Investigating Student and Teacher Perspectives on Approaches Toward Student Epistemic 
Agency through a Socioscientific Issue in Secondary Science Classrooms

By

Sarah C. Boylen

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Committee Members:

Dr. Edward Lyon, Chair*

Dr. Aja LaDuke

Dr. Michael Suarez

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Sarah C. Boylen
Name
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ABSTRACT

Purpose of the Study: This research study hopes to address the negotiation of important aspects in teaching such as how to foster inquiry and literacy while adhering to standards, specifically the Next Generation Science Standards, and if those standards allow for student epistemic agency in secondary science classrooms. The future of science education lies in teachers instilling in their students the skills that will help them gain scientific literacy and student agency in the classroom, and beyond. For the purposes of this study, a framework was developed around scientific inquiry and literacy, while negotiating varying pedagogical approaches, along a theorized spectrum of increasing student agency. The framework is a tool to help educators visualize a variety of pedagogies as they relate to important characteristics of stages of inquiry that could offer increasing epistemic agency for their students. This research study intends to shed light on the perspectives and opinions of a selected group of high school life science teachers and some of their students in regards to these approaches to teaching a controversial, or Socioscientific Issue (SSI), in the science classroom. The student outcome goals that were considered were critical thinking, personal decision-making, ethical questioning, outreach and “social justice” as activism. The three classrooms include one Sheltered Learning biology class and one Advanced Placement biology, both at the same high school, and one Integrated 3-4 biology class in a neighboring County. Within and across the three different classrooms, how do participating teachers, and their students’ perceive, or view, (a) varying approaches toward using a controversial, or Socioscientific Issue (SSI), such as GMOs, in secondary science classroom, and (b) activities designed for the science classroom that have the end goals of outreach, social justice or activism, on or off campus? Finally, how does student preference compare to the proposed theoretical framework set forth in this study?

Procedure: This mixed-method study is a one-phase embedded design approach; where quantitative data is the secondary data that was collected while qualitative data was being audio recorded during teacher and student interviews. Four activity “scenarios” were designed, along with interview questionnaires, and used as tools and guides during teacher and student interviews. Three high school life science teachers and 13 of their students were interviewed to investigate their perspectives on using the four different activity scenarios which would explore the topic of genetically modified organisms (GMOs) as food. Quantitative and qualitative data were collected and analyzed.

Findings: Overall, two classes preferred Activity 1; critical thinking in the lab, whereas one classroom preferred Activities 3; outreach and 4; activism, although students had a variety of responses as to why. All three teachers and many students agreed that outreach and activism are
important. However, teachers believed that activities that stayed in the classroom were more feasible than activities that left the classroom. Teachers were fairly accurate when predicting their students preferred activity scenario. All the participants said that GMOs as food would be a good topic for learning science in the classroom. Teachers and students felt that activities that are controversial, or that might cause conflict in the classroom, are acceptable for learning at school. Those who were asked felt that conflict can be managed and usually does not leave the classroom. When the varying perspectives within classrooms were reflected on the spectrum, new ideas about what student epistemic agency and scientific literacy are emerged.

**Conclusions:** Student epistemic agency can be defined in many ways, including what the students want to do most. However, agency through varying teaching approaches and a variety of student outcome goals can bring different forms of agency to students while doing inquiry in the science classroom. Finally, students may come into the classroom with prior experiences that give them a different “position” when negotiating a controversial, or socioscientific, type issue. Implications for teaching practice involve balancing factors that are within our control, such as activity planning and pedagogical approach, with factors that are out of teachers control, such as the starting point of a student’s position when they enter the classroom for learning. This starting point position can have large impacts on a student’s perceptions, and willingness, to “like” activities. Finally, teachers play a large role in how learning can happen in the classroom, as well the school and society that they lie within.

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Thank you,

To the professors at Sonoma State University; particularly in education, philosophy and biology.
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Chapter I: Introduction

The type of science learning needed for the 21st century should go beyond simply memorizing scientific information and extend its reach toward exploring concepts around how science manifests itself in society. In other words, why science research is done, who is interpreting the data and what the consequences of those scientific results are. To extend this idea to science education, Fensham (2014), explains that “the outcome goal for school science needs to be science-informed citizens who know when to be s[k]eptical about science, and when to put their trust in science” (p.659). The big question is how can science educators assist their students in this type of engagement? The type of engagement that is on-going, stimulating and that can potentially lead to literacy, agency, and even civic engagement inside and outside of the classroom. One way this can occur is for students to participate in activities that go beyond traditional learning within the practice of science to also engage in activities that explain how that practice of science gets used in the world. In addition, allowing time and resources for classroom learning to involve investigating the consequences that scientific issues might have on individuals, groups, the environment or on society as a whole, could engage students in a way that is meaningful for them and their families. More importantly, introducing this type of activity engagement can help teachers help students gain crucial, critical skills - enabling them to make their voices heard and to be able to know where to start if they feel compelled to teach others or to suggest that some type of reform might be needed in a local policy, a broader law or even a social norm.

The ability to engage our students in this way may depend on how teachers deliver information to their students, including activities for learning and all the expectations that go
along with those activities. How teachers and educators deliver information to their students is often referred to as teaching style, or more formally, pedagogy. There are two ends to the pedagogy spectrum. At one end is Essentialism, often referred to as teacher-center, meaning the teacher decides what is learned and when it happens. At the other end of the spectrum lies Progressivism, and in teaching is seen as a theory of pedagogies that involve student-centered approaches toward learning that focus more on students being individuals with different types of learning styles and needs and that knowledge should be constructed by the many and not the few. To further this discussion, there is an ongoing debate between Essentialists and Progressives, specifically arguing which end of the spectrum is most conducive for learning. Essentialists typically adhere to the principle that there are certain skills that all students should learn and know before they are ready to move on to the next level. This claim is probably true to some degree, although Progressives would argue that if too much focus is on those traditional methods students will not develop other important strategies needed for succeeding in life, such as cooperation, empathy, and autonomy.

Progressive learning environments that are safe, student-centered, and flexible can encourage student engagement. Increased student engagement can promote something called student agency. Student agency is one way that students can gain autonomy in the classroom, at school and in their lives, giving them confidence when finding information that is valid and then using it to make important decisions. More specifically, student epistemic agency is the type of agency needed for students to fully realize their potential in the classroom, and in their lives beyond school - it’s the type of agency that is created by allowing students’ perspectives into the classroom and supporting them in having some say in what is being taught and learned at school. Student epistemic agency can be seen as a “construct that allows us to explore what it means for
students to participate in meaningful scientific knowledge construction” (Miller et al., 2018, p.4). So, what can educators do to construct student agency in the classroom, while keeping in mind that there are certain criteria that needs to be met - such as the suggestions and requirements within educational standards and time schedules.

First, schools and educators usually adopt some form of curriculum, such as lessons, activities, quizzes, etc… with the intentions of meeting certain standards set forth by their school, District or State. Educational standards have changed over time and today some science educators in K-12 have been presented with the Next Generation Science Standards (NGSS). NGSS describes their standards as providing an “in-depth understanding of content” for developing “key skills—communication, collaboration, inquiry, problem solving, and flexibility—that will serve them throughout their educational and professional lives” (nextgenscience.org). However, one question to raise is whether the NGSS allow the aforementioned progressive ideas toward promoting student epistemic agency into the classroom. Although the principles underlying NGSS intent to address issues of diversity and equity, it is quite possible that inquiry, as articulated in the NGSS, does not go beyond scientific investigation and may still leave students epistemologically naïve regarding how science actually works in the world and how it might impact society. However, I will argue that the NGSS do offer many opportunities for learning, although, often lack guidance on approaches toward teaching, which can then confine student learning to essentialist goals without meeting the standards’ full potential.

Second, when thinking about agency and the NGSS for secondary science classrooms, in terms of some of the broader topics, such as the physical earth, ecology, structure and function of DNA, etc., it is very helpful for students if teachers provide some sort of context for that
learning. And if that context applies to them and their lives it can bring in personal attachments to the act of wanting to learn. One way that educators can do this is by allowing their students to engage in activities and discussions regarding topics in science that may seem controversial, or that may spark debate in the classroom, such as global warming, nuclear energy, or genetically modified organisms (GMOs). Some experts in educational research argue that for a deeper form of inquiry, looking at issues that are controversial, that contain conflict, or have impacts on society and the environment can be useful to create the context for learning that brings meaning to students’ and teacher's lives. This type of discussion and activity has been called *Socioscientific Issues (SSI)* and is being investigated in many countries around the globe (Christenson, Chang-Rundgren & Zeidler, 2014; Ekborg, 2008; Albe, 2008; Kolsto, 2006). As explained by Virginie Albe (2007) “socio-scientific issues [SSI] has been proposed to democratize society” (p.67). SSI has been suggested by science educators and researchers as one method of enhancing scientific understanding in a way that is both educational and meaningful for the students involved by giving real life context, with the hopes that students will gain a deeper form of knowing about science, such as critical thinking, multiple perspectives, moral citizenship and civic engagement. *Civic engagement* can be many things, and for the purposes of this paper will be defined as outreach and social justice as activism.

This brings us to the third concept of teaching science; a term that kept precipitating up from the SSI literature known as *scientific literacy*. Discovery Magazine cites The National Science Education Standards (NSES), defining scientific literacy as the ability of students to be able to “describe, explain, and predict natural phenomena” and to understand science as it appears in the “popular press and to engage in social conversation about the validity of the conclusions” by being able to “pose and evaluate arguments based on evidence” with an overall
goal of helping students understand and use science for “personal decision making, participation in civic and cultural affairs, and economic productivity” (Kirshenbaum, S., 2009, p.1). There have been some shifts in thinking about scientific literacy, more importantly, there are different perspectives on what it means, although, the NSES definition is the one that is most referred to. Shaffer, Ferguson and Denaro (2019) cite the National Research Council (NRC) from 1996 and describe scientific literacy as the ability to “use evidence and data to evaluate the quality of science information and arguments put forth by scientists and in the media” (p.1). However, these definitions are just guidelines and do not come with prescriptions or instructions regarding pedagogies or classroom activities.

In the 21st century, science, particularly biology and biotechnologies, are more and more a part of our everyday lives. One such issue that I find personally important, that fulfills many of the recommendations within SSI, is genetically modified organisms (GMOs), specifically genetically modified food. More importantly, over the years CRISPR technology has become readily available for use all around the world. “Today, CRISPR Cas9, the most popular form of the powerful gene-editing technology, is widely used to accelerate experiments, grow pesticide-resistant crops, and design drugs to treat life-threatening genetic diseases…” (McDermott-Murphy, C., 2020, p.1). These processes within genetics may seem difficult to understand but it is possible to use these complex and sometimes controversial, or Socioscientific Issues (SSIs), to drive scientific inquiry in secondary classrooms, with an overall goal of promoting student agency, scientific literacy and civic engagement.

This paper specifically focuses on understanding what teachers and students think about using progressive, student-centered teaching approaches, within the context of genetically modified organisms (GMOs) as an SSI, to promote student epistemic agency and scientific
literacy while doing scientific inquiry in the classroom. The research began with synthesizing the literature, developing a theorized spectrum of progressive pedagogical approaches toward encouraging student agency and developing four activity “scenarios” for students. A variety of progressive, student-centered approaches in teaching were aligned with student outcomes that have the end goals of critical thinking, personal decision-making, ethical question, outreach, and social justice as activism. Through interviews with three life science teachers and 13 of their students, quantitative and qualitative data was collected to investigate their perspectives regarding the four activity scenarios. Students were asked about their likes and dislikes about the activities and about using SSI type activities, including GMOs, for learning at school. Teachers were asked about activity scenario feasibility for teachers, adherence to NGSS standards, difficulty for students, and their expectations regarding student preference. In addition, teachers and students were asked about using controversy, that may cause conflict, outreach, and social justice as activism for activities in high school science classrooms for learning. Data was catalogued and analyzed to determine trends and differences within and across the three different classrooms.
Chapter II: Literature Review

Chapter 2 will describe and explain, through scholarly literature, student epistemic agency and scientific literacy, as well as the Next Generation Science Standards (NGSS) and the importance of using controversial or Socioscientific Issues (SSI) for learning in the classroom. Furthermore, it will introduce a spectrum of five progressive teaching pedagogies: critical thinking, constructivism, existentialism, critical perspectives and social reconstruction, which theoretically, and respectively, increase the potential for student agency in the classroom.

Student Agency for Science Learning

One goal for science education is to help teachers help students acquire some form of student agency in the classroom. Giving agency to students can engage them and give them some ownership over their learning. In very general terms, “an agent is a being with the capacity to act, and ‘agency’ denotes the exercise or manifestation of this capacity” (plato.stanford.edu, 2015).

Epistemic agency, for this research study, is the “active process of choosing when, what, and where one learns and how one knows, as well as the capacity to create knowledge in a community” (Lai & Campbell, 2017, p.79). And, according to Sosa (2015) “…such agency is related to normativity, freedom, reasons, competence, and skepticism” (p.198). So, what compels someone to act, to take agency over something in their life? Typically, action is a product of wanting or needing something - something that we know or believe is important to us. According to Miller et al (2018), agency is tied to “free will coming out of a legal, ethical, moral and practical need to assign responsibility for actions” (p. 5). The next step is how we relate this type of agency to students in a classroom. According to Miller et al., (2019), student agency refers to “a student’s ability to shape and evaluate knowledge and knowledge building practices in the classroom” (p.5). Accordingly, there is strong emphasis on the teacher’s role to assist their
students in harnessing their ability to be knowledge builders and makers in the classroom (Miller et al., 2018). Finally, at the 2018 NARST Conference, Dr. Dana Zeidler also referred to the type of agency needed in the science classroom as epistemic agency.

**Using the Next Generation science Standard (NGSS) for Student Agency**

As of 2013, the National Science Education Standards (NSES) have been replaced by the (K-12) *Next Generation Science Standards* (NGSS) (nap.edu, 2020). More and more science teachers are now being presented with the Next Generation Science Standards (NGSS) for use in their classrooms. The NGSS website explains their intention as “standards that “give local educators the flexibility to design classroom learning experiences that stimulate students’ interests in science and prepares them for college, careers, and citizenship” (nextgenscience.org, 2020). Stroupe (2014) explains that “recent efforts, such as the Next Generation Science Standards, expand expectations for students to learn *science-as-practice*, meaning that students, in addition to learning concepts and methods, should become legitimate participants in the social, epistemic, and material dimensions of science” (p.488). Intended to be guides to help teachers help students master certain skills in science, these types of standards as “tools”, have the potential to constrain student epistemic agency in the classroom. Miller et al. (2018) reveals in a series of vignettes, documenting 7th grade students’ work on a local invasive species dilemma, that the students were capable of engaging in the issue and producing solutions. However, “despite their potential, the NGSS are not a silver bullet for transforming science classrooms.” Instead, NGSS come from a “long history of reform documents that have sought to shift instruction in ways that engage students in knowledge construction—to position them as doers of science, rather than receivers of facts” (p.4). However, Miller explains that using NGSS could create unresolved issues around agency (p.1) because of the concern that when teachers tightly
adhere to the NGSS standards they may try too hard to shape the information in a way that makes sense for the teacher and not necessarily for the student. One might argue that the ability of a student to fully understand scientific phenomenon lies in the amount of time the student is allowed to engage in it, and if the student is on a strict schedule for learning they do not have as much control over how they are learning.

If science education is truly for ALL students, then it could be problematic that the content within the NSES, as well most other science teaching guidelines, frameworks and standards, including NGSS, were developed by individuals making their own independent judgements based on what they believe “all students should know and be able to do” (NSES, 1996, p.15). Therein lies the problem - a group of few are deciding what and how all students should learn. Miller, et al (2018), describes a seventh grade class exploring lakes and a water flea and discusses “learning environments consistent with the NGSS” and that the exploration within those standards “reveals contradictions and unresolved issues around epistemic agency” (p.1-2).

However, in Miller’s example, the teacher chose not to open up a class discussion on the student’s personal feelings and perspectives regarding the real issue of the invasive species: the activities of humans, specifically their boats. The teacher decided to keep the conversation “objective” because of the concern that “students’ perceptions of the problem, each of which are potentially dramatically different—and even contradictory—depending on how their sub-communities interface with the problem” (p.14), could interfere with the activity as planned and cause conflict in the classroom.

Stroupe, Moon & Michaels (2019) also urge educators to consider that “students’ recognition and use of epistemic agency aim to disrupt a common occurrence in classrooms — the denial of knowledge production opportunities to certain individuals and communities, and the
silencing of their voices by marginalizing them from public discussion” (p.2). One way that teachers can “disrupt” the classroom in a positive and engaging way is to introduce topics within science that could be considered controversial, in that not everyone agrees with it. These topics, such as global warming, nuclear energy, “fracking”, or GMOs, can introduce ways to deal with disagreements within science and how to negotiate those types of conversations. Finally, using a controversial issue, or an issue that has not been resolved, can also inspire students to get involved beyond the classroom. These real-life issues take science and embed them in society.

As quoted by Mayer & Zebec (2014), Hasselmann (2011) states that “conflict is a social phenomenon that occurs in interpersonal relationships while embedded in the social sphere” and refers to this branch of understanding as “socio-scientific theory” (p.158).

**Socioscientific Issues (SSI): Theory & Practice**

Issues that are controversial, or that cause conflict, could also be considered real-life dilemmas that could promote “children’s development of social and moral judgement” (DeVries & Zan, 2012, p.183). There is strong support within some spheres of science education research that claims using conflict or controversy in the classroom, as context for teaching science, can aid in critical thinking, as well as increased student engagement. In the mid-1970s Dr. Dana Zeidler began developing ideas for science teachers that grew much attention in the science education community because it addressed the lack of ethical questioning and moral considerations within teaching standards for science, particularly regarding its relationship with society. Zeidler and Nichols (2009), claim that what’s “missing from most science classrooms are engaging activities that focus on contemporary social issues that require scientific knowledge for informed decision-making” (p.49). Over the decades, Zeidler’s methods and diagrams have become known as Socioscientific Issues, or SSI. To further the conversation on what something
like SSI is, Stewart (2009) explains that “socioscientific controversies might then be described as extended argumentative engagements over socially significant issues and comprising communicative events and practices in and from both scientific and nonscientific spheres” (p.125). In other words, students can expand on textbook and laboratory knowledge by learning about and engaging in science that is embedded in a real-life situation. Zeidler, et al. (2009), describes SSI as “…moral implications embedded in scientific contexts” (p.74). SSI uses topics within science that could be seen as controversial, or that still need to be solved, to engage students in critical thinking and critical theories, by assessing more than one side of an issue or by actively participating in thinking about solving problems.

Using a framework, such as SSI, can open up new discussions about important questions regarding, what some experts refer to as, The Nature of Science (NOS) (Zeidler, 2014, p.712), or the normative components of nature, science and the people who call themselves scientists. There are several controversies, or issues, that have been mentioned in the SSI literature, including global warming, genetically modified foods, nuclear energy, invasive species or even something happening in the local community, or on the school campus. The “issue” should be something that impacts the students directly or that will have impacts on them in their near future, or even something that students have heard about on social media. For instance, this type of inquiry might go beyond physical science and may look into verifying facts versus personal opinions, conflicts between sides, or impacts on society and/or the environment.

Using a Reflective Judgment Model (RJM), Zeidler et al, (2009), discovered that conflict and controversy can help students “reveal more sophisticated and nuanced epistemological stances toward higher stages of reflective judgment” (p.74). Many new ideas have arisen on how to best use this type of framework to discuss controversial issues in the science classroom.
(Kinslow et al, 2017; Zeidler, 2014; Fensham, 2013; Tomas, 2012; Taylor, Lee & Tal, 2006, Fountain, 1999). Taylor, Lee & Tal (2006), discuss the importance of participation in the process of using SSI in the science classroom, particularly that of collaboration and a final dissemination to someone or something outside of the school - something to the community. In this sense, using SSI as a framework for teaching science can also promote virtue, citizenship, and social action (Zeidler, 2014).

Overall, studies show that most teachers are willing to use controversial, or SSI, topics in their science classrooms but lack the knowledge on how best to accomplish that goal with their students. Ekborg’s study using 13 teachers showed that “teachers had not encountered the concept of SSI before, [but] they all had ideas about connecting school science to reality” (p.612). Ekborg (2013), completed an “in-depth” study in Sweden and concluded in the “contradictions and tensions” sections that “even though [teachers] felt competent in their work, three teachers expressed explicit need for support” (p. 609). Ekborg’s study looked more at the benefits that teachers and students might have received as a result of participating in a workshop geared toward using SSI instruction in the classroom. Once a teacher can decide to embrace controversial issues in the science classroom, and overcome the constraints they have been faced with, there are benefits for both teacher and students. “Thirteen teachers commented on benefits beyond the actual work…and a lasting interest in the content among the students.” (p.609).

In addition to strategies, some of the hurdles that teachers must get over before they can use a SSI in the classroom are their own personal beliefs about blending ethics and science. In addition, there is also something Zeidler (2014), refers to as “institutional obstructions (either real or perceived)” (p.701). Teacher beliefs about using Socioscientific Issues (SSI) or controversial scientific issues in the classroom also play a large role in how the issues get
interpreted in the classroom, or if they even get used, at all. For example, studies conducted on teacher beliefs around using controversial issues when teaching science show that most teachers are willing but need support. When asking how science teachers handled topics that involved ethical questioning and how that interplays with their own beliefs, Sadler et al. (2006) found five general profiles. (A) Teachers believe that it is important to ask ethical questions in science, and they do try to implement it in the classroom; (B) Teachers who believe ethics in science is important, but feel constrained by outside forces; (C) Teachers who were “non-committal”; (D) Teachers believe that science should be “value-free”; and (E) Teachers who believe every subject in school should involve ethics and controversy (p.361-2). In Sadler’s study, only one teacher fell into the category of believing that science and ethics should not be mixed in school. Overall, most of the teachers tried to avoid expression of their own opinions but believed there is value in using a framework such as SSI when teaching science in the classroom. The researchers in Sadler’s study state that “even among those high school science teachers who supported the idea of SSI curricula, most reported that they failed to incorporate them in their own classrooms because of constraints imposed upon them” (Sadler, et al, 2006, p.368).

If pedagogical approach plays an important part of teaching SSI in the classroom, then that gives the teacher a pivotal role in the students’ learning. When using a controversial issue or topic as a foundation for scientific inquiry in the classroom, Zeidler (2014), describes a framework for using SSI that includes evidence-based reasoning, moral concerns/ethical issues, character formation/conscience, scientific inquiry, and controversial issues (p.698). Taylor, Lee & Tal (2006) expand on this to include students being held responsible for producing assignments and materials that would be put out into the public, inviting some scrutiny about their work and allowing for new evaluations. Finally, the on-going project should be student-
driven and involve active learning rather than being transmitted through traditional pedagogical styles (Zeidler, 2014; Levinson, 2012; Zeidler & Sadler, 2009; Taylor, 2006; Fountain, 1999).

When asked if he had any comments about the need for using SSI today, Dr. Dana Zeidler responded,

The transparency of sharing information, the response of countries, the trust of the media, the confidence in governments, and the depth of character that individuals’ display have fundamentally shifted the ground under our feet... I have argued in past writings that having a broad functional conceptualization of scientific literacy necessarily means having an appreciation for the central sociocultural role that SSI plays in science education (Zeidler, 2014; Zeidler, Sadler & Herman, 2019) … the need for creative pedagogy that can foster the SSI framework has never been more critical than it is at this point in time, as the SSI framework is ensconced in a progressive tradition of education that fosters moral intelligence and social responsibility as part and parcel of the science education curriculum (Zeidler, 2019).

**Using Scientific Literacy to Inform Activity Development to Enhance Student Engagement**

When using an SSI to negotiate scientific inquiry in the classroom, with the intention of encouraging student epistemic agency, solutions to the problem in understanding what scientific literacy is, emerge. In a 1996 guiding framework science policy makers, curriculum developers and teacher practitioners created The National Science Education Standards (NSES), and they defined *scientific literacy* as “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (p.22). And that,

“SCIENCE IS FOR ALL STUDENTS. This principle is one of equity and excellence. Science in our schools must be for all students: All students, regardless of age, sex, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science, should have the opportunity to attain high levels of scientific literacy” (NSES. 1996, p.20)

They explain that Americans are increasingly confronted with “questions in their lives that require scientific information and scientific ways of thinking for informed decision making” and
“an understanding of science [that] offers personal fulfillment and excitement - benefits that should be shared by everyone.” (nap.edu).

Over the decades the definition of scientific literacy has not really expanded, although it has tried to include more diverse populations of science learners. *Benchmarks for Science Literacy* (2013), explains that explanations of what scientific literacy could be do not advocate “any particular teaching methods or curriculum design” and it additionally does not “spell out goals for advanced performance,, but that it “encourages greater curriculum diversity than is common today.”

Apparently, almost all definitions of scientific literacy start off broad and all encompassing, but often get reduced to simply the recommendations about the practice of science, leaving other important concerns such as, why science is practiced, who is doing that science, and what are the consequences of that on society. Moreover, how can teachers encourage their students to insert themselves in the dialog, the practice, and the consequences of science if they are merely handed a list of ingredients with no instructions. Stroupe, Moon & Michaels (2019) ask, “How can we as a community of teachers, researchers, and policymakers develop a useful consensus and shared language around “epistemic tools,” while also allowing for divergence—different perspectives, positionalities, contexts, cross-talk, and innovation?” (p.3).

**The Framework: A Spectrum of Progressive Pedagogies for Establishing Agency through Inquiry**

If teachers want to promote student epistemic agency, inquiry must go beyond experiments and data collection. So, *how* do we deliver this type of learning to our students? According to Zeidler (2014), one of the main goals of using SSI in the science classroom is to promote ethical questioning and moral decision-making while using progressive, student-
centered teaching approaches (p.698). Stroupe (2019) suggests “social aspects of classrooms also require new strategies, tools, and approaches, on the part of both students and teachers” (p.1). In addition to progressive pedagogies, the National Association for Research in Science Teaching (NARST) called for “Collective Activism” at their 2019 conference. However, promoting activism requires wanting (or demanding) political change.

Through the process of acknowledging what scientific inquiry is, and could be, and by connecting the literature in Socioscientific Issues (SSI) with various educational theories, a spectrum of learning began to emerge. For the purposes of this paper, five educational pedagogies will be explored: critical thinking, existentialism, constructivism, critical perspectives, and social reconstruction - all increasing the potential for study agency.

**Critical Thinking within Essentialism**

According to Burbules & Berk (1999), critical thinking is about “formal and informal logic” and to “supplant sloppy or distorted thinking”, whereas, the primary concerns of critical pedagogy “is with social injustice and how to transform inequitable, undemocratic, or oppressive institutions and social relations” (p.162). Critical thinking traditionally stems from deciphering out logical fallacies, but can also apply to other disciplines, as well. Critical thinking is an important component for learning, although it can have its limitations. Critical pedagogies, or critical perspectives, can help to push inquiry toward deeper questions that include perspectives from multiple sides.

**Critical Perspectives for Ethical Questioning**

Critical perspectives is a phrase that describes what the perspectives of other people are. Often, in teaching, it is referred to as critical pedagogies, which have roots in Paulo Freire. Critical pedagogy stems from Critical Theory of the Frankfurt School, which has it’s background
informed by Karl Marx (Kellner, 2017). For the purposes of this study, critical perspectives, is one way to view other people’s perspectives about a situation or about a controversial issue. Moreover, it can also help uncover the voiceless by investigating multiple aspects of the impacts and consequences that an issue, particularly in science, might have on some populations or on animals and the environment. Even though some groups have not been heard by those in control, and ecosystems can not speak with words, there are groups that speak for them and this information can be extremely valuable with negotiating multiple sides within a controversial issue and when asking questions about the impacts of a SSI that might have to do with ethics, that is the oughts and ought nots of the conflict.

**Existentialism & Constructivism for Personal Decision-Making**

Another progressive teaching strategy, existentialism, can also be used in the classroom to push inquiry into deeper levels of knowing and can, potentially, produce high levels of student agency. Malik & Akhter (2013) assert that “existentialism is concerned with the subjective [vs objective], or personal, aspects of existence” (p.87) and “an existential pedagogy promotes self-worth, and takes in to account individual learners rather than prescribed curriculum” (p.89). When using existentialism in the classroom the goal is to assist learners in developing their own values within their culture. However, once again, thoughts about “being” don’t require action.

Valuing independent thought along with critical perspectives regarding “Other” are crucial components of any inquiry into ethical questioning and informed decision-making. In addition, another very progressive theory, constructivism, according to Devries & Zan (2012), is often about “planning activities that promote children’s active reasoning… [and choosing] materials that are open-ended and can be engaged at more than one developmental level” (p.227). At its roots, is Piaget’s idea that to learn, children must experience “disequilibrium”.

Constructivists also “facilitate cooperation” (Devries & Zan 2012, p.228). Robottom (2012), sheds light when thinking about socioscience in the classroom, stating that “these issues involve human judgment and competing interests” (p.102) and “constructivist educational assumptions" recognize that “community constructions" of socioscientific issues are “shaped by human interests and social and environmental impacts" (p.95). So far, none of these approaches mentioned require taking any form of action. Even constructivism, which involves exploration and immersion into the curriculum - which is closer to action, still does not necessarily mean activism.

**Social Reconstruction for Outreach & Social Justice as Activism**

Kinslow et al. (2017), it is suggested that combining the practices of science with an SSI framework “supported secondary students in building robust understanding” and the activities included “social dimensions… to illustrate the complexity of the issue” and “…views of various stakeholders” (p.44), acquainting them with multiple perspectives. Since “socio-scientific issues are necessarily and irrevocably located within a community context” (Robottom, 2012, p.97), what can educators do to emphasize the socio part of socioscience? Collaboration is an effective way to stimulate cooperation and can present multiple perspectives of community constructions about science in the classroom, and beyond. In an essay about collaborative writing, Kennedy & Moore-Howard (2014), revisit what Rorty calls “socially justifying belief” and Brufee’s three principles about collaborative learning, particularly reminding us of his “social reconstructionist perspective” believing that “to learn, is to work collaboratively… among a community of knowledgeable peers” (p.37). Finally, Barton’s 1998 work on teaching science to homeless children is an excellent example of how scientific inquiry can lead to student agency and community action. However, Barton is not confined by a school or a classroom.
This pedagogical spectrum for student agency (Figure 1) connects several educational pedagogies that promote critical engagement and collaboration for student agency, potentially leading to outreach or even activism.

**Figure 1**

*A Spectrum of Pedagogies for Increasing Student Epistemic Agency*
Chapter III: Method

Research Questions and Design

This study is an investigation into what three high school life science teachers’ and 13 of their students’ perspectives are on various approaches to teaching and learning in regards to using a controversial, or Socioscientific Issue (SSI), such as genetically modified organisms (GMOs), as context for learning science at school. Furthermore, this research study introduces four different classroom activity scenarios with varying pedagogical approaches to teaching a controversial, or Socioscientific Issue (SSI), such as GMOs, in secondary high school science classrooms. Within and across the three different classrooms, how do participating teachers, and their students’ view, (a) varying approaches toward using a controversial, or Socioscientific Issue (SSI), such as GMOs, in secondary science classrooms, and (b) participating in activities designed for the science classroom that have the end of goals of outreach, social justice as activism, on or off campus?

This research study is mixed methods by design, using both quantitative and qualitative data from teacher and student interviews. It is a one-phase embedded design approach; where quantitative data is the secondary data that was collected while qualitative data was being audio recorded during teacher and student interviews. In other words, the quantitative data played a supplemental role within a qualitative method design. Mixing the quantitative and qualitative datasets provides a better understanding of the research paradigm “than if either dataset had been left alone” (Creswell & Plano Clark, 2007, p.7). For question part (a) the teacher responses about their views and perspectives about the varying approaches used in each activity scenarios regarded (1) feasibility of the activity for the teacher; (2) adherence to NGSS; (3) difficulty for student, and (4) predicted student preference, were compared qualitatively and quantitatively to
each other and to their students. Students were asked to explain their “likes” and “dislikes” about each activity scenario and order them by preference, which was qualitatively and quantitatively compared to each other and to the teachers predictions on the preference ordering of scenarios by their group of students. Finally, student preferences were also compared to the theorized student epistemic agency spectrum created for this research project and introduced in Chapter 2.

**Participants**

The participants for this research study include three high school life science teachers and a total of 13 high school life science students. This research study was conducted at the end of the 2018-2019 school year in two different neighboring counties in Northern California. According to the California Department of Education and Edsource, these two counties total about 1.7% of the student population in California. Overall, both counties are comparable to California as a whole, although, the two high schools that were selected for this study fall on the extreme ends of the demographics, especially in terms of white and Hispanic ethnicity, English Language Learners, and eligibility for free/reduced lunch (Table 1).
Table 1
State, County & High School Demographics

<table>
<thead>
<tr>
<th></th>
<th>Total Students</th>
<th>African American</th>
<th>Hispanic</th>
<th>White</th>
<th>Asian</th>
<th>other</th>
<th>English Language Learners</th>
<th>Free or Reduced Lunch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide</td>
<td>6,200,000</td>
<td>5.4%</td>
<td>54.6%</td>
<td>22.9%</td>
<td>9.3%</td>
<td>7.8%</td>
<td>19.3%</td>
<td>58%</td>
</tr>
<tr>
<td>County 1</td>
<td>69,800</td>
<td>1.6%</td>
<td>45.6%</td>
<td>42%</td>
<td>3.1%</td>
<td>7.7%</td>
<td>20%</td>
<td>47%</td>
</tr>
<tr>
<td>Ms. Megan &amp; Ms. Fiona</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>County 2</td>
<td>34,000</td>
<td>1.8%</td>
<td>30%</td>
<td>55%</td>
<td>5%</td>
<td>8.2%</td>
<td>15%</td>
<td>28%</td>
</tr>
<tr>
<td>Ms. Gina</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School 1</td>
<td>1040</td>
<td>1.3%</td>
<td>80%</td>
<td>8%</td>
<td>6%</td>
<td>4.7%</td>
<td>29%</td>
<td>61%</td>
</tr>
<tr>
<td>Ms. Megan &amp; Ms. Fiona’s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>High School 2</td>
<td>1600</td>
<td>3%</td>
<td>10%</td>
<td>70%</td>
<td>8%</td>
<td>9%</td>
<td>2.6%</td>
<td>9%</td>
</tr>
<tr>
<td>Ms. Gina’s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Note. Some slight approximations have been made to protect school identity

**Participant Recruitment**

**Teachers.** The teacher participants for this study were recruited by reaching out to contacts known to the Masters’ thesis committee chair, and who teach different levels and content of life science across a varying population demographic. All three teachers signed consent forms and were told they could stop the interview at any time. Since the content of the research questions in this study are most aligned with secondary life science education, only teachers who teach life science at the secondary school level were recruited. The differences between teacher participants that were to be expected were the life science subjects that they teach, their years of teaching experience, and school at which they teach.

**Students.** Students were recruited for this research study by being selected by their science teacher, who was also recruited to participate in this study. Groups of 4 or 5 pre-selected students,
from each of the three science teachers, were given consent forms to be signed by guardians. The students recruited for interviews ranged in age from 15 to 20 years old, and the criteria for participating in the study for students were good attendance and a passing grade in the science class. Good attendance and a passing grade in the class as criteria were chosen to help teachers narrow their selection down to students who would not be negatively impacted by missing some of class to complete their interview. Furthermore, these criteria help ensure that the student participants have a fairly good understanding of what they learned that year in their science class.

**Participants by Classroom**

**Classroom 1: Ms. Megan.** Ms. Megan is currently teaching a “Sheltered Learning” (SL) biology class in Northern California. The high school is public (non-charter) and has about 1000 students, 600 of which are on free/reduced lunch, with a 29% English Language Learner enrollment. Ms. Megan has been teaching science for 18 years, including biology and earth science. Five of her SL biology students were interviewed, and their ages ranged from 15 to 20 years old; including four seniors (12-th) and a sophomore (10-th) (Table 2). The students in Ms. Megan’s SL biology class speak their home and native language and are all English language learners.

**Table 2**

*Classroom 1: Students in Ms. Megan’s Class (n=5)*

<table>
<thead>
<tr>
<th>Class</th>
<th>Student</th>
<th>Grade Level</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheltered Learning</td>
<td>1</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>Ms. Megan</td>
<td>2</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>12</td>
<td>20</td>
</tr>
</tbody>
</table>
**Classroom 2: Ms. Fiona.** Ms. Fiona has been teaching for 25 years and is currently teaching Advanced Placement (AP) biology at the same school site as Ms. Megan’s SL biology class. Four students were selected to be interviewed from Ms. Fiona’s class and they are all juniors (11th grade), and either 16 or 17 years old (Table 3). AP biology is academically advanced and mostly prepares students to take the AP biology exam. Students in this class are both juniors and seniors, but seniors were unavailable due to preparations for graduation.

**Table 3**

*Classroom 2: Students in Ms. Fiona’s Class (n=4)*

<table>
<thead>
<tr>
<th>Class</th>
<th>Student</th>
<th>Grade Level</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Placement</td>
<td>1</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Ms. Fiona</td>
<td>2</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>11</td>
<td>16</td>
</tr>
</tbody>
</table>

**Classroom 3: Ms. Gina.** The third teacher is Ms. Gina, and she has been teaching an integrated science class for two years in a different high school in a neighboring county to Ms. Megan and Ms. Fiona’s high school. Ms. Gina’s high school is also public (non-charter) and has about 1600 students, with less than 3% English Language Learners and only 9% free or reduced lunch eligibility. Four of Ms. Gina’s students were interviewed and they are all 10th graders who are either 15 or 16 years old (Table 4). Integrated science is a combination class, focusing on both physical and life science “integrated” together.
Table 4

Students in Ms. Gina’s Class (n=4)

<table>
<thead>
<tr>
<th>Class</th>
<th>Student</th>
<th>Grade Level</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Science 3-4</td>
<td>1</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Ms. Gina</td>
<td>2</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Ms. Gina</td>
<td>3</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Ms. Gina</td>
<td>4</td>
<td>10</td>
<td>16</td>
</tr>
</tbody>
</table>

**Instruments**

The instruments used to collect data for this mixed method research project were two different ‘interview guides’; one for teachers and one for students. These interviews guides both included the same four classroom activity scenarios, which were developed for the purpose of this research project only.

**Classroom Activity Scenarios: Development and Structure**

At the onset of this study, six classroom activity scenarios were developed, all highlighting chosen points along the spectrum of student epistemic agency. All scenarios are intended to be on the topic of genetically modified organisms (GMOs), mostly focusing on GMOs as food. Individually, each scenario represents a different teaching approach, or pedagogy, rooted in a different, but complimentary, progressive educational theory. In theory, each scenario (and pedagogy) progresses down the spectrum of approaches for teaching, increasing the potential for students to gain epistemic agency through science learning in the classroom. For the purposes of time and simplification, only four scenarios were used (Appendices A-D), which were created through slight modifications and recombinations of the
original six - to represent four points along the spectrum; Scenario 1 (critical thinking), Scenario 2 (opinion forming), Scenario 3 (outreach) and Scenario 4 (activism).

**Activity Scenario 1.** Critical Thinking (Appendix A) is a series of activities that is intended to help promote student agency in the classroom by having them create their own experiment with a partner. It requires students to plan and conduct the experiment so that they can experience what it is like to *be* a scientist. The teaching and learning that happens with this activity is driven by essentialism and critical thinking. Essentialism in science specifically involves the scientific method, which is a form of positivism or reductionism. The *critical thinking* portion comes from the additional task of having students focus strictly on experimental design and data collection, particularly taking note of all the complications or “pitfalls” that occur. The experiment should go for at least a week, or more, and there should be something to measure that changes over time or across samples. The underlying idea is that it gives students an idea about understanding reliability and validity within, not only, experimental design and data collection, but also to be able to understand the results that are given by that data and design. What makes this activity slightly more progressive is that, in theory, student epistemic agency is increased by taking students into new ways of learning that they might not have experienced before from traditional assignments involving typical classroom experiments. The reason is because even though it has parameters and learning outcomes it does allow for some freedom for students to be creative and to learn from their mistakes without being penalized. Additionally, Activity 1 has some tasks for the teacher. Teachers are expected to be able to explain probability to the students in a way that helps them understand the statistical value of a particular attribute of experimental design, specifically sample size. In other words, when students have a small sample size, their results are statistically less significant. Ideally, the
endeavor could be linked to GMOs by extending the activity to include inviting a GMO scientist to the classroom to discuss their research design and data collection, while encouraging students to ask questions while reflecting back on their own experience with their experimentation process.

**Activity Scenario 2.** Personal Decision-Making, (Appendix B) was created to bring even more agency to students by combining ethical questioning and informed personal/moral decision making within the context of GMOs as food. In theory, the underlying progressive pedagogies that would drive this type of inquiry in the classroom are rooted in existentialism, constructivism and potentially critical perspectives. Students are asked to investigate and form a personal opinion about GMOs as food. The goal is for students to use internal reflections about who they are individually and who they are as a part of their family and culture - all in the context of taking a position on GMOs as food. The implicit intention of this scenario is for students to take scientific exploration one step further by taking a position on and making an opinion about a controversial or Socioscientific Issues (SSI), such as GMOs as food. In addition, the students must find sources and resources, both scientific and others, to support their opinion. Finally, students can creatively present their findings using almost any format as long as quotes and citations from mostly scientific sources are used. Although other forms of information can sparingly be used to support one’s opinion, such an essay or art.

**Activity Scenario 3.** Outreach (Appendix C) stretches further down the agency spectrum and theoretically introduces the potential for more student agency through requiring students to interact with the greater community outside of the school in a way that educates and informs them about GMOs as food. Ideally this is an unbiased endeavor and meant only to teach others in an interactive way, although student groups can choose varying aspects, or subtopics, within
GMOs as food, such as farms, environment, safety or labelling. Science outreach, will be defined as teaching others about science and is scientifically based in its initial planning and investigations and it requires students to learn about structure, function, process and mechanism, while also demanding additional skills needed to teach others about the outreach topic. Furthermore, interacting and describing information to others in the community may inspire students to take their work more seriously. This could add additional levels of engagement for the student, as it will be under the scrutiny of a larger and more diverse group of people, however, this type of project would take several weeks to plan and execute. This type of teaching and learning would require many teaching approaches and begins to enter social reconstructionism because it involves choosing and assessing a problem and educating others in the community about it.

**Activity Scenario 4.** Social Justice as Activism (Appendix D) is theorized to bring maximum agency to students while harnessing ideas that begin with critical perspectives and extend into social reconstructionism. The unique features of this activity include learning through large group collaborations, social justice, and activism - with an emphasis on planning and executing some sort of request for change. For this activity, not only do students need to understand what GMOs are, they need to understand what the impacts of GMOs are on society and the environment on either a local or global scale; emphasizing on fairness, safety, laws and policy. Since activism is more than outreach, it involves stepping out of the field of “science” and entering into other more philosophical realms such as history, sociology, policy and ethics. Moreover, activism implies wanting and even demanding change in policy and, ultimately, in regulation and law. Social justice has many definitions, but for this research project it will be defined as “the objective of creating a fair and equal society in which each individual matters,
their rights are recognized and protected, and decisions are made in ways that are fair and honest” (Oxford, 2020). Overall, for Activity 4, it doesn’t matter which “side” students want to take, as long as they put forth the effort to educate themselves, educate others, and decide on a method to take action to ask for change. Some examples given to in activity were writing letters to Congress, attending a Town Hall, contacting the EPA, organizing an event, protest, or march, on or off campus. Furthermore, students do not actually have to be successful in their social justice goals, they just need to be creative, come up with suggestions and execute a plan of action.

**Interview Guides: Development and Structure**

A student interview guide and a teacher interview guide were created by the author/lead investigator for the purposes of collecting both qualitative and quantitative data by the interviewers and to maintain some consistency across all interviews. The interview guides were reviewed and revised in consultation with the thesis committee chair. Both teacher and student interview guides were designed specifically for this study to meet the mixed methods approach and to answer the research questions displayed in Figure 2.
**Teacher Interview Guide.** The teacher interview guide was created and used to interview all three teachers, who were all interviewed by the author/lead investigator. The teacher interview guide included two general questions: number of years teaching and subjects taught. The guide also includes prompts for planned questions for teachers including scenario ordering for feasibility of scenarios for teacher, adherence to NGSS, difficulty for students, expected student preference, and using controversy in the science classroom. The interview guide also reminded the interviewer to have teachers order scenarios from most to least, for all four questions. Feasibility of the scenarios for the teacher was described as how easy or hard the scenario would be for the teacher to make happen in the classroom, and the scenarios would be ordered most feasible to least feasible. Adherence to Next Generation Science Standards (NGSS)
was described as how closely the scenarios lined up with expectations set forth in NGSS, and the scenarios would be ordered most closely adhering to NGSS to least. Difficulty level for the student was understood as how demanding or challenging the activities would be for the students to complete, and the scenarios would be ordered most difficult for the students to least difficult. Teacher expected student preference was also ordered most preferred to least preferred and was defined as which activity the students would most like to do as an activity in the science classroom. The teacher interview guides also included suggestions for additional open-ended questions for qualitative data collection. These open-ended questions included using controversial issues in the science classroom, using GMOs specifically as a context for learning science, and whether they think outreach and social justice should be used in science education. Controversial issues were described as issues that can create conflict, debate, or that cause individuals or groups to take a side on a given issue. Social justice in the science classroom was defined as having students take some form of political action and participate in activism involving science policies, regulations, and laws.

**Student Interview Guide.** The student interview guide was designed to help the interviewers collect data, both qualitative and quantitative, for all 13 students. Both interviewers used the same interview guide when collecting student data and data was either manually recorded on the student’s scenarios, or audio recorded for later transcription. Student interview guides included three general questions for students: grade level and age, type of science class taken and how much they like science. “Liking science” was explained to the students as how much they like science as a subject in school. Students were asked to rate it 0 to 5; where 0 is “hate it” and 5 is “it’s my favorite subject”. To collect qualitative data, the student interview guides also contained prompts for the three planned question domains for students; likes about
the scenarios, dislikes about the scenarios and opinions on using controversial topics in the classroom and at school. Students were told the same explanation about the term controversy as where the teachers. Lastly, the student interview guide included an open-ended question regarding their opinions on using GMOs as a topic for this type of discussion at school.

**Data Collection**

All the data for this research study were collected during interviews with teacher and student participants, which were audio recorded with their consent. All participants, both teachers and students, were told they could stop the interview at any time and they did not have to schedule another interview. Student interviews were 15 to 25 minutes long and teacher interviews were 45 to 60 minutes long. Before interviews began, signed consent forms were obtained from both adults and minors, including parent/guardian permission. Teachers and students were all given the same visual representations of all four scenarios.

**Teacher Data Collection**

All three teachers were given visual representations of the four scenarios. All three teachers were also given written explanations of what each classroom activity scenario would be like when doing them in the classroom. All three teachers opted to read the written explanations themselves rather than listen to the verbal description by the interviewer. Each scenario given to the teachers also contained a small data table to collect quantitative data, specifically the teachers’ responses for how long they have been teaching and what subjects they teach. Additionally, each scenario had a place to record the ordering of the scenarios for: feasibility of scenario for teacher, adherence of scenario to NGSS, difficulty of scenario for students and expected student preference of the scenarios. For the qualitative questions, teachers were asked additional probing questions on using controversial issues, or SSIs, in the science classroom for
learning, and about using GMOs, specifically, as a topic. Additionally, teachers were asked how they felt about having social justice as activism be a part of learning science at school. All teacher interviews were audio recorded for later data analysis.

**Student Data Collection**

Students were given the same visual interpretations of the scenarios, however, the interviewers read the verbal prompts aloud to the student instead of having them read it themselves. Data for student grade level and age, what science class they are taking and how much they like science as a subject in school were collected from student participants, either before or after the discussion and questions about the scenarios. Students were given one scenario at a time and then asked to explain what they liked and what they didn’t like about each one. Students were then asked to put the scenarios in order of preference, most to least, while discussing the reasons why. Towards the end of the interview, students were also asked probing questions about controversy in the classroom and GMOs as a topic. After the first five students from Ms. Megan’s class were interviewed, the author/lead investigator added additional probing questions for the remaining eight students in Ms. Fiona’s and Ms. Gina’s class. These eight students were asked additional questions about whether classroom debate over controversy ever left the classroom and what other controversial issues might be interesting to use as context for learning science at school. During the point in the interview were Activity #3 and #4 were discussed, these eight students were also asked if they thought outreach and social justice (as defined for this study) were things they would want to do in their science classroom for school.

**Data Analysis**

**Quantitative Data Analysis**
Teachers. Quantitative data for teachers includes number of years teaching, and the ordering of the four scenarios, from most to least, for the four parameters: feasibility for teacher, adherence to NGSS, difficulty for students, and expected student preference. All quantitative data for teachers was entered into a data table. Quantitative data for teachers was compared between each teacher and to their own students. Ordering of the scenarios was completed four different times by teachers, one for each of the four parameters: feasibility of scenario for teacher, adherence to NGSS, difficulty for students, and expected student preference. This data on ordering of scenarios by teachers were placed in a table and compared to each other to find major commonalities in teacher responses. A commonality was defined as all three teachers giving the same response about the ordering of the scenarios. The quantitative data on the order of teacher expected student preference was compared to the actual student preference order data for that teacher’s class, and agency scores were given.

Students. For students, quantitative data was collected which included age and grade level and how much they like science as a subject in school. The students also ordered the activity scenarios from most to least preferred. Quantitative data for students was recorded on the activity scenarios and then later compared with each other, with other classrooms and to their science teacher.

Qualitative Data Analysis

Qualitative data was collected through the entirety of the interviews and was audio recorded for later content analysis intended to answer the planned question domains described in Diagram 1. Then, descriptive coding was used to uncover emerging themes that were not directly asked during the interviews. Qualitative responses for the three teachers and the 13 students were organized into within-case and cross-case data display tables. Finally, patterns of student and
teacher responses toward varying approaches to teaching controversial, or SSIs, in the science classroom using GMOs as context and opinions on the use of social justice as science activism for school were observed. To increase validity, any qualitative response to a question that included confusion to which scenario was being discussed was disregarded.

Qualitative data from teacher interviews was extracted and organized through provisional coding to support the original planned question domains: feasibility, adherence to standards, difficulty for students, expected student preference, using controversial topics for learning science in school, GMOs as a topic, and social justice in science education. In addition, three themes from further probing during teacher interviews emerged. Qualitative responses from teachers, fitting the initial codes and the themes that emerged, were organized into data tables in terms of the various parameters within the research questions. Additionally, codes from further probing questions were added in relation to conflict leaving the classroom and other controversial issues, or SSIs, that would be good topics to use for discussion in science education. Finally, student qualitative responses on preference of scenarios and the use of social justice and outreach for science education were compared to quantitative data on agency scoring and student positioning on the agency spectrum.
Chapter IV: Findings

Within and across the three different classrooms, how do participating teachers, and their students perceive, or view, varying approaches toward using a Socioscientific Issue (SSI), such as GMOs, in secondary science classrooms?

Teacher Perspectives on Feasibility, Adherence to NGSS, and Difficulty for Students

Teachers were asked about the four activity “scenarios”, specifically about: (1) feasibility of each scenario for the teacher; (2) adherence to NGSS; (3) difficulty for students, and (4) expected student preference and the data on the ordering of the scenarios by all three teachers for three parameters: feasibility, adherence to NGSS, and difficulty for students is displayed in Table 5.

Table 5

Teacher Quantitative Data and Ordering of Activity Scenarios

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Years teaching</th>
<th>All Subject(s) Taught</th>
<th>Feasibility for Teacher (Most to least)</th>
<th>Adherence to NGSS (Most to least)</th>
<th>Difficulty for student (Most to least)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Megan</td>
<td>18</td>
<td>*Sheltered Biology/Earth Science</td>
<td>2, 1, 4, 3</td>
<td>1, 2, 3, 4</td>
<td>4, 3, 1, 2</td>
</tr>
<tr>
<td>Fiona</td>
<td>24+</td>
<td>*AP Biology/Physical Chemistry</td>
<td>1, 2, 3, 4</td>
<td>1, 2, 3, 4</td>
<td>4, 1, 3, 2</td>
</tr>
<tr>
<td>Gina</td>
<td>2</td>
<td>*Integrated Biology 3-4</td>
<td>1, 2, 4, 3</td>
<td>1, 4, 2, 3</td>
<td>3, 4, 1, 2</td>
</tr>
</tbody>
</table>

The commonalities among teacher responses are defined as all three teachers giving the same response. For this paper the terms teacher views, perspectives and beliefs are used
interchangeably and refer to the four planned questions for the three teachers. *Feasibility* was explained as how easy an activity scenario would be for the teacher to execute. The teachers ordered the scenarios from most feasible to least. *Adherence to NGSS* refers to how closely an activity scenario meets the standards set forth in the Next Generation Science Standards (NGSS), and teachers ordered the scenarios from most closely adhering to least adhering to the NGSS. *Difficulty for students* was rated by teachers as how difficult they believed each scenario would be for the students to execute. In short, the activity scenarios were described as, Activity 1: Critical Thinking while doing an experiment; Activity 2: Personal Decision-Making regarding GMOs as food; Activity 3: Outreach as Educating the community about an area of GMO food; and Activity 4: Social Justice as Activism regarding science policy and laws of GMO food. The quantitative data for all three teacher participant responses were analyzed for trends, patterns, and commonalities within and across the three different classrooms.

**Feasibility**

All three teachers did agree that Activities 1: Critically thinking while doing an experiment, and Activity 2: Personal decision-making about GMOs, were more feasible than Activities 3: Outreach, and 4: Social justice as activism. In other words, activities that stayed in the classroom were more feasible for the teacher than activities that could potentially interact with other people or leave the school grounds. For example, when teachers were asked about their students doing an experiment and graphing their data, three responses were, “We have access to excel”, “I do this one a lot” and “I have Chrome books that can go into the lab.” For Activity 2: Personal decision-making, one teacher thought that it was “fairly safe and prescriptive.”
When comparing Activities 1 and 2 with Activities 3 and 4, in terms of feasibility for the teacher, one type of response for Activity 3: Outreach was “bringing in community members is time consuming… to be able to do it in a meaningful way” and for Activity #4 being “least feasible”, mostly because of making their thinking public. For example, one teacher asked, “who would we be addressing this letter to? Where would they go?” and “I would want to know what the students are reading.” For Activity 4: Social Justice as Activism, one teacher explained that it “requires the most teacher preparations.” A common theme around feasibility of activities for teachers, something that was mentioned on more than one occasion, was the issue of time. For example, one’s teacher’s perception of Activity 4 was that it “could be a PBL” because they would “need lots of time.” Furthermore, when discussing feasibility for all the activities, one teacher said “time… how much time needed to really dive in and make it worth their while.”

Adherence to NGSS

Within the question regarding whether the activities adhered to the NGSS, all three teachers agreed that all the activities could fit the NGSS in some fashion, making statements such as, “they all do” and “all of them have students working collaboratively.” However, even though they felt that all four activities could qualify in some way, they all agreed that Activity 1: Critical Thinking, adhered most closely to the Next Generation Science Standards (NGSS). Activity 1 included critically thinking about science while partners do a tedious, and hopefully, lengthy experiment, including measuring and graphing some sort of change over time, followed by a presentation about the process, results and complications. For example, two teacher responses about the feasibility of Activity #1 were, “the scientific method and technology through presenting data is big in NGSS” and “being a scientist is most aligned.”
The second commonality within all three teachers regarding adherence to NGSS was that Activity 2: Personal Decision-Making, adhered to the NGSS standards more closely than Activity 3: Outreach. One teacher stated, when considering Activity #2 on Personal-Decision-Making, “making a claim and supporting it with evidence, technology through internet research big in NGSS.” Another said, “showing them a film, do some research, formulating an opinion, writing it, presenting - they do this in their classroom all the time”.

One important outlying comment about adherence to NGSS, regarding Activity 4: Social Justice as Activism, was from Ms. Gina, who teaches Integrated Biology 3-4 at a different high school than the other two teachers. Even though Ms. Gina believed that Activity 2: Personal decision-making about GMOs using scientific sources adhered closer to the NGSS than Activity 3: Outreach, she said that Activity 4: Social Justice as Activism was second after critical thinking because it contained “real world context, researching for and evaluating information, creation of an artifact” and that going “into science policy meets NGSS.”

**Difficulty for Students**

All three teachers agreed that Activity 4: Social Justice as Activism would be more difficult for students than either Activities 1: Critical Thinking, or 2: Personal Decision-Making. When the teachers were asked specifically about the difficulty level for students with Activity 4, which was described as having the end goal of social justice in science as some form of activism in the community, some responses were, “there are a lot of levels” and “identifying the people who they need to go to affect change - I have ended up with superficial products when involving activism”. Furthermore, they all felt that Activity 1: Critical Thinking would be more difficult for students than Activity 2: Personal Decision-Making, because all three teachers felt that Activity 2, making a personal decision about GMOs as a controversial issue would be the least difficult
for students to accomplish, saying it would “easy showing them a film, do some research, formulating opinion, writing it presenting… they do this in their classroom all the time” and that Activity 2 is “easy because the kids can just go to work without much support.” The reasons why Activity 1: Critical Thinking, which involved setting up an experiment and collecting, graphing and presenting data with a partner would be more difficult than the activity about personal decision-making were described as, “Designing an experiment, collecting data, and spreadsheets is difficult. Difficult for them to conduct a controlled experiment. Difficult to analyze data and see what is reliable.” and “Needs a lot of scaffolding and guidance” and “Might not really see the results to their work.” One response why Activity 2: Personal Decision-Making was perceived as easier for the students than setting up an experiment was explained as, “Easiest… Clear expectations”, but that any activity involving open internet searches, was that there needed to be guidelines set up first.” Overall, the main concern about Activity 3: Outreach was that the students lacked experience doing that type of activity.

Student Preference & Perspectives, as “Likes” and “Dislikes”, on Activity Scenarios

Student Preference: First Choice Activity Scenario by All 13 Students

Students were asked to qualitatively describe their “likes” and “dislikes” about all four of the activity scenarios and then to order the scenarios from most preferred to least preferred. Student preferences of activity scenarios were compared with each other and with teacher predictions and reflected on the theorized spectrum of increasing student epistemic agency. The findings suggest that, in relation to the original proposed spectrum theory in the framework of this study, student epistemic agency would rely heavily on the student “liking” an activity. In that light, one classroom (Integrative Biology) fit the spectrum’s theory of student epistemic
agency, while two (AP Biology and Sheltered Learning Biology) did not. However, that adds to the discussion on ideas about what student epistem agency is, and can be.

The most liked activity scenario by students is their first choice activity when given all four options. Overall, the most liked activity scenario, when using data from all 13 students, was Activity 1 (Figure 3). Out of the 13 students, six preferred Activity 1: critically thinking while doing an experiment. Four of the 13 students preferred Activity 2: personal decision-making about GMOs as a controversial issue as their first choice, making it second most preferred activity. One student preferred Activity 3: outreach; and two students preferred Activity 4: social justice as activism.

When discussing why they liked Activity 1: Critical Thinking while doing an experiment, they said, “we do this in our class; we like to learn about data and what our partner thinks.” Similarly, students liked aspects of measuring and working with a partner. For example, one student said, “planning the experiment and learning from your mistakes, fun to see outcomes when you are collecting the data” and that they like “the experiment and presenting to the class the information”. Another perspective from students about doing an experiment and collecting, graphing, and presenting the data was “I like how it's an example of what you would do in the real world.”

The responses about liking Activity 2, making a personal decision about GMOs as a controversial issue, while using scientific sources, were explained as “more open to look for more sides” and “I like that it’s open and you are required to have citations and quotes… in academia it’s necessary.” Another insightful response from one student about liking Activity 2 was, “I like how you explore the Internet by yourself” and in terms of the final presentation, they
said, “and that you get to have your own opinion...I like how there are many formats to choose from.”

**Figure 3**

*Most Liked Activity (First Choice) Scenario by All 13 Students*

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**Student Preference and Teacher Prediction: Ms. Megan’s Class**

Ms. Megan’s Sheltered Learning Biology class’ findings were similar to what the overall most liked activity was because they only chose Activities 1 and 2 (Figure 4). Three students chose Activity 1 and two students chose Activity 2. None of the students in the Sheltered Learning Biology class wanted to do outreach or social justice as activism as a first choice activity. Their reasons for preferring Activity 1: Critical Thinking, were from their personal experiences in the science classroom, where they negotiated understanding the challenges, but also enjoying parts of it, such as “it’s difficult to make graphs” but, “I like planning the experiment and finding the results” and “I like to measure and put numbers into the computer, I love math”.

When the student’s in Ms. Megan’s Sheltered Biology class discussed their reasons for liking Activity 2, personal decision-making about GMOs and using scientific sources, one stated
“I like to give an opinion and tell others about it… like creating a film. I would like a video of us explaining things, kind of like a movie”. Another perspective from this classroom about this type of learning was “I like the internet search and the movie. It is important to give an opinion… and the thinking. I like the essay to explain.” Furthermore, one student liked one of the end goals of the activity, which was “I like it, we can learn more about the food that we have.”

**Figure 4**

*Most Liked Activity by the Sheltered Learning Biology Students in Ms. Megan’s Class*

Ms. Megan predicted that her students would like the activities in their presented order: 1, 2, 3, 4, which was mostly accurate. Ms. Megan predicted that her students would like Activity 1, doing an experiment the best and that Activity 2, on personal decision-making would probably be second. When referencing her comments about the “likable” elements of activities 1 and 2, she said her students “like to be in the lab” and that they would also enjoy “opportunities to debate, to agree and disagree and having those kinds of conversations” and added that “forming an opinion is essential for them to connect contextually.”

Below, Table 6, shows the *preference order* of each student in Ms. Megan’s class and what Ms. Megan predicted her Sheltered Learning Biology students would like; from most to
least. One important note in these findings is that 3 out of the 5 students in Ms. Megan’s class preferred Activity 3: Outreach - which means even though it wasn’t their first choice, the idea of doing outreach had some appeal to the students.

**Table 6**

*Activity Preference by Sheltered Learning Biology Student & Ms. Megan’s Prediction*

<table>
<thead>
<tr>
<th>Student</th>
<th>Activity Preference Order (most to least)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2, 4, 1, 3</td>
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<tr>
<td>2</td>
<td>1, 3, 2, 4</td>
</tr>
<tr>
<td>3</td>
<td>1, 3, 2, 4</td>
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<tr>
<td>4</td>
<td>2, 3, 4, 1</td>
</tr>
<tr>
<td>5</td>
<td>1, 2, 4, 3</td>
</tr>
</tbody>
</table>

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**Ms. Megan’s Prediction**

1, 2, 3, 4

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**Student Preference & Teacher Prediction: Ms. Fiona’s Class**

There were four students interviewed in Ms. Fiona’s Advanced Placement (AP) Biology class and they all preferred Activities 1 and 2 (Figure 5). In addition, almost identical to Ms. Megan’s Sheltered Learning Class, none of these four students preferred Activities 3: Outreach or 4: Activism, as a first choice. Three of the students’ first choice was Activity 1: Critical Thinking with an experiment. One statement made by a student about likability for Activity 1 was “planning the experiment and collecting data as you go along... and it’s kind of what I
imagine science is like… noticing the differences as time goes on. Validity and reliability are really important.” Only one of the four students interviewed in the AP biology class preferred an activity other than Activity 1 as a first choice, and they chose Activity 2, on personal decision-making as their first choice because they “enjoy the artsy part about it.”

**Figure 5**

*Most Liked Activity by the AP Biology Students in Ms. Fiona’s Class*

When comparing the student’s first choice with what Ms. Fiona predicted there was a match because she predicted Activity 1 and three of her four students that were interviewed also liked that activity best (Table 7). Ms. Fiona said, “they really like to be in the lab.” However, she chose Activity 4, social justice as activism as second guess for what her students might like and none of the four students interviewed chose that activity as a first choice. She did say “I think they might like to do [Activity 4] the most… but they do really like to be in the lab.”
Table 7

Activity Preference by Advanced Placement Biology Students & Ms. Fiona’s Prediction

<table>
<thead>
<tr>
<th>Student</th>
<th>Activity Preference Order (most to least)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1, 3, 2, 4</td>
</tr>
<tr>
<td>7</td>
<td>2, 3, 4, 1</td>
</tr>
<tr>
<td>8</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>9</td>
<td>1, 3, 4, 2</td>
</tr>
</tbody>
</table>

| Ms. Fiona’s Prediction | 1, 4, 3, 2 |

Student Preference & Teacher Prediction: Ms. Gina’s Class

Figure 6 represents the most liked Activity Scenario by Ms. Gina’s Integrated 3-4 high school biology class. Two of the four students chose Activity 4, outreach as their first choice, while the other two students chose Activities 2 and 3 as their first choice. None of the students in Ms. Gina’s class chose Activity 1, critical thinking while doing an experiment, as their first choice activity. One of the student’s reasoning around Activity 1 was, “I like how it's an example of what you would do in the real world” but, “you would mainly learn about the scientific method and you might not learn that much about the topic GMO….It could make people tired of science. Another student also made the conclusion that they “like being able to do hands on research”, but that they “don’t like having to write a report.” The four students from the Integrated 3-4 Biology classroom, which is a different high school than the other two classrooms,
preferred Activities 2, 3 and 4, and not 1 as their first choice. Two students liked Activity 4: Social Justice as Activism as an activity for school and the other two picked Activities 2 and 3 as their first choice. When one student was describing why they liked Activity 4, they said “I really like the social justice… in order to have change… all the perspectives… come to a midway and collab. Then bring in the Town Hall and say this is what these people want.”

Figure 6

_Most Liked Activity by the Integrated 3-4 Biology students in Ms. Gina’s Class_

The four students that were interviewed in Ms. Gina’s Integrated 3-4 did not prefer Activity 1: Critical Thinking as a first choice. When Ms. Gina was asked during her interview what she thought her students would prefer most, she picked Activity 2: Personal Decision-Making - which was open and had the most freedom to explore (Table 8). Ms. Gina predicted that Activity 4: Activism might be a second preference option by her students, saying “they get really into the social justice piece and they like controversy.”
### Table 8

**Activity Preference by Integrated 3-4 Student & Ms. Gina’s Prediction**

<table>
<thead>
<tr>
<th>Student</th>
<th>Activity Preference Order (most to least)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>3, 4, 2, 1</td>
</tr>
<tr>
<td>11</td>
<td>4, 3, 2, 1</td>
</tr>
<tr>
<td>12</td>
<td>4, 1, 3, 2</td>
</tr>
<tr>
<td>13</td>
<td>2, 3, 1, 4</td>
</tr>
</tbody>
</table>

**Ms. Gina’s Prediction**

2, 4, 1, 3

---

**Students’ Least Preferred Activity and Agency “Scoring”**

The theory behind the framework of the spectrum for promoting student epistemic agency is that Activity 1 would provide less agency than Activity 2, and so on. Meaning that if a student has an activity scenario preference order of 1, 2, 3, 4 they have preferred to do the opposite of what the spectrum suggests, in terms of helping students attain agency. In other words, if student epistemic agency is defined as a student’s capacity to make informed decisions about science, know who to trust, and where to go if they desire suggesting reform, then keeping them in the classroom doing experiments and Internet searches could be considered lower agency activities. In contrast, the activities with end goals of ethical questioning, outreach or social justice and activism, could have the potential to give students more agency by providing them with opportunities see other perspectives and to go into the community (physically or
virtually) to see and hear what science research is for in the real world and who might be benefiting from that science research. Overall, when looking at all 13 students, the least preferred activity was Activity 4: Social Justice as Activism (Figure 7).

However, when looking back between the classrooms, the Sheltered Learning and AP Biology classes both chose the activities that did not involve leaving the classroom environment. Whereas, Ms. Gina’s Integrated 3-4 class did prefer activities 3 and 4, which both had end goals of interacting with people outside of the classroom and the school. In fact, none of the four students in Ms. Gina’s Integrated 3-4 class chose Activity 1: Critical Thinking while doing an experiment, as their first choice.

**Figure 7**

*Least Liked Activity Scenario by All 13 Students*

![Graph showing the least preferred activity by students.]

**Perspectives on GMOs, Controversy, Outreach and Social Justice as Activism**

What are teacher and student perspectives, or views, about (b) activities designed for the science classroom that may be controversial, or that have the end goal of outreach or social justice as activism? All participants were asked about using GMOs as a topic for learning about science in the classroom, and all three teachers and 8 of the 13 students were asked more
specifically about using outreach, social justice and activism as activities for learning science at school. **Teacher Perspectives on Controversy/Conflict and GMOs as Food for a Topic**

All three teachers agreed that controversy in the science classroom is important. Ms. Gina said, “yes!”, Ms. Fiona said, “yes, it’s important. It’s a hook and gets the students interested”, and Ms. Megan claimed it was “absolutely important. It’s essential. It lights the kids up.” When asked if they were worried about conflict leaving the science classroom all three teachers felt it did not. Ms. Fiona stated, “no, because the conflict is more intellectual”, Ms. Megan said “we’re not bringing in conflict, we are bringing in debate and discussions - that are rich and have multiple perspectives. And the ground rules for that need to be set up at the beginning.” Furthermore, Ms. Gina said that conflict, from controversial issues that are being discussed at school, “can live within the walls of the classroom.”

When teachers were asked specifically about using the topic of genetically modified organisms (GMOs) as food, all three teachers agreed that using GMOs as a controversial topic would be acceptable and useful for scientific inquiry in the classroom. Ms. Fiona simply said, “yes!” Ms. Gina stated, “yes, GMOs spark a lot of conversation and there is a lot of misconception” and it's a “big topic… a lot of different aspects.” Ms. Megan said, “yes” her Sheltered Learning Students would benefit from GMOs as a topic, but that her students ‘would be more dialed into other topics… poverty or asthma for Low SEL… who lives where and who has what” and that even just the act of “digging into data can be controversial.” Even though all three teachers thought using GMOs as a topic would be important, two teachers brought up a concern about the complexity of the topic saying, “understanding the benefits and risks of the science behind GMOs is very sophisticated” and “a lot that they have to grasp to truly evaluate the impact of GMOs.”


**Student Perspectives on Controversy/Conflict and GMOs as Food as a Topic**

When all 13 students were individually asked about using a topic in the classroom that might end up being controversial, or that might cause some conflict and debate, 12 students understood the question and agreed that using a controversial issue in the science classroom for learning would be acceptable, or “OK”.

Overall, the students had many reasons why controversial issues in the science classroom for inquiry and activity were “important”, “essential” and “useful”. For instance, one student said “yes, because maybe in the future we will have this opportunity to decide if you want to do it, or not.” Another reason was “I think we should definitely do it…having that discussion brings awareness”. Two other students claimed that controversy in the classroom can “make students more engaged and maybe even enjoy the process more” and “it’s useful to learn from different perspectives because it helps us learn new things.” A fourth student answered “I think it would be amazing. It would represent what each student believes are right and wrong… and these are the reasons why. It would be very educational at the same time.” When asked specifically about controversy in the science classroom, one of the students from the Sheltered Learning class said, “I really like science and I want to be a doctor. DNA is important” and another student from Ms. Gina’s Integrated 3-4 class said, “once in a while is ok” but, “not all the time.”

Additionally, some of the students were either asked about using GMOs as a topic, or they commented on it specifically while discussing their “likes” about the activities, in general. A few of their responses were that the topic is “important because GMOs can make better food” and that “GMOs would be mostly neutral, more personal and not religious. Religion could be an issue for some people”. Furthermore, students had perspectives such as, “I like it. I’m the kind of person that likes the natural things…modifying the food could damage people’s bodies”
and “learning if the GMO is healthy… there might be consequences for the people.” When thinking about presenting an issue like GMOs as food as an outreach project to the community, one student perceived that they “wouldn’t know how to make GMO research entertaining to people.”

Finally, five of the 13 students were asked if this type of controversial discussion ever turned into conflict that left the classroom, and they all said either no, or if it did it was not necessarily negative. For example, three students said “no, not really” and one student said, “sometimes it has, but it doesn’t cause issues… not arguing.” One student said “outside of the classroom, I might tell someone what I think. And then, I know what that person thinks.”

**Teacher Perspectives on Outreach and Social Justice as Activism**

When analyzing the teacher's qualitative statements given during individual interviews, their responses about using Activity 3: Outreach, were similar to each other. Activity 3 was explained to the teachers as having many levels: involving learning about GMOs as food in the classroom through teacher prepared lessons and internet searches, picking a subtopic within GMOs as food; such as safety, labeling, impacts on the environment or farmers, etc., and then finally developing an interactive table to educate others, preferably community members. The comments about this activity were that it would be “difficult to go off campus to present to the community”, “bringing in community members is time consuming… to be able to do it in a meaningful way” and that the students might “like the outreach part”, but that it would be difficult for students because they might “not really think about the preparation pieces.” Another comment by one teacher was that students would “need more opportunities to practice.” Finally, the most notable claim that was made about any activity was regarding Activity 3, saying that “this could be terrifying and hard for them.”
When the three teachers were asked about doing “social justice” in the science classroom, in the form of activism in the community - with the intention of getting the students involved in learning how reforms are made, teachers had similar perspectives. Just like in the outreach activity, teachers were concerned about making connections for this kind of endeavor. For example, one said “who would we be addressing this letter to and where would they go?” Another teacher made the point that the activism activity “requires the most teacher preparations” and asked how they would “identify the people who they need to go to affect change. I have ended up with superficial products when involving activism.” Another teacher’s view was that if students, “get too fatigued… it could push them away from change.” Finally, one teacher perspective about Activity 4 was, “anything out of the school day would be difficult for me” and it “depends on if I can actually support the students…if they can find valid sources. I would want to support them if they found really good things to read… but I want them to really question what they are reading.”

Students Perspectives on Outreach, Social Justice and Activism

Outreach for Science Learning. When analyzing the views and perspectives of the students regarding their “likes” and “dislikes” about Activity 3: Outreach, or outreach in general, there was a trend within the classrooms, although overall, all the students had something positive to say about it. In Ms. Megan’s Sheltered Learning Biology class, which has majority English as second language learners, four of the five directly expressed concerns about communicating and talking to others, explaining that idea of the “presenting to the community” was important, but that they “worry because I won’t understand all of the people.” In addition, one student said “This is a good idea to explain to others about this theme. Others might not know. It’s a fun
way” but, “I prefer to not talk to other people, just the class.” The fifth student had the opinion, “I would need a lot of information to be able to present to the community.”

In Ms. Fiona’s Advanced Placement (AP) Biology class, the students were also open to the idea of doing outreach in the community for a school assignment, but they expressed concerns about specific details within the activity scenario on outreach. One student said, “I like creating a master reference list. Small groups makes sense” but, “school events kind of get ignored, especially scientific ones.” When thinking about this activity another student said that they “need guidance from the teacher on where to go if we leave the school. Without help, I wouldn’t know where to start.” A third student from the Advanced Placement Biology class simply said, “I don’t like talking to people.” Another AP student explained what they liked about Activity 3 and said “it’s good for any community to acknowledge what is in their food or what is provided around their community” and another said, “I really like the community outreach. I really like getting involved with the community” and that they like the “open Internet search to have your own sources and I think the interactive table will really help discuss the result. The school should have a list of where we should go in the community”

In Ms. Gina’s Integrated 3-4 Biology class the students also had positive things to say about doing outreach, such as “getting to see other people’s presentations is part of the reflection process” and “I like communications and to be able to be aware of what educates people… raising the knowledge can be very powerful.” When discussing “likes” about the activities within Activity 3, one student in Ms. Gina’s class said, “I like that you’re allowed to do you your own research and combine it with what the teacher gives you… to the community is really nice because they might not know what affects some things have and what we are doing in school. I would like to have freedom to decide who and where we show.”
Overall, most of the students felt some version of the statement, “I like the outreach… getting other people’s opinions.

**Social Justice as Activism in Science Education.** Two classrooms, Ms. Gina’s Integrated 3-4 class and Ms. Fiona’s AP Biology class, were asked questions specifically about using social justice and activism as activities for learning science at school. Seven of the eight students agreed that this type of activity would be good for learning at school, and that they would like it. A few of the statements from the four AP Biology students regarding this type of activity for school were “it’s necessary to mix politics with science” and “you are really getting your word out - it could help change things.” Another student in Ms. Fiona’s AP class said “yes, because there might be political issues that are conflicting with the science.”

To support these perspectives, three of the four students in Ms. Gina’s class also viewed social justice in school as an acceptable activity saying, “I really like the social justice… in order to have change” and another Integrated 3-4 student said, “I like that we would get to do social justice… It's horrible to know that humans are destroying other creature’s homes. Sometimes we have to put our foot down about some things.” Ms. Gina’s Integrated 3-4 Biology class was the class that preferred activities 4, using social justice as activism and 3, outreach, respectively, as a first choice. However, one student in this class, when asked about using social justice, as described in Activity 4, for learning in the science classroom, said it would not be that great of an idea for a science class because they “learn how to do that in other classes.”

Finally, even though they were not asked directly, the five students in Ms. Megan’s Sheltered Learning class did give some responses regarding Activity 4: Social Justice as Activism when they were asked about “likes” and “dislikes” about it. For example, one student said “I like to organize an event. Collaboration is important” and another student in Ms. Megan’s
class said, “I like the part about communicating with others and collaborations, but “difficult to change their decisions.” A third student’s perspective, from the Sheltered Learning Biology class, on using social justice as activism for science learning at school was “it’s hard to understand” but, “it’s important for everyone to be equal under the law.”
Chapter V: Conclusions

Perspectives on Approaches: Seeing Different Forms of Student Epistemic Agency

The participants in this study were asked about their perspectives and views about the four activity “scenarios”, which all were organized to encompass different approaches along the theorized spectrum of student epistemic agency. Where, in theory, certain pedagogical approaches, that align with specific student outcome goals, have the potential to offer broader avenues of student agency while doing scientific inquiry in the classroom, and potentially beyond. The teachers were asked about their perspectives on the varying approaches within each activity, which were based on feasibility for teacher, adherence to standards, difficulty for students and student preference. The students were asked about their “likes” and “dislikes” because it gave perspectives on what kind of activities the students want to do. For the theory of epistemic agency put forth for the spectrum in this study, it is very important to understand what the student prefers to do. The reasons why a student wants, or prefers, certain activities over others is very important for activity development, however, in theory, unless those reasons are purely to escape the endeavor, their preferences should be considered as one way teachers can create a more authentic participation for students in an activity without worries that it is merely a form of manipulation by the students. For example, if a student prefers to work in groups because they like that social aspect, then a teacher can use that as one way to encourage students to keep on track so that they continue to have both social and academic experiences in the classroom. Afterall, creating knowledge should be done by the many and not the few.

It’s also important at this time to revisit the assumptions that teachers and students were working under while being asked questions during their interviews. When interviewed, the participants in this study did not see the spectrum shown in Figure 1, nor were they told about
the names of teaching pedagogies listed along the spectrum. However, they were all giving their statements with the understanding that each activity scenario had certain outcome goals such as doing an experiment, forming an opinion, outreach and “social justice”, using the topic of GMOs as food. There were a few limitations in this study. For example, there was probably a slightly different interview style by the two different people conducting the interviews with the students. This could have potentially led to a difference in the amount of qualitative data being obtained during the interviews with the students in Classroom 1, Ms. Megan’s Sheltered Learning Biology class. However, they could have also been due to potential language barriers in the Sheltered Learning class, therefore causing less probing and fewer questions. Overall, having only a few teachers to interview did limit the scope of teacher perspectives, but it allowed for deeper probing during each interview with individual teachers. Despite these limitations, we can still place trust in the study.

The outward trend to the right along the spectrum suggests different progressive teaching pedagogies that line up with specific outcome goals for the students. In theory, each learning outcome (critical thinking, decision-making and ethical questioning, outreach, activism) moves outward along the spectrum for a broader understanding of science, what science is used for in the real world, and what the consequences of those uses are on different entities involved. Furthermore there is intention at the end of the spectrum to give students tools on how to interact with their community in productive ways if they feel compelled to tell others, or even suggest that some change or reform is needed within a controversial issue in science that impacts their lives. The similarities in all the student responses assisted in understanding the most liked and least like activities by all the students, however their varying responses about different aspects within the activities suggests that the spectrum of teaching pedagogies, or approaches, for
student learning outcomes also can be one way to see different forms that student epistemic agency can take in the classroom while learning science at school.

**Critical Thinking in Science Education**

Activity “scenario” 1, focused on critical thinking and was about the scientific method and being a scientist. In alignment with Burbules and Berk (1999), critical thinking is different from critical theory, in that the former is about logic of facts (data) and the later is about the perspectives of others who are impacted by those facts (data). Activity 1 intentionally did not include any moral decision making or ethical questioning. The personal choices that the student and their partner made were purely about how to set up their data collection as assigned, and how to graph that data in some way that is explainable to the rest of the class. The “critical thinking” aspect was about the possible difficulties in experimental design, data collection over time, and how to interpret and display that data. The critical thinking, for this activity, was regarding validity and reliability within data and results through the tedious process of making mistakes and learning from those mistakes.

In terms of teacher perspectives, why was Activity 1 seen as most feasible and most closely aligned with NGSS? Perspectives reveal that this is due to expectations within the standards, by the teacher and from the school site. Why did the students in the Advanced Placement (AP) Biology and the Sheltered Learning class prefer this activity? The responses varied, and some of it was because it was something, they were already comfortable with. The AP biology class had the added factor that Activity 1 was most closely aligned with what they already needed to accomplish in the class. The reasons behind why the Sheltered Learning Biology class chose Activity 1, on doing an experiment in the classroom and lab, were slightly more complicated, and nuances regarding a student's positioning when they come to class for
learning rose. Finally, in theory, as tasks within Activity 1, move down the spectrum to give more freedom to the students in creating their experiment’s design and to be able to make mistakes, it begins to become more closely aligned with a “constructivist” approach toward teaching.

**Existentialism and Constructivism for Science Informed Decision-Making**

The progressive theories of existentialist philosophers and cognitive psychologist Piaget have, over time, developed into teaching approaches, or pedagogies for teachers, to explore and to use in their classrooms to encourage a more authentic participation for students. These forms of understanding, that involve explorations into the self through open-ended and hands-on activities, can engage student learning - particularly when personal decision-making is involved. Using a real-life situation, or an issue in science that may be seen as controversial, can inspire students to investigate. Furthermore, asking students to make a decision, or take a science informed position, on that controversial issue can enhance their desire to find out information. In relation to the findings of this study, all the 16 participants (3 teachers; 13 students), except one student who misunderstood the question, independently agreed that it would be productive and important in some way to use an issue such as GMOs for learning in the science classroom. The consensus among all three teachers showed very strong support for using a controversial, or Socioscientific Issue (SSI), which is consistent with Sadler’s study on teacher perspectives, (Sadler et al, 2006). In addition, the consensus among the three teachers also showed that the topic would still be acceptable even if the issue became controversial, causing some debate or conflict in the classroom. All the participants that responded about the controversy said it was important, manageable and that the debate enhanced student engagement, by sparking their interest. Using controversial issues, such as SSI’s, can enhance student knowledge and increase
awareness through learning about “possible institutional interests, different signs of competence… an appreciation of concurrent expert views… and methodological norms in science” and “an appreciation of evidence and disclosure of sources” (Kolstø, et al, 2006,p. 633).

Furthermore, the positive student perspectives on conflict that may arise from using a controversial issue, such as GMOs, in the classroom supports the idea that controversy can be managed in high school classrooms, and many said it is also important. This is consistent with DeVries & Zans (2012), who claim using real-life dilemmas gives beneficial context for constructivist approaches toward learning. Overall, investigating sources in a creative way can help students make scientifically informed personal decisions about issues that might be seen as controversial - which can be seen as another form of student epistemic agency in the classroom. These approaches help students learn how to learn in a way that is academically acceptable, but also acceptable for their own personal way of knowing.

**Critical Perspectives & Social Reconstruction for Science Outreach Education & Activism for Learning**

There is something to be said about the findings regarding the participants' perspectives when asked about outreach and social justice as activism as assignments for science class. Everyone who was asked about outreach agreed that using it as a way to learn about GMOs as food would be acceptable for learning science at school. Outreach, as defined in this study, is the act of educating others about a specific topic, usually to raise some form of awareness. Usually science outreach tries to remain educational and avoids getting political, to encourage as many people as possible, including children, to participate in their learning experience. However, outreach is one way to encourage reform by informing others about something important going on in the science research community. Educational science outreach can show others how a scientific process works and what its role is in the lives of humans and other organisms. For
example, students could create an interactive and educational “table” that explains what genetic modification is, why we do it to food, and then branch off into labeling, pollen or safety - depending on what interests the students. They can work together to learn and to teach; giving the information to other people so that they too can begin to make informed personal decisions about science that impacts their lives.

Deciding to adhere to science education outreach as an activity for science students is one way to avoid getting political. In Activity 3: outreach, the students are required to pick a subtopic within GMOs as food to explore deeper, but they are not required to ask or convince others for changes, or reforms. The goal of outreach is to educate others, although, in the process of choosing a subtopic and exploring it more closely the students become exposed to other factors that are driving the division of those subtopics. For outreach, the investigation could end with just explaining to and informing others about labeling, such as genetic enhancement is not considered a food “additive”, and then the individual learners decide for themselves how they feel. Basically, the educational outreach creates awareness, with no direct intention of following through with activism, or suggesting, or even demanding, change in laws and policies. However, if a group chooses labeling as a subtopic within GMOs as food, they may discover underlying details that get them to ask questions about why an altered gene is not considered an additive, and what the laws and policies are that guided that decision.

If it decided that students take outreach to that political level, using critical perspectives, which is a derivation of critical theory, emphasizes “the importance of critique, reflexivity, and gaining emancipatory consciousness…” (Kellner, 2018). This means bringing about awareness by looking through a critical lens to see multiple sides, particularly those that are oppressed and voiceless. This is an essential tool for using controversial issues, if the learning outcome goal is
to discover different sides of a controversy, and assist students in understanding why some
people or groups might be saying something very different than other people and
groups. Another important part about using a controversial issue, one that has more than one
side, is that it offers a view into other perspectives about an issue. This is where critical
perspectives play a role in investigating the experiences that other people are having, or into the
experiences of others who are speaking for those who voices cannot, or are not, being heard.
This again, is another form of agency that students can explore while learning about complex
science at school.

All the participants who were asked, except one student, agreed that “social justice”-described as some form of political activism, was a good idea, and they would be “ok” with
doing it for science class. Many emphasized that it is important, as well. There are many ways to
engage in “activism” that are safe and productive. Writing letters to Congress, Senate or a
Governor is a safe and effective way to be heard. The actions that the students take can be
completely organized by them and approved by the teacher, or it could be more organized by the
school. A teacher could invite someone into the classroom to speak about environmental rights,
such as an attorney, or on what their perspective is about the impact of some science and how it
ends up being used in the real world. One great example would be a farmer who is impacted by
GMOs in some way. Some vetting by the teacher or school principal may be needed, but it could
be useful, and one way to not leave campus. Moreover, there are many SSI type issues that could
be explored by students to broaden the capacity of the potential for the type of student epistemic
agency that gives students tools if they feel compelled to take some form of political action.
More specifically, if they want to ask for some kind of change because of the consequences that
science has.
**Using Controversy to Drive Scientific Inquiry & Scientific Literacy for 21st Century Learning**

If the term *scientific literacy* is important, particularly the notion that science learning should be for ALL students, then using progressive pedagogies to enhance student learning by encouraging certain outcome goals that take on different forms of student agency in the science classroom would be helpful to push inquiry into deeper forms of knowing. Moreover, if we want our students to be prepared to make science informed decisions in their lives and know when to trust science and when to ask hard questions, then using controversial, or SSIs, to drive inquiry is also important. Finally, if we want our students to know when and how to act if they feel compelled to make a change about something important to them, or something that is having a consequence on something else that makes them feel uncomfortable, then using outreach and activism for learning could be a useful tool so that student feel empowered and informed instead of existentially frustrated. The 21st century is a place of vast multiculturalism, learning styles and abilities, and student agency comes in many forms, as does the approach a teacher takes when planning activities and lessons, especially when they are within some designated educational standards, such as NGSS. Encouraging students to take on new forms of agency through different types of learning, or through a series of learning activities that build on each other, can strengthen skills within, what many call, scientific literacy, and reach a broader range of learners. Encouraging multiple forms of agency in the science classroom can have positive impacts on equity and making science learning for ALL students. Agency promotes equity because it gives students more autonomy in their learning. It assists them in learning how to think critically and constructively about science even when teachers are not there to organize and plan the period for them. Exploring different learning approaches and different forms of student agency can also reach a broader range of learners, with different learning styles and abilities.
Implications

Considerations that teachers should keep in mind while encouraging student epistemic agency through scientific inquiry in the classroom are that every student comes into the classroom with a prior “position.” One way to look at student positioning, is through the lens of this study, and shown in Figure 8 - where the student is in the center and they are surrounded by layers of factors, like a matrix, that describe what could influence a students’ position when they, not only, enter the classroom for learning, but also when they enter into the thinking and discourse involved in negotiating learning in the classroom, and beyond.

Figure 8

Student Positioning When Negotiating Activities in The Classroom and Beyond
In the first layer of the “matrix”, the student is surrounded by what is nearest and most influential in their growth. This includes the student’s family and their culture, combined with their preferences and willingness when negotiating their assignments in the classroom and at the school. Moving into the second layer, the student’s learning position is also embedded into their teacher’s framework, or their teacher’s approach. Is it student-centered? Is it teacher-centered? The teaching approach, or style, includes how student learning will happen in the classroom, including expectations that the teacher has for their students. Teachers come into the classroom with their beliefs about teaching pedagogies and strategies, assignments and quizzes, grading, rules, and the schedule for time in the classroom. In the third layer, the teacher is also embedded in the school’s framework, and therefore must negotiate school policy and school culture, including the school’s time schedule and recommended standards and testing expectations. Finally the fourth layer, where the school is under scrutiny by larger entities in society that are also governed by grander concepts such as Constitutional laws and regulations and societal norms. In the end, and what can be open to negotiations, is that each layer can adjust their frameworks on how learning happens and how it impacts the subsequent levels within the matrix of student positioning for learning in the classroom. The student has a starting point position that can have large impacts on a student’s perceptions, and willingness, to “like” activities that involve new experiences.

The layers should not be seen as barriers, but as invitations for learning opportunities that could help students gain some form of student epistemic agency in the science classroom and in their lives. Each layer can be seen as an opportunity to exchange ideas and information about a topic that is interesting and important, giving a more authentic exploration of what it could mean to be a science informed and civically engaged citizen. Ultimately, this is an introduction to
understanding what study epistemic agency and scientific literacy could be in secondary science classrooms. Overall the more invitations for learning opportunities a student has the greater potential there is for that student to broaden their understanding of science and what that science’s place is in their lives or in the local community, or maybe how that science impacts society and the environment. Within every layer of the matrix, there are more learning possibilities and opportunities for knowledge building by the student, teacher, the school and within the broader “society.” And, within every layer are more opportunities for that student to gain different forms of agency in their lives by using what they learned in their science classroom while doing inquiry within the context of a Socioscientific Issue (SSI), such as GMOs, global warming, vaccines, or even pandemic modeling.

Overall, student agency can be influenced by many things. Some of those factors are negotiable and others are less flexible. Moreover, Stroupe (2014) explains it as teachers should “not underestimate what students are capable of” and instead support them as “intellectuals, scientists, and epistemic agents” (p.513). There are many teaching avenues that a teacher can take, and because we are all creative and critical thinkers it is possible to work with the students to help them maintain some original position, while also encouraging them to step out of their learning norms to experience new forms of learning that can help bring them a sense of long lasting autonomy through establishing a variety of authentic forms of agency, and deeper forms of knowing, in their lives.
Appendix A

Activity Scenario 1: Critical Thinking

<table>
<thead>
<tr>
<th>Activity Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan an Experiment</td>
</tr>
<tr>
<td>Collect Data</td>
</tr>
<tr>
<td>Make a Graph</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Method</td>
</tr>
<tr>
<td>Reliability &amp; Validity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Presentation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment Results &amp; Difficulties</td>
</tr>
<tr>
<td>Extension Activities:</td>
</tr>
<tr>
<td>Discuss research on GMO foods</td>
</tr>
<tr>
<td>Invite a GMO scientist to the class to discuss their research</td>
</tr>
</tbody>
</table>

Students pair up and plan and set up an experiment. Experiments would involve a variable (measurement of weight, height, etc...) and some sort of change over time or variation among samples. Data will be collected and graphs will be made and printed from an Excel Spreadsheet. This should last for, at least, 1 week.

Students will experience the process of designing an experiment and collecting data, taking note of all the complications that happened through the process. Accidentally messing up is good!

Teacher will explain probability

Partners organize their results and discuss all the "pitfalls" they encountered while doing their experiment and collecting their data.

Partners present what their experiment was, how they set it up, how they measured things, what the results were and all the difficulties they encountered in a presentation to the class.

Extensions: Students and teacher gather articles and experiments on GMOs as food to discuss in class. Is the information "scientific"? Is the information reliable? Or, bring a GMO scientist to the classroom to talk.
Appendix B

Activity Scenario 2: Personal Decision-Making

<table>
<thead>
<tr>
<th>Activity Goals</th>
<th>Science Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opinion on GMOs as Food</td>
<td>Watch a GMO Film</td>
</tr>
<tr>
<td>Final Project Citations &amp; Quotes Reference List</td>
<td>Open Internet Search (GMOs)</td>
</tr>
</tbody>
</table>

First, the class will vote on and watch a documentary film on GMOs as food.

Then, students will spend a few days exploring materials and doing open Internet searches to form and support their opinion. Students can find a partner, or work alone.

Eventually, students will form a personal opinion about GMOs as food and support it with:
- 3 scientific sources
- 2 other resources

Sources & resources can be experiments, articles, online, from movies, images, etc... as long as they are quoted and cited in a bibliography.

Your opinion could include:
- Agree
- Disagree
- Explain why you are conflicted

Individuals or partners will creatively display or present their opinion, using quotes, citations and images. This can be a slideshow, an art piece, a short film, an essay, a skit, or something else approved by the teacher.

Extension: Present final products to the school, family and friends
Appendix C

Activity Scenario 3: Outreach

<table>
<thead>
<tr>
<th>ACTIVITY #3</th>
<th>Community</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity Goals</td>
<td>Outreach</td>
</tr>
<tr>
<td>GMO Science Reference List</td>
<td></td>
</tr>
</tbody>
</table>

Students will spend a week learning about the science behind GMOs, why they become food, and how scientists test their safety. Students will complete a worksheet to help with learning about basic DNA manipulation in the lab, why it can be useful and why it may pose safety concerns. Then, for another week, students will create some form of educational and informational display to present to the community.

Science Learning

- Materials from Teacher
- Open Internet Search (GMOs)

Teacher will provide basic intro resources for learning about GMOs, what kinds of foods are genetically modified, and how tests are being done. Students will do open Internet searches to support the information they have learned.

Type of Presentation:

- Interactive Table
- Small Groups
- Short Film

Students will form small groups and create some form of display for their information. This can be an interactive table with games, surveys, quizzes, etc., and they will create a short film (if resources are available).

Outreach projects will be presented to the community at either an on-campus family/friend event, or at an off-campus venue such as a fair or meeting.
## Appendix D

### Activity Scenario 4: Social Justice as Activism

<table>
<thead>
<tr>
<th>ACTIVITY #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity Goals</td>
</tr>
<tr>
<td>Multiple Perspectives in Society</td>
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<table>
<thead>
<tr>
<th>Science Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaboration</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Presentation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can and should we change policy on GMOs as food? How?</td>
</tr>
<tr>
<td>EPA, Town Hall, Letters to Officials &amp; Newspapers</td>
</tr>
</tbody>
</table>

Students will work together, and with the teacher, to better understand biases in GMO science, GMOs as food, the benefits of GMOs as food, and the safety or health concerns related to GMOs as food, and how they might impact the environment. Students will decide together, what could be done about some of the concerns about the safety and fairness of GMOs as food.

Teacher will provide a worksheet and help students understand GMO science, GMO science policy, and how to find out more information online. Students will do open Internet searches on the topic of GMOs as food and choose two or three areas that could be addressed through simple policy changes (labels, safety testing, environmental impact reports, etc...)

Brainstorm ideas on how changes in science policy could be suggested, and to whom they would go? Where could the class go for support? What kind of action could happen? What are the consequences of acting, or not acting?

Plan one or two ways to take action.
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