



Designing for Engineering: A Model for Integrating Engineering and Science NGSS Middle School Benchmark Assessments

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**The
Lawrence**
Hall of
Science



Project Description

- Four-year project (concluding 2022)
- Funded by The Carnegie Corporation of New York
- Goals:
 - Design summative, NGSS-aligned, curriculum-neutral, three-dimensional assessment items for all middle school Performance Expectations
 - Freely provide assessments for educator use and adaptation



Design Approach for Integrating ETS PEs

- Unpack each dimension of the ETS PE
- Create ETS Knowledge, Skills, and Abilities (KSAs)
- Use KSAs to draft initial, science-content-neutral learning performances
- Analyze science item sets for PEs that include ETS DCI elements (secondary)
- Determine missing ETS KSAs
- Modify or add to science item sets to incorporate missing ETS KSAs



Research Question

- Does the project design approach allow for the integration of the NGSS ETS PEs with science PEs such that the resulting items elicit 3D student performances aligned to both PEs?



Data Types

Multi-Curriculum Group

Reviews: FOSS, The Learning Design Group, SEPUP (project lead)

External Expert Panel Review:

Review by external panel of NGSS-assessment experts for each item set with specific criteria

External Testing*: Conducted with non-project staff with NGSS familiarity, various science backgrounds and teaching experience, and “middle-school hats on”

*Covid-19 disclaimer



Item Set Types

Stand Alone

- Engineering content only
- Item set per PE (ETS 1-1 and 1-4) or with two ETS PEs (ETS 1-2 and 1-3)

Integrated

- Engineering PE and content PE (e.g. ETS1-1 and PS 2-1)
- Engineering DCI and content PE (e.g. LS2-5) Note: engineering DCIs identified as secondary per framework



Question: Does the project design approach allow for the integration of the NGSS ETS PEs with science PEs such that the resulting items elicit 3D student performances aligned to both PEs?

We looked at...

- multi-curriculum group review: alignment between PE dimensions within item sets and curriculum instructional content
- external expert review: individual items and overall item sets scored on three-dimensionality and alignment to NGSS, with annotations and comments provided
- external testing: sample responses and moderated scoring



Question: Does the project design approach allow for the integration of the NGSS ETS PEs with science PEs such that the resulting items elicit 3D student performances aligned to both PEs?

Generally the data showed...

- multi-curriculum group review: strong alignment
- external expert review: >85% rated 4 or above for eliciting 3D responses
- external testing: scorers agreed prior to moderation or easily reached a moderated score, item sets all elicited 3D responses

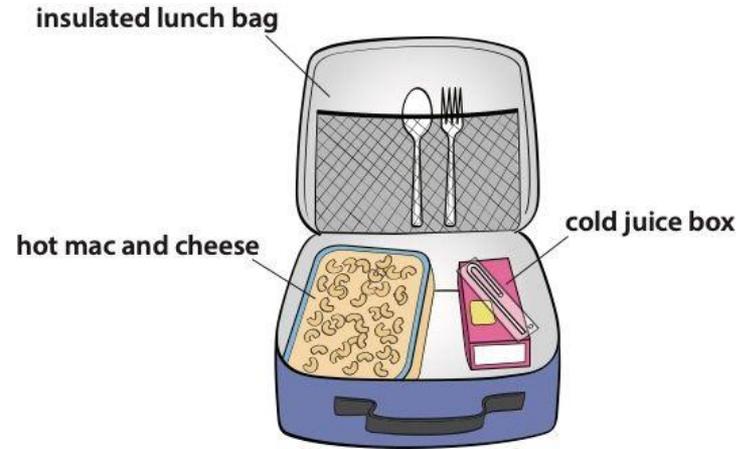


NGSS Dimensions - Example 1

PE	SEP	DCI	CCC
ETS 1-1	Asking Questions and Defining Problems	ETS1.A Defining and Delimiting Engineering Problems	Influence of Science, Engineering, and Technology on Society and the Natural World
PS 3-3	Constructing Explanations and Designing Solutions	PS3.A Definitions of Energy PS3.B Conservation of Energy and Energy Transfer ETS1.A Defining and Delimiting Engineering Problems ETS1.B Developing Possible Solutions	Energy and Matter

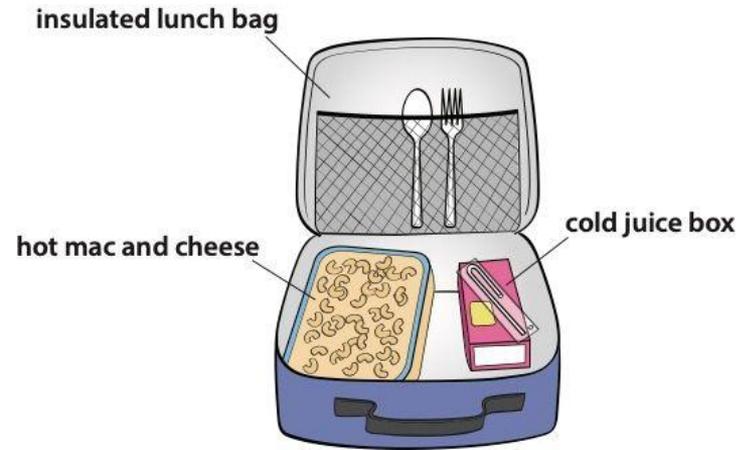
Assessment Item Set Scenario ETS1-1

Your friend Kira needs a new lunch bag and asks you for help in designing a good one. Before you can design it, you need to figure out the criteria and constraints for the design. Kira wants a lunch bag that will have room for both macaroni and cheese and a juice box. She wants to keep the macaroni and cheese hot and the juice box cold at least until lunch time. She knows the lunch bag will need to be insulated to maintain the temperature she wants. People tend to like hot food between about 60C and 70C and cold drinks between 3C and 8C. Kira only has \$15 to use for the lunch bag, and she needs to be able to carry it in her backpack.



Assessment Items ETS1-1 (Summarized)

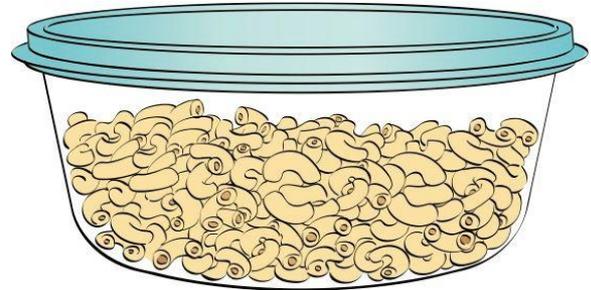
- List criteria and constraints and explain how you can tell if they were met.
- Explain why the lunch bag pictured would not solve Kira's design problem.
- Identify a criterion Kira could add to reduce the impact of her lunch bag design on the environment.



Assessment Item Set Scenario PS3-3

Your friend Kira brought her lunch to school one day. She opened her plastic container and was disappointed that the macaroni and cheese was not hot, even though she had heated it up in a microwave before she filled the container.

Kira wanted to understand why her container didn't keep her food hot. She decided that a model would help her because temperature depends on the motion of particles that are too small to see.



Assessment Items PS3-3 (Summarized)

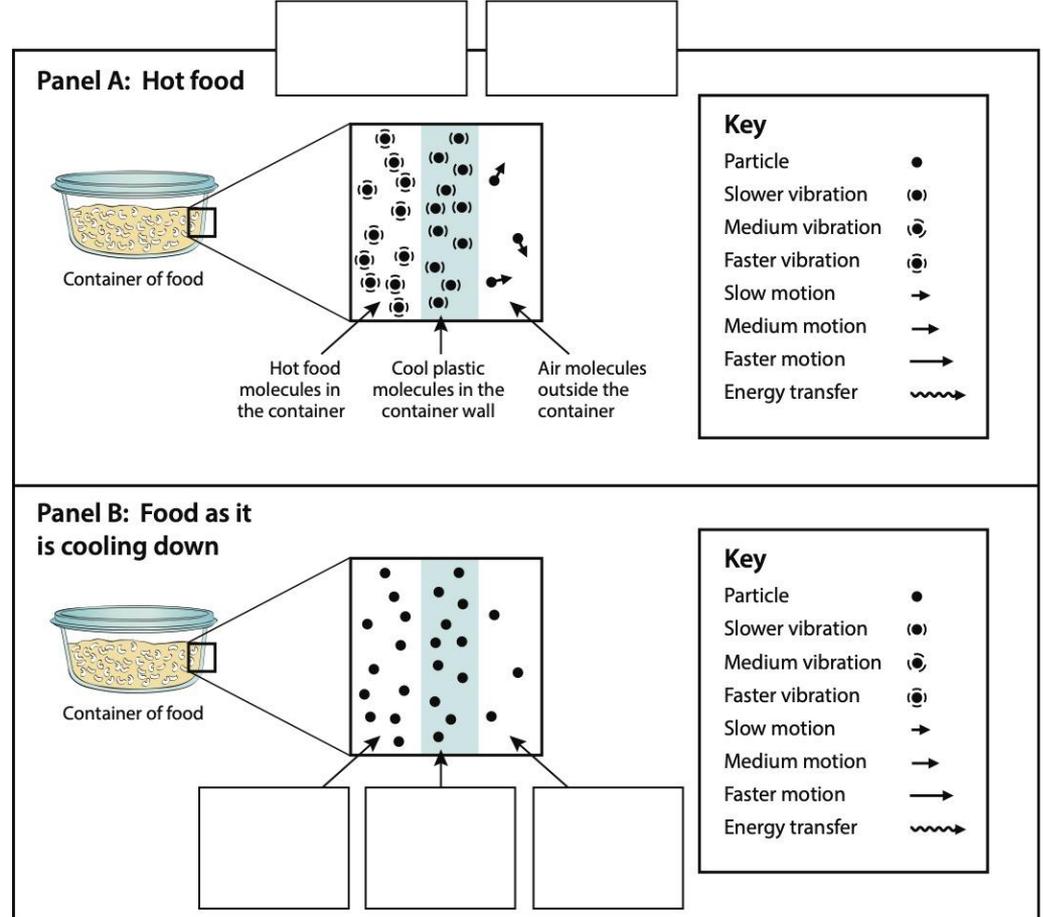
Item 1

a. Add symbols and captions to the model

b. How would you improve the design?

Item 2

Identify criteria and constraints for redesign, including science ideas about energy transfer in new design. Sketch new design and environmental component.



Note: Distances between particles are not to scale



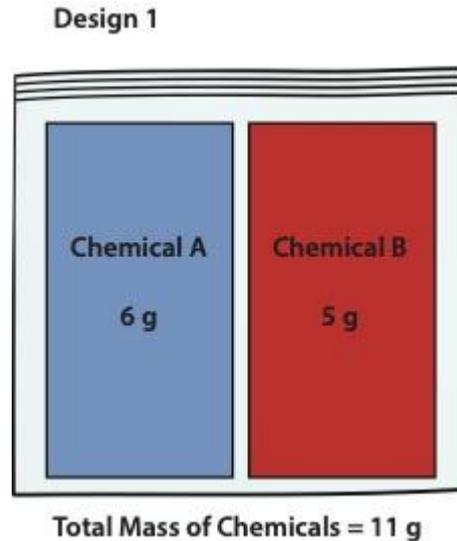
NGSS Dimensions - Example 2

PE	SEP	DCI	CCC
ETS 1-3	Analyzing and Interpreting Data	ETS1.B Developing Possible Solutions ETS1.C Optimizing the Design Solution	Not designated in framework
PS 1-6	Constructing Explanations and Designing Solutions	PS1.B Chemical Reactions ETS1.B Developing Possible Solutions ETS1.C Optimizing the Design Solution	Energy and Matter

Assessment Items and Sample Responses - PS 1-6

Item 1 Scenario

Your class has been asked to evaluate and improve designs for a hand warmer that can be used on a cold day. The hand warmer designs contain two pouches of chemicals inside a plastic bag. When the plastic bag is squeezed, the pouches break and the chemicals mix, causing a chemical reaction. During the chemical reaction, the plastic bag should feel warm. There are four designs.



Time (minutes)	Temperature (°C)
0	30
1	35
2	40
3	45
4	46
5	47
6	47
7	47
8	47
9	47
10	46



Assessment Items and Sample Responses - PS 1-6

Item 1a

Review the four designs and explain the energy transfer that takes place for each design.

In Designs 1, 2, and 3, the chemical reactions release energy, which causes the bags to get hot. In Design 4, the chemical reaction absorbs energy, which causes the bag to get cold.

NGSS Dimensions: [Analyzing and Interpreting Data](#), [Chemical Reactions](#), [Energy and Matter](#)



Assessment Items and Sample Responses - PS 1-6

Item 1b: Describe how well each of the four designs meets the criteria and constraints shown below.

Criteria:

- Warms to at least 40°C within 3 minutes.
- Temperature stays above 45°C for at least 5 minutes.

Constraints:

- Two pouches of chemicals inside a plastic bag that will keep the chemicals safely contained.
- Total mass of chemicals not to exceed 10 g to control costs.
- Maximum temperature not to exceed 50°C to prevent the handwarmers from getting too hot and causing burns.

Design 1 meets both criteria. It warms to 40°C within 2 minutes and stays above 45°C for 8 minutes. It does not meet all of the constraints. It does have two pouches and does not exceed 50°C but the mass is 11g. Design 2...

NGSS Dimensions: [Analyzing and Interpreting Data](#), [Chemical Reactions & Developing Possible Solutions](#), [Energy and Matter](#)



Assessment Items and Sample Responses - PS 1-6

Item 1c

What design do you think comes the closest to meeting the criteria? How could you modify that design to try to meet the criteria and constraints? Use the data and your response for Part A to explain why you would test this modification.

The only design that meets the criteria is Design 1. However, it does not meet all of the constraints. I would try to decrease the mass of one of the chemicals by 1 gram. Because Design 1 stays warm for so long, decreasing the mass of one chemical by one gram might make it stay warm for less time but probably not so much that it would stay warm for less than 5 minutes.

NGSS Dimensions: [Constructing Explanations and Designing Solutions](#), [Developing Possible Solutions & Optimizing Design Solutions](#), [Energy and Matter](#)



Lessons Learned - Broadly Applicable

- Stand-alone ETS PE items do elicit 3D responses
- Integrated item sets allow for deeper sensemaking
- Lack of CCC designation in some ETS PEs does not mean they can't be applied and assessed



Lessons Learned - Limitations

- Different curricula may integrate ETS PEs with varying content
 - All ETS PEs integrated in a bioengineering unit
 - ETS PEs spread across Earth science Units
 - ETS PEs incorporated across physical science and life science units
- Integration is not always possible
 - State or other assessments across districts using different curricula
- Limitations to broadly-applicable design applications



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Contact Information

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Assessments will be available soon at:

<https://www.lawrencehallofscience.org/educators/cinga>