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Donna Governor & Lorraine Ramirez Villarin

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Exploring Socioscientific Issues Through Evidence-Based Argumentation With MEL Diagrams

BY DONNA GOVERNOR AND LORRAINE RAMIREZ VILLARIN

CONTENT AREA

Earth & Environmental Science

GRADE LEVEL

6–12

BIG IDEA/UNIT

Socioscientific issues provide opportunities for students to engage in evidence-based argumentation

ESSENTIAL PRE-EXISTING KNOWLEDGE

None; scaffolds are available to help students understand concepts and evidence related to scientific models

TIME REQUIRED

45–90 minutes

COST

All materials available free online; see MEL Project link in Online Resources for information on NSF support.

SAFETY

N/A

ABSTRACT

Critical thinking skills are best taught as students participate in the scientific practice of argumentation. When engaged in scientific argumentation, students are expected to engage in active listening and social collaboration through the process of negotiation and consensus building. Socioscientific issues are ideally suited for such activities. Model-Evidence-Link (MEL) diagrams provide an ideal scaffold for helping students learn to build arguments that can help them make connections between evidence and scientific explanations. In these activities students compare competing models by making plausibility judgements, then comparing how well scientific evidence supports each model. In research-based activities, these scaffolds have been shown to help students better understand scientific concepts, to shift students' plausibility judgments, and to provide insights into how students negotiate consensus through argumentation. In this article we share both the resources and instructional methods for including MEL diagrams in the middle school classroom.

KEYWORDS: Earth/Environmental Science; Argumentation; Critical Thinking Strategies; Teaching Strategies

One of the most important changes in teaching science that came out of *A Framework for Teaching K–12 Science* (NRC 2012) was the emphasis on engaging students in evidence-based argumentation. Argumentation is a critical science process skill that requires students to exercise critical thinking by using evidence to support claims. In science, the process of argumentation is what scientists do to move knowledge in their field(s) forward as they examine, present, critique, and evaluate new ideas and understandings.

In the classroom, it is critical that students engage in scientific argumentation through a process of collaborative discourse by evaluating claims and evidence. As students negotiate scientific claims and evidence through discussion, they engage in the culture of science and see how new knowledge is constructed (Governor, Lombardi, and Duffield 2021). However, for students to successfully engage in scientific argumentation, they must be taught a variety of skills. These include comparing alternative explanations, evaluating models for accuracy and quality, critically evaluating and interpreting texts, and engaging in productive discourse to examine competing explanations (Osborne et al. 2019).

One way to engage students in the practice of scientific argumentation is through Model-Evidence Link (MEL) diagrams. These instructional scaffolds have been developed to present students with different scientific models connected to real-world socioscientific issues (SSI) and then ask them to evaluate evidence and negotiate the plausibility of the competing scientific models. Scientific models are the basis of these activities and are broader than claims in science. Models provide an explanation for a phenomenon that can both predict and describe why it occurs, whereas claims are more limited in scope and usually based on the results of an investigation (Lombardi et al. 2022).

Argumentation through MEL activities

According to *A Framework for K–12 Science Education* (NRC 2012), scientific models must be connected directly to lines of evidence to facilitate building arguments about the causes and effects of scientific phenomena. In the MEL activities, students are asked to do just that, with an emphasis on the concept of *plausibility*. Plausibility is a judgment made about the potential truthfulness of a scientific explanation. In MEL activities, students are asked to make evidence-based appraisals about the plausibility of scientific models, both before and after engaging in argumentation through negotiation. Each of these activities is grounded in a current SSI. These topics are ideal for engaging students in argumentation in that they engage students by exploring real-world phenomena. As students become more comfortable negotiating relevant SSI, their participation in argumentation can foster socioscientific reasoning and lead to more robust discussions about those issues (Villarin and Fowler 2019).

Over the last decade, the Science Learning Research Group (see Online Resources) has developed and tested multiple MEL scaffolds connected to various SSI. These have been implemented in middle and high school classrooms in several states. The first four MEL activities require students to evaluate models and evidence related to climate change, fracking, wetlands, and the formation of the Moon. The second four MEL activities are connected to fossils as evidence of past climates, the availability of freshwater resources, causes of extreme weather, and the origins of the universe. Currently, the team is working on new MELs related to natural resources, food security (soil), and dead zones (eutrophication). These resources are available for free to teachers at the project website (see Online Resources). Next, we provide an instructional summary of the MEL teaching sequence for use in the middle school classroom (see Table 1 for a summary).

TABLE 1: Instructional sequence for MEL activities.

Stage	Activity	Teacher does	Student does
1	Presenting models: • whole-group introduction of models Note: Plausibility judgements are made individually	Present students with competing models to explain scientific phenomenon	• Follow along and ask clarifying questions in whole group introduction of models • Make individual plausibility judgments about each model
2	Introducing the evidence: • whole group	• Read and review texts with students • Assist students in interpreting the evidence	• Follow along and ask clarifying questions • Make notes or comments on evidence text handouts
3	Evaluating the evidence: • small group	• Circulate and monitor discussions • Ask guiding questions	• Groups negotiate the relationship of evidence to each model • Either individually or in groups, students determine relationships
4	Re-evaluating the models: • individual evaluations • whole-group discussion	• Revisit the competing models and have students re-evaluate each model • Lead whole-group discussion	• Rerate each model based on the evidence • Construct explanations about their reasoning

Stage 1: Presenting models

In this stage of the activity, students are presented with competing scientific models connected to a specific SSI. These models are presented with an extended explanation designed to help students understand the socioscientific context for each model. The teacher usually reads aloud each of the models and leads a class discussion to help students comprehend the competing models. Students are then asked to make plausibility judgments independently about each model based on their background knowledge, which can provide insights to the teacher on their initial understanding of the issue under consideration. Figure 1 illustrates an example of competing models presented in the climate change MEL.

Stage 2: Introducing the evidence

This activity starts with the teacher introducing various lines of evidence that are connected to the phenomenon. There are four different lines of evidence that are evaluated in each MEL activity. Each starts with a statement that provides a simplified summary. Then, in one to two paragraphs, more information is provided that elaborates on that idea. Usually, a graph, an illustration, or a chart is included to help make the concept more concrete (Figure 2). It is important to provide students with hard copies that they can write on to facilitate a class discussion. Most teachers will project these onto their whiteboard and cover one evidence text at a time in a whole-group setting. Some choose to have students work in a jigsaw activity where each student becomes an expert on a specific line of evidence to prepare for the small-group discussion.

Stage 3: Evaluating the evidence

Through a process of collaborative negotiation, students are asked to work in groups to determine how each of the lines of evidence is connected to the different models. To keep relationships simple, students are asked to choose one of four associations:

- the evidence strongly supports the model
- the evidence supports the model
- the evidence contradicts the model
- the evidence has nothing to do with the model

FIGURE 1: Competing models for climate change MEL.

Model A: Climate change is caused by humans who are releasing gases into the atmosphere.

A person who supports this model makes the following argument:

A few gases in Earth's atmosphere prevent some of Earth's energy from escaping out into space. Human activities are increasing the amount of these gases in the atmosphere. Therefore, humans are causing climate change.

Model B: Climate change is caused by increasing amounts of energy released from the Sun.

A person who supports this model makes the following argument:

The Sun is the main source of energy for planet Earth. Scientists have shown that for thousands of years Earth's average temperature increases when the Sun releases more energy. Therefore, the Sun is causing climate change.

FIGURE 2: Sample evidence text from fracking MEL.

Evidence #2: During recent years, the number of earthquakes near fracking sites was 11 times higher than the 30-year average.

Significant earthquakes are increasing within the continental interior of the United States. Figure 1 below shows the number of earthquakes in Oklahoma since 1978. The first bar is the average number of earthquakes over the period 1978-1999. Each line after that is one year. In 2011 alone, there were five earthquakes of magnitude greater than 5.0. This increased earthquake activity has occurred at the same time that nearby fracking activities have increased.

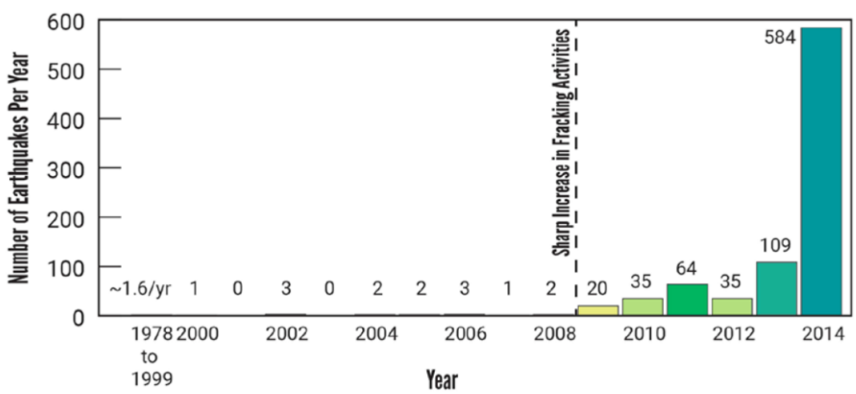

Figure 1. Annual number of earthquakes in Oklahoma from 1978 to 2014. Credit: Wright Seneres

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The strength of each line of evidence is important to evaluating the models. However, when evidence is deemed to contradict a scientific model, it generally provides opposing evidence that decreases its plausibility in the scientific community. Through the process of collaborative discourse and scientific argumentation, students are expected to discuss, critique, and evaluate each line of evidence and its relationship to the competing models.

As students engage in scientific argumentation while determining the relationship between evidence and models, they generally work in small groups. We have seen middle school students extremely engaged as they debate the links between models and evidence. To get the most out of the activity, it is highly recommended that once students have completed their MEL diagrams, the classroom teacher should lead a whole-group discussion during which students are expected to share their results and debate the connections with other groups.

Finally, students are asked to make a final determination on how all lines of evidence connect to each model using a graphic organizer (the MEL diagram) to show the relationships they established (Figure 3). Students can be asked to reach a consensus and construct a single diagram for each group, or they can create their own diagrams independently, depending on the instructor's goals for the activity. Examples of student work on a freshwater resources MEL activity can be found in Figure 4. Students are also asked to write an explanation to describe their thought process in making connections from the evidence to one of the models.

Stage 4: Re-evaluating the models

The last step in the activity is for students to reevaluate the plausibility of each model, based on the evidence presented. As part of the final evaluation, students are asked to construct an explanation about which model they feel is most plausible and why. They are expected to cite the evidence presented in the activity as they explain their reasoning (Figure 5).

FIGURE 3: Sample MEL diagram from the wetlands MEL.

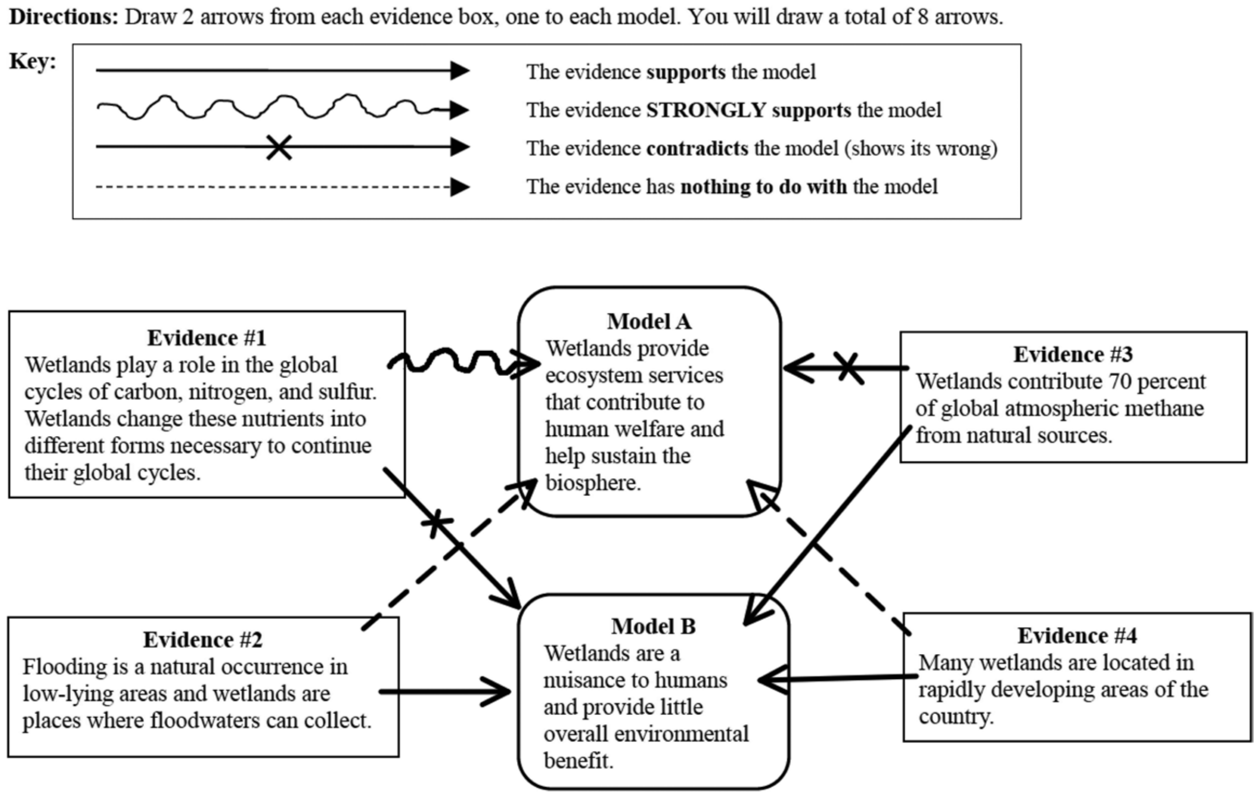
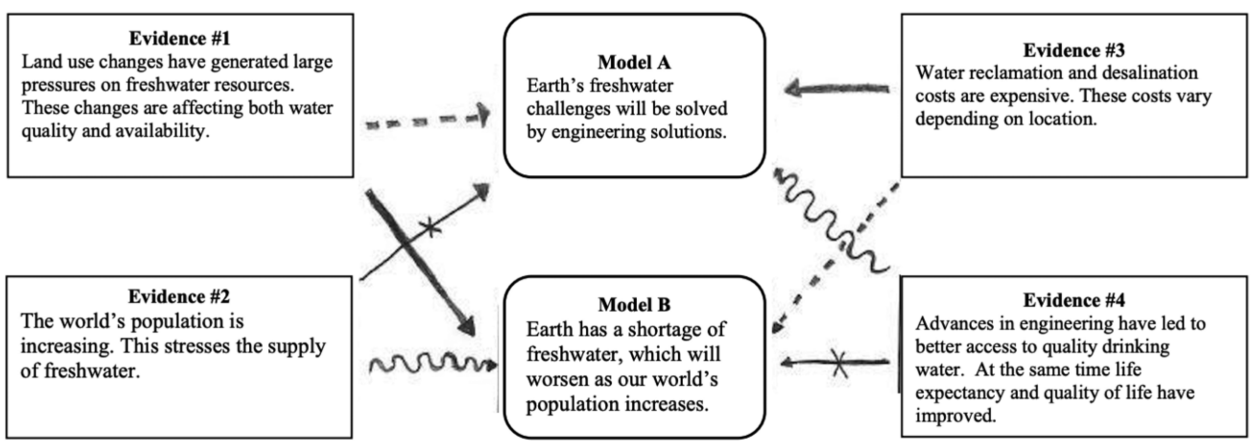


FIGURE 4: Student work samples from the freshwater MEL.



The goal of the MEL activities is to help students think critically about models and evidence as they negotiate the links between them. Therefore, students should be assessed on their reasoning and explanations through the scientific practice of argumentation. Assessment usually takes the form of evaluating the strength of student arguments in the final stage of the activity. Are students able to cite evidence from the text that supports their judgments? Can they make authentic connections that link the model to the evi-

FIGURE 5: Student work samples from the freshwater MEL—explanation task.

1. Now that you have completed the diagram, reconsider the plausibility of Models A and B (and C, if there is one). Circle the plausibility of each model. [Make one circle for each model.]

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10
Model C (if there is one)	1	2	3	4	5	6	7	8	9	10

2. For the model you selected as most plausible, explain why you think so.

I think model C is the most plausible. Earth's populalation greatly increases each day bringing more people who need more water. With every person usi water (more use when population increase) the presence and availbility of water will decrease dramaticly. that is why Model C is the most plausible

dence? Do they have a better understanding of the SSI that requires them to learn the science behind the issue? (Holzer, et al, 2020). The rubric that has been developed is specifically designed to evaluate the Science and Engineering Practices that are demonstrated on the final evaluation task. A slightly modified version of the full rubric is provided in Figure 6.

MEL resources

These NSF-funded MEL projects have been extensively researched with results showing that students not only learn science during the MEL activities, but also make positive judgment shifts in plausibility. Studies exploring how students interact during MEL activities have provided some interesting insights into the process of consensus building and negotiation. For example, to successfully build consensus, students will use language patterns that are more polite (such as polar questions, which have only two possible responses, such as "yes" and "no"), move from tentative to certain language modifiers as their negotiation proceeds toward consensus, and facilitate more equal turn-taking in successful negotiations (Governor, Lombardi, and Duffield 2021). Knowing how language patterns progress as students negotiate the relationships between models and evidence can help teachers monitor conversations to produce more productive discourse.

The second four MEL activities (Fossils, Freshwater Resources, Extreme Weather, and Origin of the Universe) were developed with student agency in mind. Three different models are introduced and eight different lines of evidence. After examining the models and evidence, students choose two of the models and four of the lines of evidence to compare using the MEL diagram. We call these activities "build-a-MELs" (baMEL). Each of these four activities also has a traditional or "preconstructed" (pcMEL) version, which is easier for younger students to manage. The two different versions of each of these MEL activities also provide teachers with the means to differentiate the activity within the same classroom by accommodating students at different instructional levels. Struggling students can work with the pcMEL version of an activity, limiting their cognitive load, while more advanced students can work with the baMEL version, examining more lines of evidence to make plausibility judgements. To accommodate multilingual learners or those with a lower reading proficiency, a realia wall that illustrates scientific concepts and/or vocabulary terms featured in the MELs with proper translations is extremely

FIGURE 6: Assessment rubric.

Science and Engineering Practices				
Practice	**Mastery**	**Approaching**	**Developing**	**Beginning**
Developing and Using Models	The explanation clearly and accurately evaluates the merits and limitations of the two different models of the phenomenon, in order to select the most plausible model based on the evidence.	The explanation evaluates the merits and limitations of one of the two different models of the phenomenon, in order to select the most plausible model based on the evidence.	The explanation has little or no evaluation of the merits or limitations of one of the two different models of the phenomenon, in order to select the most plausible model based on the evidence.	The explanation does not evaluate the merits or limitations of either model, or the explanation is erroneous, in order to select the most plausible model based on the evidence.
Engaging in Argument from Evidence	The student's written explanation accurately and precisely identifies the strength or weakness of the evidence to model link, based on comparing and integrating how evidence supports or contradicts a particular model, using several lines of data from the multiple evidence texts.	The student's written explanation accurately identifies the strength or weakness of the evidence to model link, but the student's analysis may not be well integrated and/or may be missing comparisons to another model, with only a moderate level of justification using the data from the evidence texts.	The student's written explanation has some inaccurate information in identifying the strength or weakness of the evidence to model link, with little integration of the data from evidence texts or weakly justifying their reasoning with evidence from the texts or incorrectly applying one of the evidence pieces.	The student's written explanation conveys inaccurate information or does not identify the strength or weakness of the evidence to model link, with no integration of the data from evidence texts or no justification of their reasoning with evidence from the texts or incorrectly applying several lines of evidence.
Constructing Explanations	The explanation of the evidence to model link is clear and justifications are based on accurate and precise understanding of the scientific content in the evidence texts and scientific reasoning about the causal connection to the model.	The explanation of the evidence to model link is clear but does not provide sufficient justification and may only use a correlational rather than causal explanation based on the scientific content presented in the evidence texts.	The explanation of the evidence to model link displays an error in understanding the scientific content, and/or the explanation is correlational and may convey errors in reasoning, or there is limited reasoning to support the explanation.	The explanation of the evidence to model link displays several errors in understanding the scientific content and there is limited or no reasoning, or completely wrong reasoning to support the explanation.

helpful. Consider creating sentence frames to guide students' reasoning and help them build evidence-based arguments.

The most recent MEL project (see Online Resources) is concentrated on integrating science with language arts and social studies as students use lateral reading strategies to evaluate the veracity of sources and claims to promote socioscientific reasoning. These products are still in the development and testing stage and will be added to the MEL repository once finalized. Additionally, an instructor guide is also available that can help teachers new to the practice of scientific argumentation successfully implement the MEL activities.

As proponents of sensemaking as an instructional model, we believe these activities are ideal for student engagement. Each MEL is based on a phenomenon that is connected to current SSI and is often involved in controversy. As students work through the argumentation process and construct their MEL diagrams, they build an understanding of the underlying phenomenon by discussing science models and engaging in scientific practices. Making connections with the SSI by engaging in argument from evidence is necessary for making plausibility judgments.

The MEL activities are not the only way to engage students in scientific argumentation. However, they provide a valuable scaffold for engaging students in the culture of science through collaborative discourse. They set a purpose for learning science content and address important SSI that are necessary for informed citizenship. ●

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ORCID

Donna Governor http://orcid.org/0000-0002-9906-0681
Lorraine Ramirez Villarin http://orcid.org/0000-0002-1872-2023

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ONLINE RESOURCES

The MEL Project: Lateral Model-Evidence Link Diagrams Project—*https://serc.carleton.edu/mel/index.html*

The Science Learning Research Group: Publications—*https://sciencelearning.umd.edu/publications*

Donna Governor (*donna.governor@ung.edu*) is an associate professor and **Lorraine Ramirez Villarin** (*Lorraine.RamirezVillarin@ung.edu*) is an assistant professor, both in the Department of Middle Grades, Secondary and Science Education at the University of North Georgia in Dahlonega.

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