014) "Unit 3: A Need for Speed?: Should speed limits be lowered to reduce traffic fatalities?" with relevant interview 2 protocol items

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Please read and **annotate** the below vignette describing the development and enactment of a curriculum unit. I would like you to make marginal notes, either with your computer's comment tool or by hand on a printout, about *anything* you find interesting or have a thought about. Again I give you the questions that will guide our next interview (after the unit text, on p. 6 of this document). You may type up some responses to them prior to that meeting, but if you do not have the time that is okay.

Ms. Franklin teaches physics at a large suburban public high school. It has always been a challenge for her to get all of her physics students interested in the subject, so the problem of relevance is always on her mind as she develops curriculum. It dawned on her that most of her students were newly licensed drivers and that they cared about their driving privileges very much. There is also a section of road near her school that is known for having lots of collisions. Most often they are minor, but everyone in the community is painfully aware that people have died there. It seemed very doable to her that a physics unit involving friction, momentum, and really most of her traditional dynamics unit could be taught through a unit on driving safety and laws.

She hoped that bringing in larger issues in her students' lives like the interplay between the responsibility to drive safely and the (literal) limitations placed on them in the form of traffic laws would be a kind of hook, but also useful topics to learn about in their own right. She approached the government & civics teacher in her building to get ideas as she began developing the unit. He noted that some ideas he engaged with in his classes were relevant: personal freedom, government regulation, and individual versus societal interests. He also shared tips on how he leads whole-class deliberations on issues like these that have no clear-cut "right answer" but are rather values-based, political decisions. Out of this work came a unit with the driving (pardon the pun) question: *Should the speed limit on Maple Road be lowered to reduce traffic fatalities*?

The opening activity was designed to give students a visceral sense of how different it is to travel on a slippery surface. She had them conduct a basic Slip 'n' Slide experiment where they timed themselves sliding on a plastic sheet first with water and then with soapy water. This was also a chance to calculate velocity and momentum from data. This exploration concluded with a discussion of the physical meaning of "slippery"; Ms. Franklin was sure to invoke "friction" as the physics concept at issue before the end.

Following the opening activity and discussion students then analyzed the Slip 'n' Slide data. They interpreted their results scientifically to draw conclusions about the relationship between velocity and mass to momentum, as well as the impact of friction on velocity. Their goal was to produce scientific evidence and mathematical models that related those quantities. Ms. Franklin then asked students to apply these findings to driving on the road under different conditions. Students demonstrated that they could rank how difficult it would be to bring vehicles of different masses and initial speeds to a stop.

The next two class periods (days 3 and 4) were spent researching various sources of data to grapple with the question of whether speed limits in general should be reduced in order to cut down on traffic fatalities. Before they dug into this work Ms. Franklin also introduced the culminating activity/assessment for the unit: a town hall meeting where students would be grouped *later* (after researching) into arguing a 'pro' or 'con' position. Students analyzed a series of articles for their main arguments, evidence, and key points. By doing so they were meant to gain familiarity with statistics and information regarding speed and the effect it has on vehicular accidents. The articles she used are listed here:

- Article 1: National Motorists Association. Does speed kill? https://www.motorists.org/does-speed-kill/
- Article 2: U.S. Department of Transportation Research, Development, and Technology. 1992. Fact Sheet: Effects of raising and lowering speed limits. http://www.fhwa.dot.gov/publications/research/safety/humanfac/rd97002.cfm
- Article 3: Nagourney, E. 2009. Safety: As speed limits rise, so do death tolls. The New York Times. July 20. https://www.nytimes.com/2009/07/21/health/research/21safe.html?scp=3&sq=highway&st=cse&_r=0
- Article 4: Reinberg, S. 2009. Deaths, injuries increase with higher speed limits. ABC News. July 16. https://abcnews.go.com/Health/Healthday/story?id=8105116&page=1

Students turned in worksheets showing their analysis of the articles and these were assessed for accuracy and completeness.

On the fifth and final day of the unit students took on the roles of truck drivers, business leaders (both con – no we should not reduce speed limits), police officers, or parents (both pro – yes we should reduce speed limits). Students used evidence both from physics lab and their assigned readings as the basis for their arguments. Ms. Franklin followed a protocol with the class:

1. Organize students to participate in a town hall meeting to determine if the speed limit should be lowered to help reduce traffic fatalities in their town. The final decision regarding the speed limit will be determined by a secret ballot at the conclusion of the discussion.
2. Begin a structured deliberation whereby all groups make an opening statement comprised of one or two claims using evidence to persuade others of their viewpoint. After all four groups have made their statements, allow students to ask questions of other groups' evidence, refute their claims, or bolster their own claims with additional evidence. Students must raise their hands to participate.
3. At the end of the meeting, review your impressions with the students and clear up any misconceptions that may have surfaced during the discussion. Have students now assume the role of the governing body and vote using a secret ballot to determine whether the speed limit should be reduced. Students should vote what they believe, ***not*** their stakeholder positions (although these might be the same). Announce the results to the class.

Ms. Franklin concluded the lesson and unit by discussing the day's decision with the students. She posed various questions to facilitate the discussion: *Were you surprised by the class decision? Do you still have questions about the relationship between speed and vehicle safety? Could we have negotiated a different outcome? Is there another idea for a policy change that could have helped? How does it feel to use evidence to inform decision-making? Did you change your mind about this issue during the debate?*

The final assessment was for students to write a letter to their local and state-level departments of transportation describing their research results and expressing their opinions on speed limits. For these, students were to expand their research beyond the initial four articles. Ms. Franklin assessed these on accuracy of data, clarity of expression, persuasiveness of arguments, and format/grammar. She combined this student work with observational notes she took during the town hall meeting to rate students' performance.

What is your top-line reaction to the instruction you see depicted in this vignette? What overall impressions does it leave?

Does this feel like a worthwhile thing to do? Why or why not?
Are there particular parts that seem especially good to you? If yes, which and why?
Are there parts that you would not do? Why?
How might you alter this for your own use? Why?

Can you think of other issues or topics that might be the basis for a similar unit in your class?

Would you anticipate getting pushback if you enacted this unit or one like it?

Do you feel prepared to perform the kind of instruction described here?

Do you see this as a good way to educate students in science to be better democratic citizens?

Can you think of other teaching colleagues at your school, from any discipline, that might be interested in collaborating with you to develop a unit like this?

What other thoughts do you have about this vignette that we haven't discussed yet today?

Appendix F

'Ms. Franklin's' biology vignette, adapted from Zeidler and Kahn (2014) "Unit 5: A Fair Shot? Should the Gardasil vaccines be mandatory for all 11-17-year-olds?" with relevant interview 2 protocol items

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Please read and **annotate** the below vignette describing the development and enactment of a curriculum unit. I would like you to make marginal notes, either with your computer's comment tool or by hand on a printout, about *anything* you find interesting or have a thought about. Again I give you the questions that will guide our next interview (after the unit text, on p. 6 of this document). You may type up some responses to them prior to that meeting, but if you do not have the time that is okay.

Ms. Franklin teaches biology and human anatomy at a large suburban public high school. She has grown increasingly concerned about the anti-vaccination movement in recent years. Immunology is certainly something she has always covered, but the topic has taken on a political dimension. She didn't want to ignore this but also worried that she would be out of her depth—that a controversial discussion could get out of hand and end up doing more harm than good. After discussing the matter with a few colleague and students, she decided to develop a unit where her students could learn to make sense of the complex moral, political, and scientific problem that is vaccination. The question she came to that would drive the unit was *Should the Gardisil vaccine be required for all 11-17 year olds?* She enlisted her colleague who taught government and economics to help her name some of the concepts and ethical issues that may traditionally fall under that teacher's purview: patient rights, right to privacy, cost-benefit analysis in health care, risk assessment, government regulation, and paternalism. She also met with and observed an English teacher colleague who was known for their competence in leading seminar discussions in class.

Ms. Franklin began the unit by inviting students to discuss whether they would take a vaccination that would "almost certainly" prevent them from getting cancer. After some initial positions are explained, she then asks them to talk about what they would do if there were a "high chance" of preventing cancer and a "small chance" that it may cause them to become ill in a different way and perhaps even die. After some reasoning had been aired she introduced some basic information about Gardisil. She then went on to say that several state legislatures were actively considering whether to make the vaccine mandatory for all teenagers. The students then tried to list at least ten (10) reasons that supported their position of either being for or against this policy of mandatory vaccination. The period ended with a discussion of the information needed and/or the difficulty of making a decision like this. She informed the class that their objective for the unit was to further research and strengthen their arguments and that it would be fine to change their minds as their thinking and information changed.

Ms. Franklin then directed students to put together a creative project titled "Journey Through the Immune System". Their primary source was an NIH booklet titled "Understanding the Immune System" and other vetted sources they could find. In their presentations, students were expected to:

- Describe the function of the immune system
- Explain how the skin functions as a defense against disease
- Distinguish between a specific and nonspecific response
- Describe the actions of B cells and T cells in an immune response
- Describe the relationship between vaccination and immunity
- Describe what happens in an allergic response
- Describe at lease one immune disorder
- Explain (diagram) the antigen-antibody reaction

Students had choice over what they created/how they communicated, but it must be scientifically accurate (they must provide evidence of having used reliable sources).

Students then in the next lesson learned about cancer. They began by observing cancerous and normal cells under the microscope without knowing which was which or their significance. Ms. Franklin utilized an interactive web resource from PBS and a PowerPoint from cancer.gov for students to use as a guide for studying the biological mechanisms of cancer. After they did so she convened the whole class to think about how this study of cancer related to the big question of whether Gardisil should be mandated.

The next time the class met they did a powerful activity that simulated the spread of infections through populations. Every student began with a small cup of water half full. One of the cups secretly had a NaOH tablet dissolved in it prior to students arriving. Liquids in cups were mixed through a few iterations of a 'musical chairs' style activity. Ms. Franklin played music as students mingled. When the music was stopped abruptly, students paired up with whoever was closest. One student then poured their water into the other's cup; half of this was poured back into the original cup, thus thoroughly mixing each. Only when students added a drop of phenolphthalein to their cup did they discover which cups were "infected." In the second half of this class meeting small groups of students checked on the veracity of 28 statements about sexually transmitted infections.

For the next lesson students were assigned "for" or "against" positions on the matter of mandating Gardisil and met to hold a formal debate. Students pulled together all they learned about immunology, cancer, and disease transmission over the previous days to make their arguments. Ms. Franklin randomly assigned groups and reassured students that they would be able to voice their actual positions after the structured debate. Each side sub-divided into groups by the phase of the debate they would be responsible for:

- *Opening statement* group presented the case, making claims with evidence
- *Cross examination* group asked clarifying questions of the other side
- *Rebuttal* group presented counter-arguments based on what they other side presented and points raised
- *Closing statement* group summarized the group's points and tried to make a final persuasive argument for the "judge"

After the debate Ms. Franklin led the class to reflect on: *What were the most compelling arguments? Why? Did the opposing team make any arguments or present evidence that you did not anticipate? What, if anything, surprised you during this process?*

For the fifth and final lesson students rethought their positions and related the Gardisil issue to the role of science in an issue like this. Ms. Franklin gave them back their original position statements to revisit. She then gave everyone a fresh, blank copy of the form for listing their position with ten reasons and asked them to re-do it. She made space for the class to discuss how they changed their thinking but no one was required to share. The class was then divided into four groups, each tasked with writing a poster giving their thoughts on their assigned group of questions:

1. What does the controversy regarding Gardisil show us about the nature of scientific claims and their relevance to society? Do some scientific claims hold more weight than others in societal decisions? Do some other claims and forms of reasoning hold more weight in societal decisions?
2. There are proponents for mandatory Gardisil vaccinations who hold valid scientific arguments and reasoning, and there are opponents who also have valid scientific arguments and reasoning. Is a differing of scientific inferences and interpretations of data a strength of science or is it a weakness?
3. What makes a scientific claim different than a non-scientific claim? What are the necessary components of a scientific claim?
4. What are valid sources of scientific information? What is required for valid scientific knowledge to become produced? Does valid scientific knowledge come from a singular authority, with a set method?

Each group took turns explaining their thinking on each set of questions and the whole class was invited to weigh in. Ms. Franklin then closed the unit by posing two questions and having the students discuss: *How did you feel about this unit? What is the most important thing you learned?*

What is your top-line reaction to the instruction you see depicted in this vignette? What overall impressions does it leave?

Does this feel like a worthwhile thing to do? Why or why not?
Are there particular parts that seem especially good to you? If yes, which and why?
Are there parts that you would not do? Why?
How might you alter this for your own use? Why?

Can you think of other issues or topics that might be the basis for a similar unit in your class?

Would you anticipate getting pushback if you enacted this unit?

Do you feel prepared to perform the kind of instruction described here?

Do you see this as a good way to educate students in science to be better democratic citizens?

Can you think of other teaching colleagues at your school, from any discipline, that might be interested in collaborating with you to develop lessons like this?

What other thoughts do you have about this vignette that we haven't discussed yet today?

Appendix G

‘Ms. Franklin’s’ chemistry vignette, adapted from Zeidler and Kahn (2014) “Unit 7: ‘Pharma’s’ Market: Should prescription drugs be advertised directly to consumers?” with relevant interview 2 protocol items

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Please read and **annotate** the below vignette describing the development and enactment of a curriculum unit. I would like you to make marginal notes, either with your computer’s comment tool or by hand on a printout, about *anything* you find interesting or have a thought about. Again I give you the questions that will guide our next interview (after the unit text, on p. 6 of this document). You may type up some responses to them prior to that meeting, but if you do not have the time that is okay.

Ms. Franklin teaches chemistry at a large suburban public high school. She came across a news article that piqued her interest that explained how drug manufacturers spend more on advertising than they do on development. As she looked into the issue further, she started to see that there was significant overlap between the chemistry in her curriculum and some ethical dilemmas within the issue of regulating markets for prescription drugs. She decided to develop a unit where her students could learn to make sense of this complex moral, political, and scientific problem.

As she thought through her planning, she decided that several topics already in her traditional scope and sequence had bearing on the issue: solubility, polarity, synthesis reactions, molecular structure, and intermolecular forces. She enlisted her colleague who taught government and economics to help her name some of the concepts and ethical issues that may traditionally fall under that teacher’s purview: patient rights, freedom of speech, cost-benefit analysis in health care, government regulation, paternalism, and free market systems.

She began the unit by having students dig into statistics on the prevalence of prescription drug use by age group, and then to develop a census of their immediate and extended families in order to calculate a likely prevalence of pharmaceutical drug use within their families. She then led the class in an open and general discussion of what they knew or noticed about prescription drugs and how they notice them impacting their lives. If the conversation slowed or got off track, Ms. Franklin would ask what students thought of patent protections, the right to advertise, and drug costs. Her approach was to often play “devil’s advocate” with the aim of uncovering as many salient questions or problems as they could. Throughout the talk the class added topics or questions they felt they would need to explore under the broad question, “Should drug companies be able to advertise directly to consumers?” This “brainstorm” document remained posted throughout the unit and was sometimes amended or altered.

The next day the class started with labels from empty drug bottles and set out to determine their chemical makeup. Groups of 3-4 students each took several drug types and used the internet to create a profile for each drug. These included descriptive information such as chemical formula, an image of its structure, serving size (i.e., mass, volume), intended use, side effects, story of discovery, whether it has competitors, and any other interesting features the students thought noteworthy. At the end of the class the whole group shared themes or surprises they found in their research.

Then the students were tasked with identifying the molecular structures of some common drugs and articulating their action at target sites. They began by modeling the drug compounds with gumdrops and toothpicks (as they had done before). Ms. Franklin then used RasMol (https://www.umass.edu/microbio/rasmol/) to display animated computer models of chemical interactions. She then explained what hydrogen bonding, dipole-dipole interactions, dispersion forces, and electrostatic forces were and their significance within that context. Students then responded in writing to prompts about how drugs work:

- Most drugs are ingested. What do they need to successfully arrive at their target site?
    - How does solubility matter?
    - How does pH matter?
    - Do you think that all drugs are ingested in an active form or do they change once absorbed?
- Describe in a full paragraph how a drug interacts with its target. Take information from class discussion, textbook, and internet sources. Include citations.
- Explain why you agree or disagree with the following statement: "Covalent bonds are not formed between a drug and its target at the active site. Only intermolecular forces hold the drug to the target."

Student work on these questions was assessed for completeness and accuracy.

The following school day the class synthesized an unknown compound in the lab. Once they had made it they then referenced their drug profiles to determine that they had made aspirin. Then as homework students read an FDA article on how drugs are developed and approved. Part of this was a 1-2-page narrative of how salmon calcitonin was developed as a treatment for osteoporosis. The reading went through details about the clinical trial and New Drug Application processes. The students were responsible for the following questions:

- Do you think there is an appropriate amount of oversight? Why or why not?
- What would you still like to know about the process of drug approval?
- Do you feel that the medications that you and your family take are safe? Why or why not?

Over the next two days the students analyzed the case of Vioxx. Ms. Franklin first had the class establish a timeline for Vioxx's approval and then *removal* from the market using an NPR piece (https://www.npr.org/2007/11/10/5470430/timeline-the-rise-and-fall-of-vioxx). She then showed them a 2004 ad for Vioxx. The class discussed why a drug might be removed from the market. Students then, in groups of 2-3, analyze a prepared case study by Dan Johnson of Wake Forest University titled "Amanda's Absence: Should Vioxx Be Kept Off the Market?" (https://sciencecases.lib.buffalo.edu/files/vioxx.pdf). Students were assessed on their responses to guided analysis questions as well as their own final written recommendations on how they think the Vioxx case should be decided.

For the final lesson, Ms. Franklin had the students do a mock congressional subcommittee hearing, convened to answer whether they should write and advance a bill to ban prescription drug advertisements on TV. This culminating activity took three class periods—one day for research and two days for presenting arguments and deliberation. She assigned students to one of five roles:

- **pharma rep** (against ban – develop arguments about freedom of speech, research costs, consumer education, responsibility to investors, and so on)
- **drug consumer** (may be for or against – look into arguments about consumer choice, autonomy in one's health care, misleading ads, drug lawsuits, and so on)
- **American College of Physicians** (for ban – research arguments that drug ads are misleading, costly, and negatively impact doctor-patient relationships)
- **FDA Center for Drug Evaluation and Research** (neutral – investigate the accuracy of ads, impact on consumers, and ability of the FDA to adequately regulate ads)
- **Senate Subcommittee Member** (conduct background research on pro and con so they can ask pointed questions of the other groups)

Ms. Franklin showed a short video of a similar subcommittee meeting so students could get an idea of what they are to be doing. Students spent the bulk of the first day and continued work outside of class to research their arguments and develop their opening statements for the next day.

For the second and third days of the hearing Ms. Franklin imposed a structure of opening statements, questioning, breaking to organize rebuttals, and so on. Each presenting group had equal time to make their arguments to the committee. The hearing closed with each group giving a closing statement and then the senate subcommittee went into a short recess to make their final decision, which they then delivered, with their reasoning explicated, to the class. Ms. Franklin then told the students to step out of their assigned roles to have a debrief conversation about the whole unit. She posed several reflective questions to guide this closing discussion: *What were the strongest arguments? What compromises might have to be made to be fair to particular groups? Where did you notice conflicting evidence on the same claim? What have we learned over the course of this unit?*

The summative assessment for this unit was to write a reflection paper. Students were instructed to reference the opening "brainstorm" list and their experiences throughout the unit to address the objectives defined in the rubric below.

Reflection Scoring Rubric

1 pt.	2 pts.	3 pts.	4 pts.	5 pts.
Reflection fails to convey information on knowledge gained or reflect on student's understanding of the complexity of the controversy, or remaining questions.	Reflection includes some insights into student's understanding of the complexity of the controversy but fails to include any information on knowledge gained or questions remaining.	Reflection conveys information on knowledge gained, but fails to reflect on student's understanding of the complexity of the controversy.	Reflection conveys information on knowledge gained, insights into the complexity of the controversy and any remaining questions, but does so in an unclear or confused manner.	Reflection conveys information on knowledge gained, insights into the complexity of the controversy and any remaining questions in a clear and thoughtful manner.

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Are there parts that you would not do? Why?
How might you alter this for your own use? Why?

Can you think of other issues or topics that might be the basis for a similar unit in your class?

Would you anticipate getting pushback if you enacted this unit?

Do you feel prepared to perform the kind of instruction described here?

Do you see this as a good way to educate students in science to be better democratic citizens?

Can you think of other teaching colleagues at your school, from any discipline, that might be interested in collaborating with you to develop lessons like this?

What other thoughts do you have about this vignette that we haven't discussed yet today?