Using a structured decision-making tool in the classroom to promote information literacy in the context of decision-making

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Abstract

An important facet of college students' science literacy and job market preparation is developing skills around finding and applying information to decision-making about complex real-world problems. We developed an interdisciplinary science course designed to support development of these skills using a decision-making framework based on normative models of structured decision-making. Students practiced decision-making skills in the context of several socioscientific issue modules. We documented a post-course increase in students' self-efficacy for finding, evaluating, and using technical information in decision-making. Additionally, we briefly review prior findings that articulate potential beneficial student learning outcomes as a result of this teaching approach. This course may provide a model for introductory courses to better align with institutional goals for science literacy and critical-thinking.

Introduction

College students will be making decisions about societally and personally relevant issues in the future, many of which have scientific underpinnings. Most scientists, science instructors, and science education researchers acknowledge a need to develop students' science literacy skills to support decision-making. For example, the National Research Council (NRC) defined science literacy with a particular focus on decision-making, i.e. science literacy is "knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (1996, p. 192). However, instructors have traditionally almost exclusively focused on increasing students' science content knowledge, a perspective that continues to dominate K-16 instruction. Yet a sizeable body of research shows that this type of teaching approach is not enough to result in development of effective decision-making skills in the context of challenging real-world issues (NASEM 2016). Instead, students must have opportunities to make sense of and synthesize complex pieces of information from multiple sources, negotiate information's intersection with social, cultural and economic values, and employ this information to evaluate real alternatives for action (NASEM 2016). In addition, more than ever, employers are calling for college graduates who have the knowledge and furthermore, ability to apply this knowledge to complex issues and problem solving. In a survey of 260 employers by the National Association of Colleges and Employers (2014), 71 percent of hiring managers said they highly desire decision-making skills in college graduates. Therefore, educators at all levels of the K-16 system have a responsibility to help students master "21st Century Skills," such as integrating evidence and decision-making (NRC 2013).

A key aspect of decision-making involves using scientific information to understand the consequences of potential actions and reducing uncertainty when choices are being made. Therefore, it is important that we train students to find, evaluate reliability of, and apply information to a problem. Therefore, it is important that we train students to find, evaluate

reliability of, and apply information to a problem. This is challenging to do, for example, evidence indicates that students have difficulty integrating scientific evidence with real-world problems (Kolsto, 2006). Students need more opportunity to practice the skills of information literacy and sense-making, particularly in the context of decision-making.

In this paper, we describe an instructional approach to developing students' decision-making that has been designed as an interdisciplinary introductory course required for STEM and non-STEM majors (enrollment is approximately 600 per academic year). The course is called *Science Literacy 101: Science and Decision-making for a Complex World* (hereafter SCIL101). The major learning goals for the course are to support students': 1) science-informed decision-making skills, 2) information literacy and 3) systems thinking. The course is structured around the use of a structured decision-making (SDM) tool to think about potential solutions about complex real-world challenges relating to food, energy, water and health. During the semester, students are presented with three modules, each focusing on a specific issue that provides context for instruction around the learning goals. These issues are framed as questions to be addressed using the SDM tool for example, "how do we find a sustainable source of transportation fuel?", "how do we conserve groundwater and simultaneously support agriculture?" and "how do we conserve wild pollinators?" The SDM tool guides student thinking as they consider various alternatives for solving the issue, the objectives by which they would judge the success of each alternative, and the tradeoffs of each potential alternative given the objectives. Much of classroom instruction emphasizes students searching for scientific information that explains the potential consequences of each alternative and if it would satisfy the objectives. The teaching approach is explained further in "SCIL101 Teaching Approach" below.

The SDM tool provides an opportunity for students to practice:

- finding information
- evaluating information
- applying information to a real-world problem
- systematically evaluating and applying values to decision-making
- thinking about multiple stakeholders and communicating with people whose perspectives may differ from their own
- recognizing the complexity of real-world problems
- applying civics to real-world problems
- understanding of the role and value of scientific information
- engaging in scientific habits of mind (e.g., skepticism, objectivity and curiosity)
- engaging in scientific argumentation skills (i.e. how to back up ideas with evidence)

While we think our teaching approach using the SDM tool described here affords the opportunity to develop many types of student skills, we will limit our claims about the effectiveness of the course to areas that we have assessed at this point in our research (see Course Outcomes section). In particular, we highlight our findings on the gains in students' information literacy skills confidence after participating in SCIL101.

Framing decision-making in SCIL101

In SCIL101 we frame decision-making instruction around locally relevant socioscientific issues. A socioscientific issue is a 'real world' problem that is informed by science as well as societal elements (e.g. economic, ethics and culture) (Zeidler 2014). Using socioscientific issues as the basis of classroom instruction aims to motivate student learning by

contextualizing scientific issues in the relevant social landscapes in which they exist (Sadler 2011). Once the issue has been introduced to students (more on course structure below), students must then grapple with how to choose an alternative for solving the problem. We ask students to consider the "decision" they are asked to make in the course to be an imagined personal action (voting, writing a letter to a legislator, or donating money to a cause, etc.) that has societal implications (global climate change, local and national economics, political change, etc.). In our module about sustainable transportation fuel, the alternatives in the SDM process included: 1) continuing with the status quo of essentially 10% corn ethanol in our fuel, 2) supporting second generation biofuels, 3) promoting and subsidizing electric cars and renewable electricity, 4) programs to encourage people to drive and fly less. The SDM tool helps students figure out which alternative they would personally support for solving the problem.

There is no predetermined choice that the instructors have identified as "the best," nor do instructors hope that students choose a specific alternative. Instead, the objective is to help students make a high-quality decision. We define a "quality" decision (Authors, 2020) as one that depends on a quality *process* of decision-making that displays the 1) ability of the decision-maker to understand scientific information and apply it to the decision and 2) final choice reflecting priorities that result from evaluation of tradeoffs among the decision-maker's conflicting values (Brewer & Stern, 2005). Therefore, informed decisions should be made based on values, but with reasoned logic that weighs tradeoffs and is attentive to how scientific information predicts the performance of each choice (Gregory et al. 2012). The SDM process allows students to select an alternative for solving the problem that aligns the best with their personal prioritization of what they value in an outcome. Therefore, we say that there could be two equally well-informed students who support two different alternatives and each student could have made a "quality" decision that best fits their values.

In course instruction we frame the importance to improve upon decision-making skills for students in multiple ways. First, we discuss with students how potential employers of recent graduates highly value people with good decision-making and communicating skills (NACE, 2014), and that many employers evaluate their employees yearly based on these skills. Additionally, we talk about how all people (not just undergraduates in SCIL101) are susceptible to cognitive biases and simplified heuristics (Arvai et al. 2004). For example, "confirmation bias" is only paying attention to evidence that confirms existing beliefs, and the "availability heuristic" is a mental shortcut that relies too heavily on information that comes quickly to mind. We give explicit instruction on cognitive biases targeted toward helping students understand the difference between formal and informal decision-making, and when each is appropriate, using the concepts of "fast" and "slow" thinking (Kahneman 2011). The course is framed with the idea that some issues are important enough to slow down and do a more structured analysis to avoid sub-optimal decision-making because of poor decision-making processes.

The SCIL101 Teaching Approach

Course structure

The course is comprised of lecture sections (of approximately 120 students per lecture) that meet for two 75-minute sessions per week, as well as four recitation sections (of approximately 30 students per recitation) within each lecture section, that meet for one 60-minute session per week. The purpose of the lecture is to explore practices and theory behind

decision-making and to discuss the biological, physical, societal, and economic content knowledge that is necessary for students to engage in the decision-making process. The purpose of the recitation is for students to enact different steps of the decision-making process in small groups. Recitations are led by hourly-paid graduate students who attend lecture, give feedback to students on assignments and work closely with the instructors. Graduate students across the lecture sections receive training in two workshops early in the semester that includes teaching techniques and standardization in grading, and additionally meet weekly with their lecture instructor for additional training, standardization and to discuss course proceedings. Next we discuss the decision-making tool and how it is used in lecture and recitation in further detail.

The Structured Decision-Making Tool

This course uses a published structured decision-making (SDM) tool designed to improve decision-making practices. The SDM tool is based on normative models designed to reduce cognitive biases (Hammond, Keeney, and Raiffa 2015; Gregory et al. 2012). The SDM tool, (modified from Ratcliffe 1997; Hammond et al., 2015) includes 7 steps that support students' decision-making process for solving SSI's, outlined in Table 1.

Step	Process
1	**Define the issue** – What is the problem that needs to be solved?
2	**Objectives** – What is important to consider in an outcome? What do you care about regarding the issue? Indicate the importance to you personally of each objective by assigning a weight.
3	**Alternatives** – List or identify the possible alternative courses of actions in considering the problem or issue.
4	**Information** – Find information that explains what will happen if this alternative is chosen. Use scientific knowledge or evidence that explains how or why (mechanisms), or by how much, the alternative will satisfy each outcome objective. Use the evidence you found to assign performance scores that that estimate the rank order of how well each alternative meets the desired outcome.
5	**Analysis of alternatives based on the objectives (tradeoffs)** - Evaluate each alternative against the objectives identified.
6	**Choice** – Choose an alternative based on the analysis undertaken.
7	**Review** – Evaluate the decision-making process undertaken.

Table 1. The seven steps of the structured decision-making framework (SDM) and the accompanying process and description of process for each step.

The first step, defining the issue occurs by giving background information on the topic and asking students to consider why the issue is a problem. At the end of the first day, the instructor defines the issue ("should we use corn ethanol to satisfy our need for a renewable transportation fuel?") and asks the students to list three outcomes that are desired for this issue. The instructor summarizes student responses into 3 or 4 specific objectives. These

refined objectives from the student responses become the objectives that the class as a whole uses to evaluate the alternatives (Step 2). We found that most students converge on similar outcomes, allowing the instructor to craft anticipated objectives before the semester in order to develop course materials. For the biofuels module, the objectives were 'fewest greenhouse gases (CO_2)', 'economic benefit to farmers and rural communities', and 'preserve the health of natural resources (water, soil, biodiversity, air quality).' Next, students assigned a "weight" to each objective with higher numbers indicating the objective is more important, and with a sum total weight of 1.0. Weights appear in the first column in Figure 1. The weights are representative of each student's individual priorities and values and so no two students may necessarily share the same weight distribution across the objectives. The potential alternatives for solving the problem (Step 3) are predetermined based on expert opinion and actual proposed action toward resolving the issue, and discussed throughout the remaining lectures.

		ALTERNATIVES		
	Status Quo (gasoline, ~10% corn ethanol)	**Second Generation Biofuels**	**Electric Cars and Renewable Energy**	**Programs to Encourage Flying and Driving Less**
OBJECTIVES ***Fewest Greenhouse Gas Emissions***	1,545 million tons (CO_2 Equivalents/yr) Perf score: *	9 lbs. (CO_2 Equivalents/yr) Perf score: ****	5,556 lbs. (CO_2 Equivalents/yr Perf score: ***	781 million tons (CO_2 Equivalents/yr) Perf score: **
Weight: 0.3	0.3	1.2	0.9	0.6
Economic benefit to farmers & rural communities	High Perf score: ***	High Perf score: ***	Med Perf score: **	Low Perf score: *
Weight: 0.5	1.5	1.5	1.0	0.5
Preserve the health of natural resources ***(land, water, soil, biodiversity)***	No Perf score: *	No Perf score: *	Yes Perf score: ***	Somewhat Perf score: **
Weight: 0.2	0.2	0.2	0.6	0.4
Total weighted performance score:	**2.0**	**2.9**	**2.5**	**1.5**

Figure 1. Example of a fall 2016 student's analysis table, illustrating a completed decision-making analysis table for the Biofuels module.

After establishing steps 1 through 3, students are asked to complete an analysis table (Figure 1) as part Step 4 & 5 that allows them to systematically compare alternatives and objectives. During recitation, groups of students are tasked with researching and explaining the implications of one alternative for a particular objective (Step 4). For example, one group may be asked to research the consequences of implementing the alternative "Second Generation Biofuels" for the objective "Fewest Greenhouse Gas Emissions." During this process, students must use provided evidence as well as search for additional scientific information. The group writes a summary of their findings and gives a presentation about the potential consequences of the alternative and if it would satisfy the objective. During this time the recitation discusses how well all the alternatives perform for the given objective based on presented evidence, and comes to consensus to assign all of the performance scores (i.e. the stars in Figure 1). In the final module assessment for each socioscientific issue topic (see Appendix A&B) students complete the analysis table independently. Students are required to independently write explanations for each alternative and objective combination (although they can use the same evidence that was discussed in recitation), linking the evidence to a justification for the performance scores they assigned, and complete all of the remaining decision-making steps (Steps 5-7).

For Step 5, students perform a quantitative analysis of tradeoffs by multiplying their unique objectives weights by each performance score (across a row), and then summing the weighted performance scores for each alternative (down a column). For example, if a student weighted "Fewest Greenhouse Gas Emissions" as a 0.3 and the alternative "Second Generation Biofuels" had a four-star performance score, the weighted performance score is 1.2 (0.3 x 4.0=1.2). Then, for the "Second Generation Biofuels" alternative, the student must add the three weighted performance scores for each objective (1.2 + 1.5 + 0.2 = 2.9) to get a total weighted performance score of 2.9 (Figure 1). Students can then compare the total weighted performance scores for all the alternatives. Using objective weights in this way allows for differences in students' priorities to be reflected in the overall final scores for each alternative.

In Step 6, students make a choice. Much of the time students choose the alternative that had the highest total weighted performance scores, as this choice should represent the alternative that best satisfies their personal prioritization of the objectives. However, they may select other alternatives as long as their reasoning is clearly justified.

Finally, students are then asked a series of reflection questions (Step 7) to review their decision: "what are the tradeoffs of the alternative you chose?" "did working through this SDM tool result in your thinking differently about the issue?" etc. To further illustrate how the SDM tool is used in class, we included a timeline (see Appendix C).

The utility of the SDM tool, is that it gives students the framework to nest their ideas and knowledge about the alternatives and objectives, reducing the cognitive load of trying to hold all the various pieces of information they need to make an informed decision in their heads. In doing so, it also makes explicit the distinct role of scientific information and personal values. It allows students to evaluate tradeoffs between multiple alternatives for each outcome (objectives) they have individually identified and then take into account their priorities among those various outcomes (weighting the objectives). In contrast, if the hypothetical student in Figure 1 made a decision solely based on her highest weighted value, economic benefit to farmers, "status quo" appears to be a good decision. However, the tool helps highlight that this option does not perform well based on other criteria, reducing greenhouse gases and the health of natural resources. The option to promote second-generation biofuels may not have been on the students' mind before engaging in formal decision-making, but it represents better tradeoffs among all of the students' values.

The course is structured such that the burden of responsibility for completing all the steps of the tool independently increases throughout the semester for students. In the course's first module, the students proceeds through all of the steps using an analysis table that already contains performance scores. In a second module students generate performance scores for a smaller subset of the table (1 or 2 objectives). In the last five weeks of the semester, student groups are asked to pick a socioscientific issue of their choice and complete the entire SDM process with support as needed from the instructors for their final project. The student groups present their final project during a public poster session in the final week of the semester.

Course Outcomes for Information Literacy

Methods

Given the emphasis in SCIL101 on finding information to use in service of decision-making about complex socioscientific issues, we sought to document student gains in proficiency around finding and applying evidence. We evaluated development in student perception around their information literacy by administering a pre/post survey, containing nine Likert-like items from an established information literacy assessment (Fuselier and Nelson, 2011). This survey was implemented during the Fall 2016 semester in the first week of class, and the last week of class in two sections of the SCIL101 course. These items were analyzed using a paired t-test with an adjusted alpha value (α=0.005) to account for multiple comparisons.

Results

A total of 177 of paired pre-post survey responses from consenting students within two lecture sections taught by the authors were used for this analysis. We saw significant gains in the mean scores from pre (mean=3.56, SD=0.52) to post (mean=3.91, SD=0.48; paired t-test $p<0.001$). For further information, we compared individual items on the assessment and found significant pre to post gains across eight of the nine items of information literacy (Table 2). Students were more likely to agree that they felt able to identify relevant information, look for information effectively, able to critically evaluate information, and engage in appropriate attribution practices.

Item	Mean Score Pre	Difference Pre to Post
I can determine the kind of information I need to answer a research question.	3.99	+0.21*
The thought of reading a scientific research article scares me.	2.88	-0.12
I know how to select appropriate keywords for searching databases effectively.	3.54	+0.48*
I am confident as an information researcher in finding scientific articles.	3.46	+0.53*
I know how to evaluate the authority behind information from the internet.	3.44	+0.62*
When necessary, I revise my selection of keywords to find information more efficiently.	3.90	+0.37*
I question the validity of information, including that from textbooks or teachers.	3.28	+0.44*

I cite (acknowledge) all sources of information I include in my reports.	4.10	+0.22*
I can understand journal articles written by scientists about their research experiments.	3.52	+0.38*

Table 2. Changes in student response (n=177) to Information Literacy survey after participating in the SCIL101 course. Items were on a 5-point Likert scale with 1= strongly disagree, 3=neutral, and 5=strongly agree. Changes were assessed with a paired t-test with adjusted alpha value (α=0.005), * indicates significant pre-post change (p<0.001).

Additional documented learning outcomes

In our broader research efforts in SCIL101, we have found other student gains as a result of the course that connect to learning goals around decision-making and information literacy. In open-ended statements about what students think should be done about complex issues that were the focus of the course, students were more likely to have greater awareness of alternative alternatives and their potential consequences after the course ended (Authors, 2017). In the same study, we observed a decrease in students' emotive arguments and an increase in students' arguments that had clearer justifications and connections to the root cause of the issue. Additionally, we often observed students "changing their minds" by moving towards a more moderate stance by the end of the semester (Authors, 2020), which may indicate that effective reasoning and argumentation has occurred in the classroom. In another study we observed that students gained significantly in socioscientific reasoning, particularly in terms of recognizing complexity and the ability to recognize multiple perspectives (Authors, in press). We have also documented significant increases in students' attitudes about social justice, interpersonal and problem-solving skills, and political awareness at the end of the semester (Authors, in preparation).

Discussion

There are multiple potential affordances to using SDM tools in science classrooms. We have anecdotally and qualitatively/quantitatively noted many of these during our experience as instructors; in the rich conversation students engage in around the topics, in their motivation to understand the complexity of the issue, and in their wrestle to make sense of science information and apply it to a real-world issue. In particular, providing STEM and non-STEM majors with the opportunity to practice finding and using information is important in order to develop their decision-making skills that are the foundation of science literacy, and to make them more competitive in today's job market which demands potential employees who are adept in evaluating and using information found online.

Given the benefits we found here in terms of significant gains in students' self-reported confidence in information skills, and other outcomes, as well as its connection to 21st Century Skills, a course structure in this vein would likely be useful at many higher education institutions. Indeed, many science educational reforms have focused on increasing emphasis of higher-order cognitive skills in science instruction (Leou et al. 2006; Miri, David, and Uri 2007; Zoller 2000; Antonenko, Jahanzad and Greenwood, 2014). The SCIL101 course outlined here can provide an outline for other institutions looking to include a course such as

this. However, there may be limitations in terms of institutional and instructional effort when attempting to create a stand-alone course of this kind. We suggest that the SDM tool may also be adapted in abbreviated ways into existing disciplinary courses, such as by using a mostly complete analysis table and researching just one alternative and objective, or by using a completed analysis table in a non-quantitative way during discussion or role play regarding controversial topics.

Developing a course around an SDM tool is one way to create explicit instruction of critical-thinking practices, in this case, decision-making, information literacy and systems-thinking, rather than specific disciplinary content. While we are still investigating learning outcomes related to this course, we do think that this classroom model may provide broad potential desirable student outcomes. The SCIL101 model is one example, among others (see Miri, David, and Uri 2007) of shifting the focus of instruction from content knowledge to supporting science literacy skills that are important for citizenship and desired by employees. SCIL101 may provide an important classroom model for thinking about how to change our expectation for college courses, particularly at an introductory level, to better align with current need for students -and thereby citizens- who are competent in higher order thinking in the context of social complexity.

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Appendix A: Student Module Assessment, Rubric and Instructions
Appendix B: Student Module Assessment, Student Work
Appendix C: Biofuels Module Timeline

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Step	Process
1	**Define the issue** – What is the problem that needs to be solved?
2	**Objectives** – What is important to consider in an outcome? What do you care about regarding the issue? Indicate the importance to you personally of each objective by assigning a weight.
3	**Alternatives** – List or identify the possible alternative courses of actions in considering the problem or issue.
4	**Information** – Find information that explains what will happen if this alternative is chosen. Use scientific knowledge or evidence that explains how or why (mechanisms), or by how much, the alternative will satisfy each outcome objective. Use the evidence you found to assign performance scores that that estimate the rank order of how well each alternative meets the desired outcome.
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I know how to evaluate the authority behind information from the internet.	3.44	+0.62*
When necessary, I revise my selection of keywords to find information more efficiently.	3.90	+0.37*
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I cite (acknowledge) all sources of information I include in my reports.	4.10	+0.22*
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OBJECTIVES	***Fewest Greenhouse Gas Emissions***	1,545 million tons (CO_2 Equivalents/yr) Perf score: *	9 lbs. (CO_2 Equivalents/yr) Perf score: ****	5,556 lbs. (CO_2 Equivalents/yr Perf score: ***	781 million tons (CO_2 Equivalents/yr) Perf score: **
	Weight: 0.3	0.3	1.2	0.9	0.6
	Economic benefit to farmers & rural communities	High Perf score: ***	High Perf score: ***	Med Perf score: **	Low Perf score: *
	Weight: 0.5	1.5	1.5	1.0	0.5
	Preserve the health of natural resources *(land, water, soil, biodiversity)*	No Perf score: *	No Perf score: *	Yes Perf score: ***	Somewhat Perf score: **
	Weight: 0.2	0.2	0.2	0.6	0.4
	Total weighted performance score:	**2.0**	**2.9**	**2.5**	**1.5**

Figure 1. Example of a fall 2016 student's analysis table, illustrating a completed decision-making analysis table for the Biofuels module.

RUBRIC & INSTRUCTIONS VERSION

PLEASE USE THIS DOCUMENT FOR INSTRUCTIONS, TYPE YOUR RESPONSES INTO THE COLORED BOXES IN THE FILE LABELED "STUDENT WORK"

Slow-thinking Decision-making Framework
Biofuels (60 points)

In this class you've read articles about this issue and you have had group and class discussions about biofuels. Now take some time to use the "Slow thinking framework: steps for high quality decision-making" to outline your thoughts about the issue. What you write in the "Student work" document should represent your own thinking, which may vary from the thinking of your group.

Remember the "decision" you are making is an individual decision that has societal impact, such as: 1) if you were to give money to support a cause, or 2) if you were to vote on a policy, or 3) if you were to write a letter to a legislator about this issue.

What you write in the "Student Work" document should represent your own thinking, which may and should vary from the thinking of your group.

1. Define the issue

How do we create a sustainable source of transportation fuel? Should we make ethanol out of corn as a biofuel?

2. Objectives/Evaluation Criteria

To help us think about possible objectives, we asked ourselves: how are you going to choose between these alternatives? What are the important things to consider? What do you care about? When coming up with objective, we "separated the ends from the means" by asking ourselves "***why*** do I care about that?" multiple times until we could go no further and have found the "ends" or the fundamental thing that we care about. Below is a list of objective based on class responses:

1. Fewest greenhouse gas (CO_2, e.g.) emissions.
2. Economic benefit to farmers & rural communities.
3. Preserve the health of natural resources (land, water, soil, biodiversity, air quality).
4. Cheapest for people at the gas pump.

[1 point] Assign weights to each objective. Weight each objective to represent ***how much*** you care about it. The sum of all the weights should equal 1. Type the weights into the table in the "Student Work" document. Replace the text "Weight: type your weight into this cell" in the red boxes with the numbers representing your weights.

0 – no weights are assigned to the objective, or the weights are not clear.
2 –student assigns weights to the objective that add up to 1, and appropriately fills out the table.

3. Alternatives

Below is a list of alternatives that we've discussed in class, based on expert opinion about this issue.

A. **Status quo: gasoline and diesel are dominant** (corn ethanol is primary biofuel, biofuels are supposed to increase in volume over the next 20 years)
B. **Support second generation biofuels (corn stover, sorghum, switchgrass etc)** (by increasing federal government spending on research and development or subsidies for these fuels)
C. **Promote and subsidize electric cars and renewable electricity** (homes and business would produce their own solar or wind energy to power vehicles)
D. **Educate and motivate to drive less and fly less** (Effective approaches and incentives need to be determined.)

4. Information [81 points total]

We asked: What additional information do we need to know about each alternative?

Step 1: While looking for information, we thought about what would be a "metric" for each objective that would allow us to compare across alternatives in a way that is not subjective. This allowed us to compare across alternatives while reducing cognitive biases. Below are metrics we will try to use for each objective:

Objectives	Metric
1. Fewest greenhouse gas (CO_2, e.g.) emissions	The amount of released CO_2 equivalents/year (or other similar measurement), or specifically how the alternative might impact CO_2 emissions.
2. Economic benefit to farmers & rural communities	The amount of profit for each alternative, or specifically how the alternative may impact farmers.
3. Preserve the health of natural resources (land, water, soil, biodiversity, air quality)	The amount of water used, amount of land used, the number of species impacted with each alternative, the amount of air pollution or specifically how the alternative would impact land, water, soil, biodiversity or air quality. (Remember "air quality" generally refers to pollution that does not cause climate change, but causes other issues for example acid rain.)
4. Cheapest for people (at the gas pump, or in terms of vehicle purchase)	The cost of fuel under each alternative, or specifically how the alternative might impact fuel prices.

Step 2 (80 points): Research each alternative to determine– if this alternative is chosen, will in result in satisfying the objective? In other words, describe the information known about each alternative with reference to specific objective. Based on information, give an argument about what performance score should be assigned each alternative for a given objective, based on the information you found.

You've discussed these alternatives and objective in depth during recitation after student groups gave their presentations. You may use information that was gathered by other groups in your recitation, or in other recitations, that is posted on Canvas in "Discussion" in discussion posts for each alternative and objective. However, you must write an argument about performance metrics in **YOUR OWN WORDS**. (Copy and pasting arguments from other group's arguments will be given a zero, copying word-for-word from a friend will result in a zero.) You may choose to assign the same performance scores that were decided on in class, or you may argue for a different performance score. You may use the same references as other groups, as long as they support your argument, are explained in your own words, and are cited properly and clearly traceable to the source. You may also do additional research on your own.

Each alternative and objective combination will be eligible for up to 5 points based on:

	Lacking	***Developing***	***Meeting or Exceeding***
Reasoning	*0 – the argument for how an alternative meets the criterion does not go beyond assumptions that everyone makes. The reasoning has little argumentative force, and does not add clarity or insight into the consequences of choosing an alternative and if it will meet the desired objective.*	*1 - an argument for how an alternative meets the criterion has some significant gaps in reasoning, for example large assumptions that could have been supported with evidence or specific information.*	*2 - the student gives a high quality, thorough argument about the consequences of the alternative, in terms of if it will meet a given objective. The argument includes specific reasons -- how, why or how much-- the objective is or isn't met using specific, relevant information or evidence from research or from class or other sources.*
Evidence	*0 – no evidence or specific information is given.*	*1 - evidence/specific information that is cited is irrelevant or disconnected from the argument.*	*2 - The evidence provided connects to the students' argument about if the alternative will meet the objective.*
Sources	*0 – no evidence or specific information is given.*	*0.5 – it is not entirely clear what the specific information/evidence is, and it does not seem to be clearly traceable to a source. (for example, references are to "irs.gov" or "https://www.lpsnrd.org" instead of linking or referencing specific information that supports the argument).*	*1 - The source of information is cited in a way that it is clear what the specific information/evidence is, and the information is traceable to the source.*

Therefore, 4 objective x 4 alternatives x 5 points = 80 points total are possible

Step 3 (1 point): Assign *performance scores*. Based on the information you found, assign ***performance scores*,** or a number of stars from 1(*) to up to 4 (****), with 1= the worst, and 4= the best. A different number of stars represents a **significant difference** between each alternative in meeting the objective, according to your research. (An example of how to assign performance scores is posted on Canvas. Note: If two alternatives perform the same according to the metric then they should get identical performance scores.)

0 – no performance scores are assigned, or the scores are not clear.
0.5 – student assigns performance scores inappropriately, and do not seem to be based on the research provided by the student.
1 –student assigns performance scores appropriately that align with the research provided by the student..

5. Analysis of alternatives based on the objective (tradeoffs) (2 points)

Multiply the weight of each objective by the number of stars (performance score) of each alternative (across the rows). Write the results of that multiplication in the blue cells of the table in the "Student Work" document.

Add up the weighted performance scores of each alternative (blue cells) down the columns for each alternative, and then write the results of that addition in the bottom row of the table in the green cells.

OR: use the excel sheet provided on Canvas to do the math for you! Simply type your objective weights into the red cells in the spreadsheet (titled "Plastic pollution analysis table.xlsx"), and see how it influences the total weighted performance scores of each alternative. Don't forget to record your final values into the "Student Work" document.

0 – no total weighted performance scores are assigned, or the scores are not clear.
1 – student has a mistake in their math or inappropriately fills out the table.
2 –student does correct math and appropriately fills out the table.

6. Choice (6 points)

A) Choose an "alternative" based on the analysis undertaken.

B) [3 points] Why do you think this is the best alternative?

0—the student does not provide reasoning for their choice, or the reasoning is weak, unclear and disconnected with the objective and tradeoffs illustrated in the analysis table
1.5—the student provides reasoning for their choice that has some weak or unclear connections with the objective and tradeoffs illustrated in the analysis table
3—the student provides clear and comprehensive reasoning for their choice that clearly links the choice with the objective and tradeoffs illustrated in the analysis table

C) [3 points] What are the tradeoffs (positive and negative aspects) associated with the alternative you chose?

0—the student does not provide reasoning for their choice, or the reasoning is weak, unclear and disconnected with the objective
1.5—the student only provides positive aspects of the alternative or describes how well the alternative performs based on only 1-2 objective
3—the student provides positive and negative aspects of the alternative or describes how well the alternative performs based on all of the objective

7. Review (6 points total)

Reflect on your own decision-making process using these steps.

A) [1.5 points] Who are the stakeholders who are "winners" and "losers" if this alternative is implemented?

0—the student offers no reflection or what is offered demonstrates no thoughtfulness
1.5—the student offers reflection that demonstrates thoughtfulness, including specific examples of the stakeholders who might gain and the stakeholders who might lose if their decision is implemented.

B) [1.5 points] Some of the alternatives are not necessarily mutually exclusive, and more than one could potentially be implemented at the same time. Are there other alternatives (either the ones listed or other things that you can think of) that you would like to see implemented to help solve this problem?

0—the student offers no reflection or what is offered demonstrates no thoughtfulness

1.5—the student offers reflection that demonstrates thoughtfulness, including specific reasoning about alternatives for solving the problem

C) [1.5 points] Do you think your chosen alternative is viable to be currently implemented in our society, and would work effectively to resolve the issue? Why or why not?

0—the student offers no reflection or what is offered demonstrates no thoughtfulness
1.5—the student offers reflection that demonstrates a deep enough understanding of the issue to understand what is a viable alternative, or is thoughtful about what they don't yet understand to determine what is viable.

D) [1.5 points] Did working through the slow-thinking decision-making framework (7 steps) result in your thinking differently about the issue? How?

0—the student offers no reflection or what is offered demonstrates no thoughtfulness
1.5—the student offers reflection that demonstrates thoughtfulness, including specific examples of why the 7 steps did or did not influence their thinking about this issue.

8. Assigning resources (1 point) See the "student work" file to answer this question.

1 point- complete answer to the question, with an X indicated for each alternative..

9. Importance of issue (1 point) See the "student work" file to answer this question.

1- complete and thoughtful answer to the question "why" and a rank given

10. Impact (1 point) See the "student work" file to answer this question.

1 – the action presented by the student is clearly related to the issue.

11. Your Actions (1 point) See the "student work" file to answer this question.

1 – complete and thoughtful answer to the question.

Name: _____ Group: _____ Instructor: _____ LA: _____

SCIL 101 Biofuels Module Assessment (60 points)

STUDENT WORK GOES HERE (IN COLORED BOXES):

In the table below you will replace the text in the colored boxes with your objective weights (red), performance scores for the first two objective (purple), weighted performance scores (blue), and total weighted performance scores (green) (see the Rubrics and Instructions file).

ALTERNATIVES / **OBJECTIVES**	**Status quo: gasoline and diesel are dominant** (corn ethanol is primary biofuel, biofuels are supposed to increase in volume over the next 20 years		**Support second generation biofuels (corn stover, sorghum, switchgrass etc)** (by increasing federal government spending on research and development or subsidies for these fuels)		**Promote and subsidize electric cars and renewable electricity** (homes and business would produce their own solar or wind energy to power vehicles)		**Educate and motivate to drive less and fly less** (Effective approaches and incentives need to be determined.)	
	Performance score:	Performance score x objective weight:	Performance score:	Performance score x objective weight:	Performance score:	Performance score x objective wgt:	Performance score:	Performance score x objective wgt:
Fewest greenhouse gas (CO_2) emissions Type a weight into this cell		Multiply the weight x the performance score, type it in these blue cells						
Economic benefit to farmers & rural communities Type a weight into this cell								
Preserve the health of natural resources (land, water, soil, biodiversity, air quality) Type a weight into this cell								
Cheapest for people (at the gas pump, or in terms of vehicle purchase) Type a weight into this cell								
Total weighted performance score:	Sum up the weighted performance scores in this cell							

4. Information, Step 4: justification of assigning your performance scores:

Objective – Fewest greenhouse gas (CO_2, e.g.) emissions**:**

Alternative 1:

Alternative 2:

Alternative 3:

Alternative 4:

Objective - Economic benefit to farmers & rural communities**:**

Alternative 1:

Alternative 2:

Alternative 3:

Alternative 4:

Objective - Preserve the health of natural resources (land, water, soil, biodiversity, air quality)**:**

Alternative 1:

Alternative 2:

Alternative 3:

Alternative 4:

Objective – Cheapest for people (at the gas pump, or in terms of vehicle purchase)**:**

Alternative 1:

Alternative 2:

Alternative 3:

Alternative 4:

6. Choice:
A) Choose an “alternative” based on the analysis undertaken.

B) Why do you think this is the best alternative?

C) What are the tradeoffs (positive and negative aspects) associated with the alternative you chose?

7. Review (Reflect on your own decision-making process using these steps):
A) Who are the stakeholders who are “winners” and “losers” if this alternative is implemented?

B) Some of the alternatives are not necessarily mutually exclusive, and more than one could potentially be implemented at the same time. Are there other alternatives (either the ones listed or other things that you can think of) that you would like to see implemented to help solve this problem?

C) Do you think your chosen alternative is viable to be currently implemented in our society, and would work effectively to resolve the issue? Why or why not?

D) Did working through the slow-thinking decision-making framework (7 steps) result in your thinking differently about the issue? How?

8. Would you support these alternatives with real resources? How likely is it that you would support the following alternatives regarding water conservation? (Think about this as if you have $10 million dollars to allocate towards any of these alternatives for solving the problem. How would you allocate the money?)

Please place an "X" in the box you agree that you would support with donations:

	Very likely to support	Somewhat likely to support	Neutral	Somewhat unlikely to support	Very unlikely to support	I don't know
Status quo: gasoline and diesel are dominant (corn ethanol is primary biofuel, biofuels are supposed to increase in volume over the next 20 years)						
Support second generation biofuels (corn stover, sorghum, switchgrass etc) (by increasing federal government spending on research and development or subsidies for these fuels)						
Promote and subsidize electric cars and renewable electricity (homes and business would produce their own solar or wind energy to power vehicles)						
Educate and motivate to drive less and fly less (Effective approaches and incentives need to be determined.)						

9. Importance of issue - Is this issue an important issue?

Rank the issue on a scale of 1 (not at all important) to 10 (one of the most important issues): _____

Why?

10. Impact - Is there anything you could do to impact this issue? What are some things you could do?

11. Your Actions - Do you think your actions regarding this issue will make a difference? Why or why not?

After you have filled everything out in purple according to the instructions, save this document with your first and last name in the file extension, then upload this document to Canvas

Week	Class Sessions	Class Topics	Step of SDM Tool
4	Lecture	Do biofuels reduce greenhouse gas emissions? How do biofuels impact the environment? (Background science, scientific uncertainty, current alternatives)	1, 2, 3
4	Lecture	Do biofuels reduce greenhouse gas emissions? How do biofuels impact the environment? (Developing deeper understanding of objectives and alternatives and the science of energy/biofuels)	2, 3
4	Recitation Meeting	Groups assigned an alternative x objective - Time for group research. Submit and receive feedback on research for next recitation session.	4
5	Lecture	Biofuel production and use in engines - guest expert speaker	3, 4
5	Lecture	Life Cycle Assessment of biofuels	3, 4
5	Recitation Meeting	½ of groups present their research + class decides performance metrics for the objective/alternative presented	4, 5
6	Lecture	Biofuels continued (economic impact, biodiversity impact etc.)	4
6	Lecture	Biofuels continued (Food versus fuel debate, municipal solid waste etc.)	4
6	Recitation Meeting	½ of groups present their research + class decides performance metrics for the objective/alternative presented	4, 5
7	Individual Assignment Due	Biofuels module assessment	4, 5, 6, 7

A sample schedule of the Biofuels Module on how the SDM tool is integrated into the course. Step 7 of the SDM tool is completed by the students individually after the final recitation meeting for the module in their individual module assessments. Lecture and recitation meetings are complementary in that lectures tend to be informational and provide background research students can use and build upon for the research and synthesis they do during recitation meetings.