The IASA Model

Project Title: Investigative Analysis and Structured Argumentation (IASA) for seeding critical thinking and inquiry skills for the 21st century

[An Edulab Project]

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OVERVIEW

In recent years, there have been widespread efforts to expand the goals of science learning. Science education scholars and policy makers are veering away from an exclusive emphasis on learning science concepts and science process skills. They argue that, while these goals remain essential to science learning, there is a need to re-position young science learners as legitimate participants to the practices of science communities. Hence, school science is framed as not just science-as-knowledge but science-as-practice. The latter entails promoting authentic disciplinary practices in the classroom.

This lesson package is intended to help teachers initiate student engagement in argumentation, one of the most widely advocated disciplinary practices in science. As society advances, problems that need to be solved become increasingly more complex and multi-faceted. If students are to thrive in our science-dominating and technology-driven society, the abilities to harness information and data in a principled and rational way, to weigh multiple options objectively and critically, and to communicate their choice in a clear and convincing manner, will be highly crucial. Learning how to argue equips them with such skills. The learning tasks we have developed and present here are intended to induct young learners to engage in argumentation within an authentic real-life context.

Here is how this lesson package is organized:

Section	Brief Description	Page
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What is the CER Framework?	Explains the Claim-Evidence-Reasoning (CER) framework that we adopted as structure to scaffold the argumentation process	3-4
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Curricular Design Features	Articulates the design components of the argumentation learning tasks to provide a greater appreciation of the underlying pedagogical principles should you decide to implement the pre-designed learning tasks or develop a new one with your colleagues	6-9
Organising Students for the Argumentation Process	Presents the affordances and limitations of various ways of organising students for the argumentation process to facilitate teachers in their pedagogical decision-making	10-11
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WHY SCIENTIFIC ARGUMENTATION?

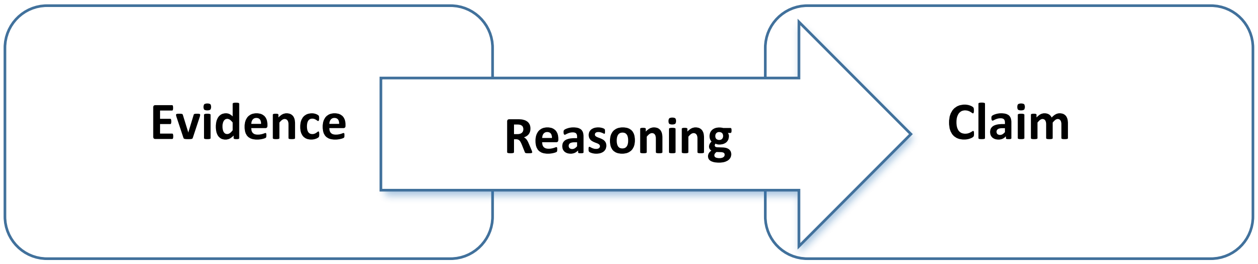
Training students in scientific argumentation should help re-focus school science from mere conceptual instruction to acculturation to scientific practices. Argumentation is one of the core practices of science, a tool that scientists use to build up explanations, models, and theories about the world. In other words, argumentation is a way of generating and confirming scientific knowledge. Therefore, when students engage in writing tasks that demand the use of data for substantiation of claims, they have the opportunity to experience the social and cognitive practices of using evidence. Through constructing arguments, they could come to a better appreciation of the processes and norms through which knowledge in science is built over time.

Students benefit from engaging in argumentation in several interrelated ways. Constructing arguments can:

1. enable students to understand science concepts. It requires them to know and apply scientific ideas as they make sense of data that they have generated themselves or collected from other sources. Students' understanding of science concepts is enriched as they shift from merely giving definitions to invoking actual instantiations of science concepts in real life.
2. change students' view of doing school science as merely memory work. It introduces them to the view that science is a particular *way of knowing* the world around us, providing descriptions and explanations of phenomena based on methods that are agreed upon by the community of scientists. When students engage in constructing arguments, they get acquainted with generating appropriate data, making sense of data and using data as evidence to explain phenomena. These affordances of the CER framework mirror some of the essential practices and discourses that scientists participate in to accomplish their work. Thus, students do not only learn science content that the syllabus requires but they also learn about the social context within and through which scientists generate knowledge.
3. train students to select, evaluate and communicate their ideas. A good scientific argument is one that is robustly supported by a set of ideas that have been carefully selected and critically examined. The process of arguing demands that students communicate persuasively their ideas that constitute the argument.
4. provide a good exercise for logical reasoning. This type of thinking is fostered when they are asked to articulate why a particular data set is considered evidence for the claim or how a scientific concept can be applied to a problem.

WHAT IS THE CER FRAMEWORK?

The CER framework is a young learner's guide for constructing scientific argumentation. Students may find learning to argue fairly daunting and so it necessary to scaffold their thinking. The three-part format - *C*laim, *E*vidence and *R*easoning – draws students' attention to three essential components of a scientific argument. It engages students to forward a claim in response to a conceptual problem or a socio-scientific issue, and to mobilise evidence and reasoning to persuade critical readers of the logic and worthiness of the claim.



IMPORTANT NOTE

It is more meaningful for teachers to position this learning tool as an epistemological tool rather than an answering technique. Students find it easy to attach a pragmatic use for the CER Framework as an answering technique because of the pressure of exams. There is nothing wrong with this per se, but while it is true that CER provides a useful template for organising ideas to craft a clear and well-supported explanation or argument, it is arguably more important for students to appreciate how the framework helps them think about what they know and how they come to know. This mode of thinking helps student achieve disciplinary understanding as they work with evidence and develop the skills to participate in scientific practices. Such a focus also avoids situation where students, who do not view CER as a useful answering technique, from giving up on its use.

CLAIM

Claim is a statement that reflects an answer or conclusion to a question or a problem. Essentially, the claim is the shortest part of the CER because it summarizes in one to two sentences the main ideas that answer the question or solve the problem. The claim is by no means the simplest part because it has to be clear and comprehensible, that is, it must be thoughtfully crafted and well-supported by a sufficient amount of evidence.

EVIDENCE

Evidence can be quantitative data and/or qualitative observations that lends support to the claim. They can be sourced from experiments or investigations that the students themselves carried out. Evidence can also be derived from text and other representational forms (tables, graphs, etc.) from well-established sources, including published reports of past research studies.

REASONING

Reasoning is a justification that shows how the data cited as evidence can support the forwarded claim. Reasoning is sometimes called “backing” because it explains why certain pieces of data were chosen as evidence for the claim. Aside from communicating the logic of the choice, reasoning invokes relevant scientific principles to enhance further coherence and credibility. Science content, otherwise known as canonical scientific knowledge, is an important resource that students must tap on in their reasoning.

ALIGNMENT OF INSTRUCTIONAL MODEL WITH MOE SYLLABUS/STANDARDS

Our CER-infused instructional model is aligned with the MOE's Science Curriculum Framework, which frames school science as the pursuit of scientific inquiry. In its articulation of scientific inquiry as a pedagogical framework, the MOE lists five essential features: (1) Question; (2) Evidence; (3) Explanation; (4) Connection; and (5) Communication. Our instructional model also features these elements, and is therefore a fitting addition to teachers' repertoire of science teaching strategies.

More specifically, our instructional model seeks to fulfil the following aims of the Lower Secondary syllabus, namely:

1. to cultivate students' perception of science as a collective effort and a way of thinking rather than just a body of facts;
2. to engage students in science-related issues that concern their lives, the society and the environment; and
3. to help students develop the domains that are integral to the conduct of Science Inquiry.

[Source: Lower Secondary Science Syllabus]

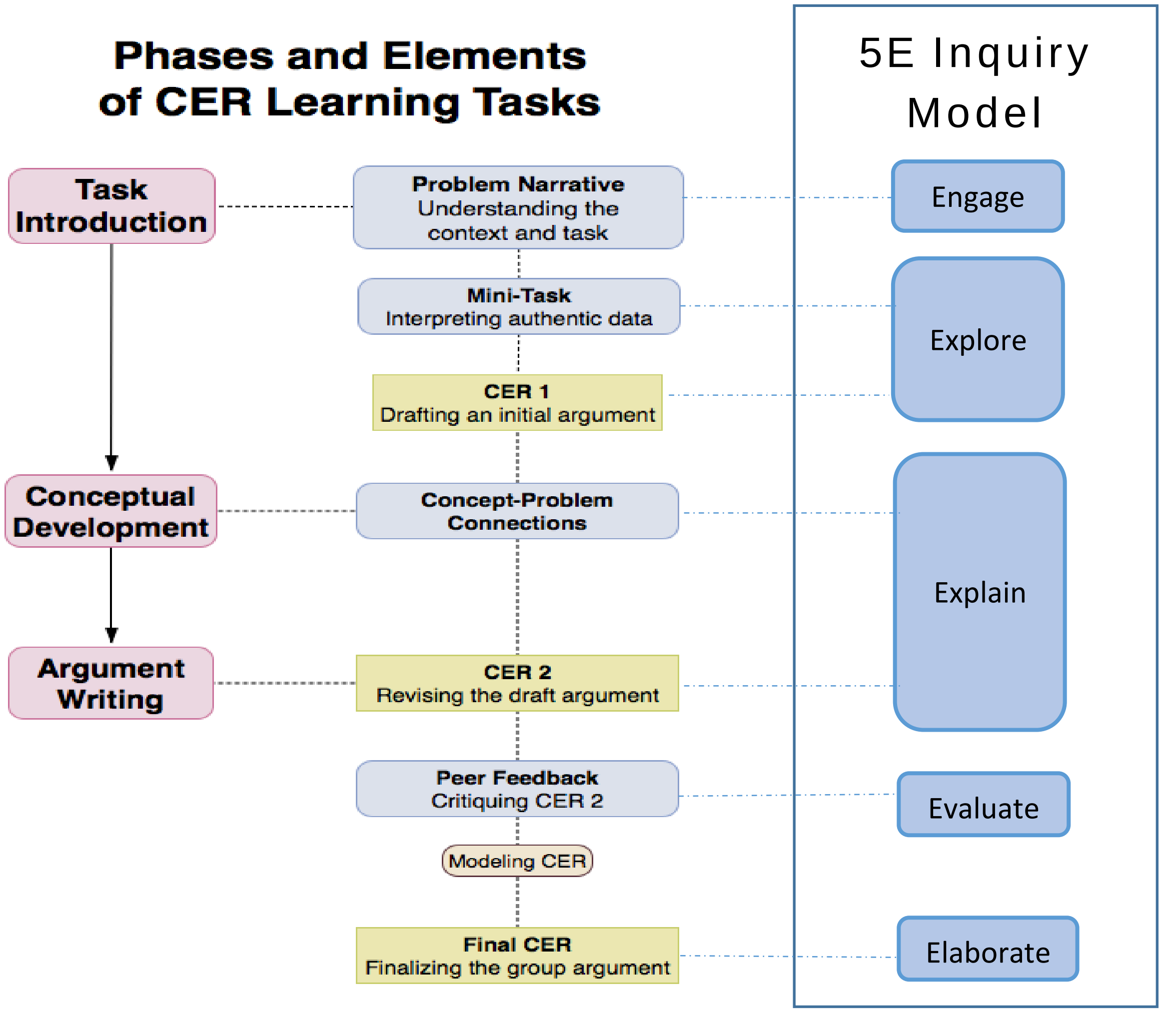
As you will see in the CER learning tasks to be described in more details in the individual learning packages (downloadable on our website), the learning progression always begins with a scenario description that situates a problem or a question in a real-life context. This design feature foregrounds the idea that science concerns itself with issues that are relevant to our day-to-day life experiences and to society in general. Additionally, in the initial and end phases of our instructional model, students work together in groups to exchange ideas and to find a consensus on their collective scientific explanation. This cooperative undertaking mimics the requisite negotiations that scientists engage in to build consensus on what counts as scientific knowledge.

The syllabus also recommends the use of assessment tools in science teaching in order to gather information on students' performance in relation to learning objectives. Our model has a formative assessment dimension. From the students' writings, the teachers can gather information on their existing ideas about a science topic and track changes as learning progresses. These texts can indicate the level of conceptual understanding achieved, including whether concepts have been applied accurately. These are valuable information for adapting instruction over time with intent to clarify and deepen students' understanding of science ideas.

Our learning tasks not only provide feedback on students' conceptual understanding but also their literacy skills. For one, constructing arguments necessitates taking up rhetorical goals to persuade their audience (which is specified in the learning task scenario) that their claim is credible and well substantiated. The ability to communicate persuasively and analytically are literacy skills that are especially useful when students are required to respond to open-ended problems and data-based problems, whether in examination or outside of it.

CURRICULAR DESIGN FEATURES

We designed three phases in students’ engagement with the learning tasks.



The phases in our instructional model also correspond with the 5E inquiry model as illustrated in the above panel on the left-hand side. We elaborate below the learning and teaching that is entailed within each of the three main phases that constitute our instructional model.

TASK INTRODUCTION PHASE

The first phase is the Task Introduction phase. Here, we introduce the main task that students will engage in throughout the duration of the unit. This task is embedded in a narrative of a real-life scenario to convey the idea that the objects of scientific investigations are relevant to everyday life and always situated in a social context.

The scenario depicted in the narrative is an invitation for students to imagine themselves as participants in a group activity whose goal is to generate well-reasoned scientific arguments. The narrative also identifies a target audience for their writing tasks. By portraying the target audience as unfamiliar with the data they possess, we hope that students would be mindful about writing more explicitly when citing data as evidence in their arguments.

The main task is complex enough to be challenging but not frustrating to students. Students are made to choose from two or more claims that represent alternative answers to an authentic problem. To determine their choice, students must not only be familiar with the scenario described in the narrative, but also know and apply certain scientific concepts.

As part of this phase, we include a mini-task to help students unpack the main question. The mini-task is a set of questions aimed at focusing student attention on the critical dimensions of the main question. Typically, we include relevant authentic data in the form of tables and graphs, guide students to make simple inferences about them, and then help them make connections to the given problem. This exercise on interpreting authentic data constitutes another authentic science practice that we want students to engage in so as to expose them to opportunities to make sense of and utilise data, a much-needed skill for answering data-based questions in examinations as well.

Creating a learning impasse is an intentional design feature of this phase. Students are asked to generate an argument (CER 1) without any prior instruction, after completing the mini-task. Asking students to choose a claim and justify their choice early on, even before conceptual instruction begins, forces them to tap on their initial understanding of the problem and expectedly unrefined knowledge of relevant science concepts. Students will most likely experience cognitive dissonance as they attempt an initial response.

Learning impasses also benefit teachers. It provides them feedback on any gaps between what students already know about the topic and the learning outcomes indicated in the syllabus. The initial writing specimen also provides information about students' writing and argumentative skills. With such information, teachers can begin to imagine how future instruction could be adjusted for more targeted conceptual and skills development.

This Task Introduction phase would correspond to the 'Engage' and 'Explore' phases of the 5E inquiry model.

CONCEPTUAL DEVELOPMENT PHASE

As the name implies, the Conceptual Development phase is concerned with the development of scientific concepts and theories during instruction. However, rather than proceeding merely to cover the syllabus topics, this phase provides students the opportunity to link the relevant concepts to the main task. This involves revisiting the task scenario as frequently as possible, at appropriate junctures during conceptual development. The idea is to make the task the centrepiece of instruction. Linking could be done through lab activities that extend evidence gathering for the problem or through discussion points (i.e. exemplification) during whole-class discussion or even post-lesson reflection questions that could be done individually or in groups.

In making regular links with the learning task through discussions, students will be able to appreciate the relevance of the scientific concepts and their role in solving everyday problems. Concurrently, students will be able to compare and contrast their pre-existing knowledge (captured in CER 1) with the canonical knowledge and be provoked to revise their conceptions accordingly. In the process, teachers will also be able to formatively assess student understanding and application of these concepts during such discussions.

ARGUMENT WRITING PHASE

Towards the end of the lesson unit, students are given the chance to revisit the task first as individuals and then in groups. As individuals, students construct their CER 2, this time armed with new scientific understanding that they lack for their CER 1. Generating CER 2 ensures that students will less likely be a passive participant during group discussion since they would already have thought through their argument for the task. During group discussion, students discuss any differences and similarities among their arguments and gradually come to a group consensus. Each group can be provided with question prompts [see section on *Supporting resources*] that open the space for recognizing agreements and critiquing differing ideas.

Working in groups provides a platform for greater exchange of ideas that could enhance argument writing. They could consolidate all the evidence they have utilised individually to strengthen support for a unanimous claim. More interestingly, during disagreement, students are likely to appropriate persuasive discourse spontaneously to convince opposing members to consider one's perspective. Thus, group discussions become critical opportunities for students to rehearse rhetoric that could be incorporated into their writing. Beyond all these benefits, adopting group work as the participation structure for discussing arguments actually reflects the real-life context of the work of scientists. Scientific knowledge is always generated by a *community* of scientists.

Students typically experience difficulty in writing their argument in the CER format in their first attempts. So, it is helpful to provide a writing sample that highlights features of good composition. Rubrics are provided to communicate to students the outstanding qualities of a claim, evidence and reasoning [see section on *Supporting resources*]. The rubrics are a helpful writing heuristic that groups can use for evaluating and revising their own or peers' written argument. Teachers can also use it as a formative assessment tool to provide qualitative feedback before and/or after students write their final group (or individual) CER.

Generating CER 2 represents the ‘Explain’ phase in the 5E inquiry model that begins in the Conceptual Development phase. The group discussion and group CER represents the ‘Elaborate’ phase; whereas the use of a criterion-reference checklist and/or rubrics for peer feedback enables both students and teachers to ‘Evaluate’ the quality of student arguments.

ORGANISING STUDENTS FOR THE ARGUMENTATION PROCESS

Constructing arguments using the CER framework can be done either individually or in groups. Teachers can choose which mode of writing will be more suitable for their own classes at different stages of learning. The advantages and disadvantages of each mode of writing arguments are elaborated below.

INDIVIDUAL CER

Having students to write their arguments individually come with the following advantages:

- The time taken to complete the argument is relatively shorter than having group CER
- Teachers are able to gauge each student's understanding
- Teachers are able to assess and track the quality of each student's argument
- Students have the opportunity to think and write independently

However, there are a few disadvantages that need to be considered:

- There will be little opportunity for students to discuss and exchange ideas
- Students have less opportunity to practice their oral argumentative skills with each other
- Teachers may not be able to support all students
- There will be more student writings to assess

GROUP CER

Having students to collaborate and write their arguments in groups come with the following advantages:

- There will be opportunity for students to work collaboratively, have discussions, and exchange ideas
- Students can learn from with each other
- Students have a chance to practice and sharpen their use of scientific language and argumentative skills when convincing their peers of their ideas
- There will be fewer student writings to assess
- Teachers are able to listen in when students verbalize their thought process to their peers and support them accordingly by facilitating group discussions

However, there are a few disadvantages of having group CER that teachers may want to take note of:

- Group CER is generally more time-consuming
- Teachers may not be able to assess and track the progress of each student
- There may be some 'free-loaders' – students who do not contribute to the discussion

WRITING SEQUENCE

For each learning task, students write and refine their arguments 3 times in total. Teacher, hence, have the freedom to combine the mode of writing arguments to reap the most benefits. The table below shows the possible combinations. However, it is worth noting that our web application is modelled after our instructional model which followed an individual→ individual → group sequence.

Sequence		**Chemical changes**			**Ecology**			**Heat**
CER 1	Individual	Individual	Individual	Group	Individual	Group	Group	Group
CER 2	Individual	Individual	Group	Individual	Group	Individual	Group	Group
Formative feedback*	SA / PF	PF	SA	SA / PF	SA	PF	SA	SA
Final CER	Individual	Group	Individual	Individual	Group	Group	Individual	Group

Note: SA = self-appraisal, PF = peer feedback; * = optional

FEEDBACK

Prior to generating their final CER, students should refine their penultimate CER. To facilitate the refinement, some form of feedback is essential. At least two types of feedback, self-appraisal and peer-feedback, are possible.

Self-appraisal

Self-appraisal is when students assess their own writing. Self-appraisal is especially suitable when the CER 2 is done as a group. Using a criterion-reference checklist/rubric and a discussion prompt card, students can critique their own group's argument and refine it further.

Peer-feedback

Peer-feedback is when students assess each other's writings. Peer-feedback is especially suitable when CER 2 is done individually. With criterion referenced checklist, students can critique their fellow group members' arguments and use the feedback received to refine their individual argument or to construct a group argument.

SUPPORTING RESOURCES

CER CRITERION REFERENCED CHECKLIST

To facilitate the construction of arguments through the CER framework in classrooms, a checklist such as one below can be used for self-evaluation, peer evaluation, and teacher evaluation.

Claim
A statement or conclusion that answers the original question/problem. The claim needs to be: (1) accurate – *Is the claim accurate in relation to the evidence and reasoning?* (2) *complete – Is the claim comprehensive?*
Evidence
Scientific data that support the claim. The data need to be: (1) specific - *Are number/value and source of evidence cited?* (2) appropriate - *Does the evidence support the claim?* (3) sufficient - *Are all the evidence cited?*
Reasoning
A logical explanation containing scientific concepts that links the claim and evidence. The reasoning needs to: (1) be accurate - *Are the concepts used scientifically accurate?* (2) be sufficient - *Does the reasoning explain whether it is a physical or a chemical change?* (3) display task understanding - *Does the reasoning show understanding of the need to explain the type of changes involved?* (4) be coherent - *Are the claim, evidence, and scientific concepts linked together in a logical and systematic way?*

Self-evaluation

Students can use the checklist as a guide while generating their CER. Alternatively, they can use the checklist to evaluate their own arguments after completing their arguments.

Peer evaluation

Prior to the final CER stage, student can be engaged in feedback or peer-evaluation session where they comment on each other's arguments. The checklist, therefore, can be used to evaluate their peers' arguments.

Teacher evaluation

The checklist can be used by teachers to evaluate students' arguments. It can be used to track students writing progress as the lesson progresses, or, to grade the quality of students' arguments.

RUBRICS TO ASSESS CER

Below is an example of a rubric (based on the topic of ecology) that teacher can use to evaluate and score students' arguments. As some criteria may not be applicable to all types of questions, some discretions from teachers are necessary when adopting the rubric. The following list can thus be viewed as a toolkit from which teachers can select relevant criteria for assessment. The selected criteria set must not only match the type of question asked but also the pedagogical goals set (e.g. key scientific concepts targeted during the lessons).

Component	**Criterion**	**Levels**	**Points**	**Description**
Claim	Clarity	No claim	0	No claim statement
		Unclear	1	Statement ambiguously expresses a claim
		Clear	2	Statement clearly expresses a claim
	Accuracy[1]	No claim	0	No claim statement
		Inaccurate	1	Statement is conceptually inaccurate
		Accurate	2	Statement is conceptually accurate
Evidence	Data Citation	No indication	0	No supporting information for claim
		Minimal	1	Mentions some established information about the control measure of choice (e.g., fogging) and/or lists organisms in the mosquito food web
		Moderate	2	Provides additional established information on the control measure (e.g. description of how pyrethroids kill adult mosquitoes during fogging) and/or includes more organisms in the

Component	Criterion	Levels	Points	Description
				mosquito food web and other relevant information
		Good	3	Provides substantial information about the control measure of choice in order to support the claim
	Breadth	No comparison	0	Does not compare across the three control measures
		Limited comparison	1	Compares only two control measures
		Full comparison	2	Compares across all three control measures
Reasoning	Accuracy	Inaccurate	0	Incorrectly pieces together evidence gathered
		Accurate	1	Correctly pieces together evidence gathered
	Depth/ Elaboration	Lacking	0	Includes no further supporting details
		Minimal	1	Includes a few further supporting details
		Moderate	2	Provides some examples, imagined scenarios to clarify justifications
		Good	3	Clearly articulates/elaborates justifications through examples and imagined scenarios
	Relevance	Totally irrelevant	0	No line of reasoning supports the claim
		Some irrelevant	1	Some lines of reasoning do not support the claim
		Relevant	2	All lines of reasoning support the claim
	Framing	Simple	1	Mobilizes ecological concepts (e.g., predation, population, species) to frame argument[2]
		Complex	2	Builds on ecological concepts to weigh pros and cons and/or provide a risk analysis[3]

Notes

[1] Claims for the Ecology learning task were not evaluated for accuracy since the question does not demand a claim statement requiring accurate concepts. The claim is simply a statement of choice of the control measure with the least impact on biodiversity.

[2] An example of simple framing:

> *I choose introducing non-native mosquitofish in ponds in Singapore. If mosquitofish were added into ponds, it means that a new species is added into the habitat, contributing to a variety of animal species present there. Also, it controls the population of mosquitos by eating the eggs, larvae and pupae of mosquitos in ponds. There will be less transmission of mosquito-borne diseases such as dengue, zika, malaria, etc. If mosquitofish's population increases greatly, there will be lesser mosquitos present in the habitat over time, decreasing its population. If too many mosquito-eating fishes are present, there will be overcrowding, resulting in a lack of food. And in the end, the fishes will start to die out.*

[3] An example of complex framing:

> *Removing artificial breeding sites of mosquitoes has the least impact towards biodiversity. Firstly, removing artificial breeding sites of mosquitoes prevents the adult mosquitoes from laying their eggs.* ***This causes a decrease in mosquito population****.* ***However, this will also affect other organisms living around the area*** *where the artificial breeding sites have been removed. Organisms such as fishes and frogs will be* ***affected due to the absence of a food source****. Dragonflies are also affected as they lay their eggs in these breeding sites.*
>
> *Fogging helps to kill any mosquitoes that could be carrying the dengue virus. The insecticide uses synthetic chemicals called pyrethroids, which are* ***toxic to beneficial insects*** *such as bees and dragonflies, fish, and other aquatic organisms such as snails and tadpoles. Pyrethroids may be washed off by rainwater to nearby bodies of water,* ***potentially exposing aquatic organisms to harmful levels****.* ***Fogging also kills animals that feed on mosquitoes as they also consume the insecticides****.*
>
> *Introducing non-native mosquitofish in ponds in Singapore allows the fishes to feed on the mosquitoes' larvae and pupae. However, the mosquitofish would also eat other native species when the mosquito population decreases.* ***The ecosystem and the food chain will also be affected due the decrease in mosquitoes and non-native species****.*

PROMPT CARDS

Prompt card suggested below can be used during group discussion to facilitate a more productive collaboration among students. It serves as a checklist if students have reach a consensus in their discussion.

DO ALL THE GROUP MEMBERS MAKE THE SAME CLAIM?

YES

- Share your reasons for making the claim.
- What evidences are available to support your claim?
- What evidences currently not available would be needed to support your claim?

DO ALL THE GROUP MEMBERS MAKE THE SAME CLAIM?

NO

- Share your reasons for making your claim.
- What evidences are available to support your claim?
- What evidences currently not available would be needed to support your claim?
- Based on the evidences available, which claim is most likely to be valid?
- What evidences and reasons can be used to support this final claim?

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