Kalei's Decision

Case Study #1:
If there is one thing Kalei knows, it's papayas. Kalei comes from a multi-generational family of papaya farmers, a business with humble beginnings to one that is locally and internationally known for its uniquely sweet, fleshy papaya. Kalei was raised to believe that the best way was the natural way, that hard work, heart, and listening to the ʻaina and the papaya is the only way to go. Because of the company's success and with her family's blessing, Kalei was able to attend college and is now pursuing advanced degrees in what she knows and loves: agriculture and biotechnology. She is currently working on a project that would insert foreign DNA into the papaya to make the papaya resistant to a disease that has, for the last decade, wreaked havoc not just on her family's farm, but on the Hawaiʻi papaya industry at large. It is a virus that has persisted and threatens to destroy 50% of the papaya trees on the islands. Kalei's research is showing that the genetic modification she is implementing will change this trajectory.

Kalei's roommate, however, will not stand for any conversation about Kalei's work in the lab. "This is a major slippery slope, what you are doing," Kalei's roommate reminds her frequently.

What should Kalei do?
Should Kalei modify her family's heirloom papaya to potentially save the business?

1. Relevant Facts (Known)	2. Questions that remain (unknown, need to know)

3. Stakeholders (people and/or entities affected by the decision)	4. Concerns/Values of each stakeholder

5. Possible Solutions
    a.
    b.
    c.

6. Decision

Justification
a.
b.
c.

Case Study #2: Cory is a self-professed science geek. He also loves being outdoors, whether exploring the back of Manoa valley or spear fishing with his friends at their secret spot. And Cory loves his Grandma Mieko. Grandma Mimi, as everyone calls her, is desperate to have a couple of papaya trees in her backyard. She eats papaya for breakfast every morning and insists on organic papaya ever since she saw something about GMOs on the news with Joe Moore. But every time Cory has tried to plant papaya for Grandma Mimi, those nasty virus ringspots appear, and he has had to chop them down. Last night, Grandma Mimi called him, asking for him to try again, because “I tired give Times my money,” she says. Fearing the papaya ringspot virus will attack once more, Cory considers an alternative. He knows that Grandma lives next door to a small papaya farm that grows genetically modified, non-organic papayas. He also knows that papayas are pollinated by wind and recently learned that people who thought they were growing organic papayas were actually not, because of this cross-pollination. Of course Cory will plant the papaya trees as Grandma Mimi requested, but at City Mill, he sees starters for both the Sunrise (non-GMO) and the Rainbow (genetically modified) papaya. What should Cory do?

1. Relevant Facts (Known)	2. Questions that remain (unknown, need to know)

<table>
<tr><td>3. Stakeholders (people and/or entities affected by the decision)</td><td>4. Concerns/Values of each stakeholder</td></tr>
<tr><td colspan="2">5. Possible Solutions
a.
b.
c.</td></tr>
<tr><td colspan="2">6. Decision

Justification
a.
b.
c.</td></tr>
</table>

Case Study #3:
Councilwoman Lee was not new to community activism or politics; throughout high school and college, she was fortunate enough to intern with some of the most well-respected politicians in Hawai'i, knowing that this would be her path in life. So when she was elected to the City Council, even as the youngest member, she was ready. She was not ready, however, for the complexities and divisiveness of one issue in particular that rocked her community: GMOs. **The question at hand was whether there should be a legal ban of genetically modified crops.** The first thing that Councilwoman Lee came to realize was that despite being born and raised in this farming community, she really didn't know much about the science or technology behind GMOs. The second thing she realized was that her constituents--the people she promised to represent as City Councilmember--(the most vocal and engaged, in any case) were largely in favor of banning genetically modified crops. Councilwoman Lee felt it her obligation to contact experts who would help her understand how and why the DNA of crops was modified. She personally investigated every claim that crossed her desk, scouring scientific journals, newspaper articles, and online sources from both pro- and anti-GMO organizations.

Tipped off by a constituent in favor of the ban, Councilwoman Lee wanted to know more about the agrotech companies that had something to gain from farmers and communities that relied on genetically modified crops. Every answer brought with it another question. What was becoming more clear was the schism between a body of scientific evidence that led her toward one conclusion and the committed, passionate understandings and voices of a community that led her toward another.

How should Councilwoman Lee vote? What is the "right" thing for her to do?

Does a vote of "yes" to the ban mean that she has contributed to the perpetuation of misinformation? Does a vote of "no" to the ban mean that she abandons her role as representative to her community?

1. Relevant Facts (Known)	2. Questions that remain (unknown, need to know)

3. Stakeholders (people and/or entities affected by the decision)	4. Concerns/Values of each stakeholder

5. Possible Solutions
    a.
    b.
    c.

6. Decision

Justification
a.
b.
c.

Case Study #3:
Councilwoman Lee was not new to community activism or politics; throughout high school and college, she was fortunate enough to intern with some of the most well-respected politicians in Hawai'i, knowing that this would be her path in life. So when she was elected to the City Council, even as the youngest member, she was ready. She was not ready, however, for the complexities and divisiveness of one issue in particular that rocked her community: GMOs. **The question at hand was whether there should be a legal ban of genetically modified crops.** The first thing that Councilwoman Lee came to realize was that despite being born and raised in this farming community, she really didn't know much about the science or technology behind GMOs. The second thing she realized was that her constituents--the people she promised to represent as City Councilmember--(the most vocal and engaged, in any case) were largely in favor of banning genetically modified crops. Councilwoman Lee felt it her obligation to contact experts who would help her understand how and why the DNA of crops was modified. She personally investigated every claim that crossed her desk, scouring scientific journals, newspaper articles, and online sources from both pro- and anti-GMO organizations.

Tipped off by a constituent in favor of the ban, Councilwoman Lee wanted to know more about the agrotech companies that had something to gain from farmers and communities that relied on genetically modified crops. Every answer brought with it another question. What was becoming more clear was the schism between a body of scientific evidence that led her toward one conclusion and the committed, passionate understandings and voices of a community that led her toward another.

How should Councilwoman Lee vote? What is the "right" thing for her to do?

Does a vote of "yes" to the ban mean that she has contributed to the perpetuation of misinformation? Does a vote of "no" to the ban mean that she abandons her role as representative to her community?

Notes for Case Study #3:
Herbicides used in conjunction with GMOs
"Once you change something like this, you can't take it back."

Separate arguments and identify bias. Determine credibility of the source.

Is she responsible for representing her constituents or disseminating what she has learned as scientific evidence?

What is the "right" thing for this Council member to do?

Should they not vote until all the questions are answered?

Willful misinformation vs. Lack of transparency

Who pays for this research? What are the issues that confound the situation?

Scientific evidence, preponderance of evidence, objectivity vs. subjectivity

Investigation of the scientific process
How do scientists know when something harms the environment?
How do scientists know when something is safe?

Again, the economic and social cost of genetic modification...what happens when the virus mutates and the genetic modification is no longer effective?

Anti-GM crop vs. Anti-big money ag companies vs. Anti-GM technology

Value-laden vs scientific vs ethical

Questions for discussion?

*Against the technology? Values - movement of DNA
*Against inserting into crops
*Against application

Science - Genetic modification itself does not cause organism to be unsafe or for it to hurt the environment. However, the product of genetic modification (the particular organism, species, or variety) may be unsafe to eat or hurt the environment.

However, the experimental fields that Monsanto has on Maui to test their GMO products and the large amounts of herbicides and pesticides used in testing may be unsafe for human health and the environment.

Is it OK to vote yes on a moratorium that perpetuates disinformation because it's the only way to stop Montsanto?

It perpetuates disinformation about GMOs - when we need GMO's might not be available. Like for Mosquitoes.

1. Scenario with question/content
2. Scientific background slides
3. Ethical Questions / developed by students or provided in case study (**In which cases should genetic modification be applied to food crops in Hawaii?**)

Scientific literacy
Implications of the application of the science
Ability to look at those applications from different perspectives
Evaluate the credibility of scientific fact or content

Possible topics for next case studies:
GMO
Kalo
Mosquitoes
Nagoya Protocol / Drug discovery

Working title: Genetically-modified papayas in Hawaiʻi

Aim: What are the benefits and the impacts of GM crops in Hawaiʻi?
Consequences of GM technology in Hawaii -
Application of technology and implications for society - Bioethics - place-based conflicts
Helping students engage in the technology so they understand
Health consequences of agribusiness
Separate fear and paranoia from technology with application of technology -

How does this technology differ from selective breeding?

Critical thinking
Look a problem through multiple lenses
Credibility of sources - Media literacy - scientific literacy

Essential Question
Papaya PCR lab
Learning objectives - reinforcing SI units, sterile technique
- ID a plant - tissue, Where's the DNA, organelles
- Extraction
- PCR
- Gel

1. Do NOW - GMO - list words - corn, soybeans, monsanto, salmon, mosquitoes

2. Taoist Confuscianist - what are your values, what perspective do you come from? Humans controlling nature vs. Value of nature in all its complexity
3. Technology - 1,000s of years, selective breeding for traits - technology has changed the speed at which we can modify traits, now can insert traits that can't have arisen through selective breeding
4. Societal implications for Maui (Credibility of sources, research, argument - claim evidence) (stakeholder exercise)
    a. Papaya - saved an industry - problem for Organic (pollination and plant biology) and how long will this last (resistance/evolution/selection) (free)
    b. Corn - seed crops (patented)
    c. Agribusiness - Testing of crops - Corn and Soybean (pesticides and testing)
5. Moratorium bill - (come to a consensus) - how would you modify so that different perspectives are understood and acknowledged.

Citizen Science Aspect - Data analysis - connecting students to larger project, real world question - 30-40% organic papaya crops contaminated - how does our data compare to that study.

Guiding questions:
- What genetic technologies are used to develop GM crops?
- What impacts do these technologies have on communities and the environment?
- How best should these technologies be regulated when the long-term risks and benefits are not yet fully understood?

Learning objectives:
By the end of this lesson, students should be able to
- Explain the main GM crop industries in Hawaiʻi and their technological origins.
- Identify the relevant stakeholders within the debate surrounding GM crops in Hawaiʻi.
- Discuss the risks and benefits of these industries from their personal perspectives.
- Model a process of civic engagement which promotes consensus-building among diverse stakeholders.

Standards alignment:

Background:
Draw from
https://www.pbslearningmedia.org/resource/tdc02.sci.life.gen.lp_bioengfood/bioengineered-foods/

Overview of genetically-modified (GM) crops in Hawaiʻi

Through much of Hawaiʻi's post-contact history, commercial sugarcane production had been a cornerstone of the local economy, shaping the demographic and cultural fabric of the islands through to the present day. But when sugar markets eventually moved on to areas of the world with lower production costs, state lawmakers were eager to develop new ways to put the vacant land and a skilled agricultural workforce to use. Since the 1990s, following the approval of genetically modified (GM) corn by the U.S. Food and Drug Administration for commercial sale, local production of bioengineered crops has become a major stimulus within a flagging agricultural sector.

Bioengineered crops are cultivated at large scale in Hawaiʻi for three primary reasons: (1) as exported seed stock, (2) as test fields for GM crop development and (3) as produce for consumption. Each of these activities has brought issues of public health, environmental protection and food sovereignty into the spotlight of public debate over the years, resulting in countless demonstrations, hefty lawsuits and even new local laws [REF].

In the early days of GM agriculture, scientists saw the potential to take food plants which had been domesticated for centuries and create new versions which could surmount biological constraints long imposed by nature: vulnerability to pests and disease, finite yield and restrictive growing ranges. As the world population grew exponentially to the many billions, biotechnology held the promise of creating new crop varieties which could grow in the most arid of climates, impervious to pests, all while providing unparalleled nutrition.

Table 1. GM plant crops approved by the U.S. Food and Drug Administration for commercial sale and their target traits.

	Drought tolerance	**Nutrition**	**Growth cycle**	**Herbicide tolerance**	**Insect/Disease resistance**	**Cosmetic**
Alfalfa				**X**		
Apple						**X**
Canola				**X**		
Corn	**X**			**X**	**X**	
Cotton				**X**	**X**	
Papaya					**X**	**X**
Potato					**X**	**X**

Pineapple		X	X			
Rice		X				
Soybean				X	X	
Summer squash					X	
Sugar beet				X		
Zucchini					X	

Over the decades, the goal of combating world hunger has given way to a less altruistic profit model. As the local GM agriculture industry is dominated by agro-chemical corporations, nearly all of GM crops cultivated in Hawaiʻi are designed to allow these corporations to sell proprietary, bioengineered pest-resistant seeds as well as the herbicides for which GM crops are designed to withstand.

Table 2: Agro-chemical companies in Hawaiʻi

In other words, the most frequently desired traits that have been developed into GM crops to date are (1) pest resistance and (2) herbicide tolerance. Pest resistance refers to the capacity for a GM plant to defend itself from attack by herbivores and/or pathogens that would normally affect its growth. In crops like GM corn and GM soybean, pest resistance is conferred through the insertion into the plant genome of a DNA segment taken from a bacterium known as *Bacillus thuringiensis* (Bt). This Bt-gene produces a protein which is toxic to specific insects, including pest species whose larvae attack corn, thereby protecting Bt-corn from its would-be invaders. By engineering plants that are resistant to pests on their own, a farmer can rely less upon external controls (including pesticides) to rid their fields of unwanted pests.

In contrast, herbicide tolerance refers to a GM plant's ability to withstand herbicide, usually glyphosate (known commercially as RoundUp). Plants are bioengineered to be herbicide tolerant through the insertion of a gene found in strains of *Agrobacterium* which produce an enzyme which is insensitive to glyphosate. By planting crops that withstand herbicide, a farmer can spray an entire field with RoundUp and only the unwanted weeds would perish, leaving just the desired crop. Prior to planting a herbicide-tolerant GM crop, this farmer would have had to continuously remove the weeds by hand and/or carefully spray each weed with Roundup without getting any droplets on the target crop.

BOX - How to make a GM crop in Hawaiʻi
-Gene gun or Agrobacterium transformation

-First, thousands of plants are genetically modified in tissue culture, and a small surviving fraction goes on to become candidates for further experimentation. The candidates are then exposed to various chemical agents to see which plants are tolerant and at what doses they can still survive.

In terms of sheer acreage, the most extensive application by far of bioengineered crops in Hawaiʻi has been the cultivation of simultaneously pest-resistant and herbicide-tolerant crops like GM corn and GM soybean. These crops are not grown for local consumption, but rather are export products grown in Hawaiʻi due to our year-round growing season, and are usually sold as GM seeds. Aside from occupying a large agricultural footprint within an archipelago that is dangerously dependent upon food imports, the primary issues raised by the local production of these GM seeds are (1) pesticide drift and (2) transgenic contamination. Pesticide drift occurs during the process of testing new GM crop varieties against over 90 different chemicals in over 1,300 open air spraying sites to determine whether transgenic herbicide tolerance has been achieved [REF - Center for Food Safety 2015]. Transgenic contamination refers to the ability for GM crops to spread their modified genetic components to non-GM plants via cross-pollination. In this lesson, we will take a closer look at a perennial local favorite: the GM papaya. It is a pest-resistant GM crop which occupies a much smaller fraction of the local GM agriculture sector than GM corn or GM soybean, but has nonetheless demonstrated widespread transgenic contamination.

GM papaya in Hawaiʻi

Many of us may already be familiar with the existence of GM foods in the marketplace, from corn and soy derivatives in everyday snacks to the GMO salmon coming soon to a store near you [REF]. GM papaya is an example of a pest-resistant GM crop which was developed locally, beginning-to-end to save a multi-million dollar industry under biological attack. As early as the 1930s, an introduced virus known as the papaya ringspot virus (PRSV) had been infecting local papaya plantations, generating outbreaks which resulted in moderate to severe crop losses. The virus is spread by an introduced aphid and causes unsightly blemishes on papaya fruits while slowly killing the tree. Outbreaks continued through the latter half of the century, during which farmers sought to protect their yields by culling infected plants, encasing entire trees or fields in nets, or by relocating their farms.

By the 1990s, the $11 million/year papaya industry was desperate for a long-term solution to the PRSV problem, and advancements in biotechnology had opened up the possibility of developing a GM papaya that could resist the virus without pesticides or the laborious farming practices previously required. They found that by inserting a segment of DNA produced by the virus itself into precise locations within the papaya genome at an early stage of the plant's development, the resulting GM papaya tree would be effectively resistant to infection, even in the presence of infected aphids. This novel GM papaya was crossed with popular local varieties to produce the GM papayas that are sold today. Unlike Bt-corn or Bt-soybean, GM papaya seeds were distributed to farmers for free, and the progeny of those GM papaya trees would continue to be resistant to PRSV for generations.

In the intervening years, several debates gained traction surrounding GM papayas which sowed division among farmers, and between farmers and consumers. The first issue arose from the fact that papaya fields in Hawaiʻi are open-pollinated, meaning the GM pollen from modified papaya trees could reach non-GM papaya trees growing in certified organic settings via insect pollinators. This issue of "transgenic contamination" pertains to all open-pollinated GM crops, and asymmetrically affects organic farmers who rely on verified non-GM seed stock to comply with U.S. Department of Agriculture (USDA) certification requirements. Following the release of GM papaya in Hawaiʻi, an organic farmer could never again assume that the seeds from their own non-GM papaya plants can consistently produce the non-GM trees that they require. This also meant that an organic consumer has no way of knowing whether the papaya seeds they planted in their own backyard were non-GM, even if the fruit the seeds came from was known to be non-GM. As a result, an unknown proportion of the papayas growing in organic settings, in ordinary citizens' yards, in schools or even along the road are in fact GM papayas.

A more recent issue to arise from these debates relates to the wavering effectiveness of PRSV resistance in today's GM papayas. As with any pest prevention effort, the biological target is capable of evolving mechanisms to evade the very control measures designed to subdue it. There is evidence that decades of PRSV evolution have resulted in novel viral strains to which GM papaya is once again susceptible. While the potential for these new PRSV strains to attack similar crops (such as tomatoes) remains unknown, the question of whether to design new GM papaya varieties to resist the new strains remains open.

Discussion questions:

- In what ways is GM papaya similar to other GM crops grown in Hawaiʻi? In what ways is it different?
- Evolving tolerance to pesticides, herbicides, antibiotics or defensive genetic modifications is a universal concern in any pest or pathogen control strategy. If we anticipate that all GM crops developed for pest-resistance will eventually become ineffective against their respective targets, is it worth it to develop them in the first place? Why or why not?

Assessment activity: GMO Moratorium Bill

In November 2014, voters in Maui County were given the opportunity to vote yes or no in a referendum known as the Maui County GMO Moratorium Initiative. Although this was not the first legislative effort launched by anti-GMO groups in Hawaiʻi to curb GMO development and cultivation, this referendum would become the most expensive single election ever up until that point in time. The question at the heart of the referendum was:

“Should the proposed initiative prohibiting the cultivation or reproduction of genetically engineered organisms within the County of Maui, which may be amended or repealed as to a specific person or entity when required environmental and public health impact studies, public hearings, a two thirds vote and a determination by the County Council that such operation or practice meets certain standards, and which establishes civil and criminal penalties, be adopted for Maui County?” - Maui County GMO Moratorium Initiative

Opponents of the bill outspent supporters by

Activity:

Students will read through the proposed legislation and conduct their own individual research into the potential impacts to stakeholders if passed. As a class, they will first identify who the stakeholders in this issue are and the teacher will assign groups to roleplay each stakeholder position. Optionally, groups can prepare a 2-3 minute testimony to deliver to the class using the legislative testimony writing guide provided. Alternatively, students can simply discuss arguments in favor or against portions of the proposed legislation from the perspectives of their assigned stakeholder, *while considering the conditions under which those positions could be changed*. Finally, the groups will work together to amend the bill in such a way that it would favor greater consensus among stakeholders, and among the general voting public.

Key questions that students should ponder as they read through the proposed legislation:
- Stakeholder identification:
    - Who are the key players involved in this legislative fight?
    - Who stands to gain the most?
    - Who has the most to lose?
- Research impacts:
    - What activities in Maui County involve the use of GMOs?
    - What about on other islands?
    - What species are involved in genetic modification and why?
- Technology review:
    - What issues surrounding GMOs are intrinsic to genetic modification technologies?
    - What issues are not universally inherent to these technologies?

See: Maui County GMO Moratorium 2014 assignment slides

GM papaya lab

GM papaya was developed in Hawaiʻi in the 1990s in order to protect an $11 million industry from the devastating impacts of papaya ringspot virus (PRSV) outbreaks. Unlike for most GM crops developed in the private sector, there were no restrictions on farmers freely propagating the GM seeds produced by existing GM papaya trees. As a result, on islands where PRSV is present, most commercially produced papaya is GM. Papaya is also one of the most ubiquitous homegrown fruit trees across the islands, which in turn supports a substantial population of largely bird-dispersed feral trees. However, due in part to horizontal gene transfer during cross-pollination, an unknown proportion of these homegrown and feral papayas are now also GM.

Our GM papaya lab utilizes PCR to detect the presence of the CaMV1 transgene promoter in papayas that the students bring from their home gardens to be screened. We use a multiplex PCR approach to simultaneously amplify a gene on the papaya chloroplast as an internal experimental control. The goal of this study is to estimate the proportion of homegrown and feral papaya trees producing GM fruits while mapping out potential areas of high GM pollen density. As the political debate surrounding GM crops in Hawaiʻi grows increasingly divisive, neither the USDA nor the papaya industry is especially keen on ascertaining the degree of pollen contamination resulting from commercial GM papaya cultivation. Our project leverages the energy and scope of the local school system to answer this question, while simultaneously teaching students basic genetics, biotechnology and bioethics.

Glossary:
Aphid
Herbicide
Organic
Pesticide
Seed stock
Stakeholder
Transgenic/transgene

Additional resources for teachers: