Learning Progressions in Science: Analyzing & Deconstructing the Multiple Dimensions in Assessment

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Introduction

The goal of our research is to develop learning progressions and accompanying assessment materials identified in *A Framework for K-12 science education: Practices, crosscutting concepts, and core ideas* (NRC, 2012). We propose to address a Science & Engineering Practice (e.g., scientific argumentation), a Crosscutting concept (e.g. patterns), and Disciplinary Core Ideas in each of the following foundational middle school science domains - physical science, life science, and Earth science. This study builds upon existing work around argumentation, physical science, and life science. Specifically, we focus on a crosscutting concept – patterns (PAT), continue our research on a practice – argumentation (ARG), and focus on the disciplinary core ideas of natural resource (NR) and natural resource - human impact (NR-HI), ecology (ECO), and structure of matter (SOM).

Selected Research Questions

The research questions of interest:

1. How well can the dimensions of the learning progressions for *scientific argumentation* and *patterns* and the three disciplinary core ideas, *physical science, life science, and earth science*, be measured?
2. How does student competency in *scientific argumentation* and *patterns* differ or stay the same across the three disciplinary core ideas?

Methods

The development of the assessment material is guided by the construct modeling framework (see Figure 1; Wilson, 2005), which consists of four building blocks – construct map, items design, outcome space, and measurement model. We use the BEAR Assessment System Software (BASS) to conduct our research.

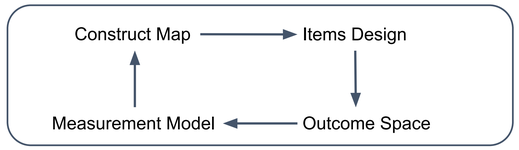


Figure 1. The four building blocks of measurement development in learning progression adapted from Wilson (2009)

Data

We collaborate with teachers in California and Arizona to co-create the construct maps, items, and outcome space. They represent an important source of information in making our learning progression practical, interpretable, and actionable to teachers. We have collected responses for from 2,401 students for the 6 constructs (see Table 1).

Dimension	# of Items
Disciplinary Core Idea-Structure of Matter (SOM)	24
Disciplinary Core Idea-Ecosystems (ECO)	24
Disciplinary Core Idea-Natural Resources (NR)	8
Disciplinary Core Idea-Natural Resources-Human Impacts (NR-HI)	4
Practice - Scientific Argumentation (ARG)	32
Cross-cutting Concept - Patterns (PAT)	17

Table 1. Items developed and tested

Highlights - Scientific Practice (Argumentation) & Crosscutting Concept (Patterns)*

ARGUMENTATION

Waypoints	Description
ARG-3	Students at this level are able to argue from evidence, making claims, supporting the claims with evidence, and connecting them with reasoning. Students need support in constructing counter arguments and identifying which of two arguments is stronger.
ARG-2	Students at this level are able to make claims and identify evidence. They need support finding reasoning to connect their claims to evidence.
ARG-1	Students at this level are starting to understand how to argue from evidence. They may be able to make a claim and are beginning to learn to identify evidence.
ARG-0	Notions - naive conceptions.

Table 2. Construct map for Argumentation (ARG)

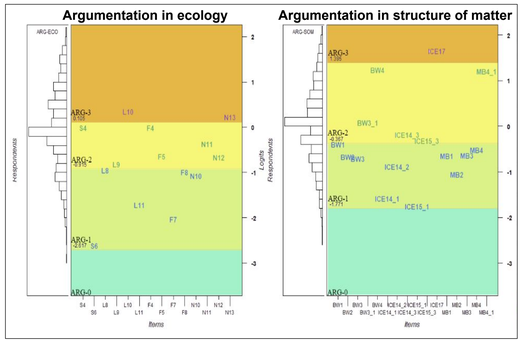
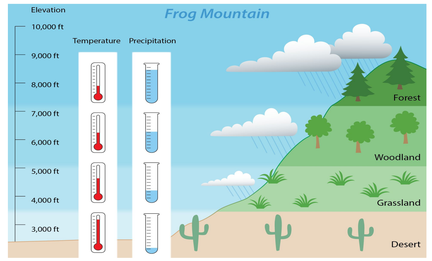


Figure 2. Wright map of ARG across ecology and structure of matter

PATTERNS

Waypoints	Description
PAT-3	Identifies and describes patterns, including relationships, that are relevant to an explanatory model.
PAT-2	Identifies and describes a how phenomenon changes between endpoints (e.g., cycles, trends, distributions)
PAT-1	Notices differences and/or similarities of two or more instances of a phenomenon or representation of a phenomenon (e.g., classification)
PAT-0	No Patterns or Naive conceptions

Table 3. Construct map for Patterns (PAT)



What is the relationship between elevation and climate?
As elevation increases, temperature [increases/**decreases**/stays the same] and rainfall [**increases**/decreases/stays the same].

Figure 3. An Exemplar Patterns Item addressing the highest waypoint (PAT-3)

Here are our current versions of Construct maps for the Disciplinary Core Ideas (as mentioned in the *Next Generation Science Standards*, NGSS Lead States, 2013)

Natural Resources - Freshwater as a Limited Resource (NR-LR)	Natural Resources - Human Impacts (NR-HI)	Interdependent Relationships in Ecosystems (ECO)	Structure of Matter SOM)
NRLR-4: Not all people have equal access to clean freshwater. Social structures, cultural relationships, economic systems, and political boundaries can limit or facilitate access to water.	NRHI-4: The impacts of human activities on environmental systems are not evenly distributed. Some communities are disproportionately impacted.	ECO-3: Complex relationships among organism populations	SOM-4: Reasoning about chemical changes using imagined entities
NRLR-3: Rainfall and groundwater are unevenly distributed. Plant and animal communities grow where conditions meet their needs; people can collect, store, and transport water to where they need it, but this requires energy and capital.	NRHI-3: Some technologies and human systems can be designed to improve access to and quality of freshwater, but implementation of these technologies requires capital, energy, and cultural, social, and political commitments.	ECO-2: Indirect relationships among organism populations	SOM-3: Reasoning about physical changes using imagined entities which does not require concrete referents
NRLR-2: Natural processes can limit freshwater availability (e.g., drought).	NRHI-2: Humans have engineered systems to obtain, clean, and distribute water. These systems and structures can alter the availability and quality of water for people and other organisms.	ECO-1: Direct relationships among organism populations	SOM-2: Reasoning about invisible/imagined entities but only with concrete macroscopic referents
NRLR-1: Water is essential for life. Freshwater is available from surface and underground sources. There is also water in the atmosphere.	NRHI-1: Humans are living organisms and are connected to other organisms and elements in the environment.	ECO-0: Naive conceptions	SOM-1: Reasoning is about macroscopic entities
NRLR-0: Naïve Conceptions	NRHI-0: Naïve Conceptions		SOM-0: Initial conceptions

Table 4. Construct maps for the four science content areas under study.

*Argumentation, Patterns, and Ecosystems are highlighted given space constraints.

Ecosystems (ECO)

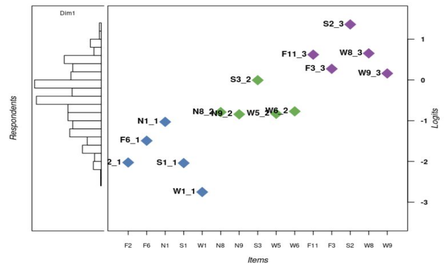


Figure 4. Wright map for ECO

Implications

- Thus far, we have designed construct maps for a crosscutting concept (Patterns), a practice (ARG), and four disciplinary core ideas (i.e., natural resources, natural resources - human impacts, interdependent relationships in ecosystems, and the structure of matter). This provides preliminary evidence that constructs of these types can be developed and validated. Specifically, the order of waypoints in Wright maps support the validity of the construct maps for ECO, ARG-ECO, and ARG-SOM.
- Assessment material has been developed and preliminarily tested so that we can loop the empirical and theoretical together and ultimately provide evidence to the practice community regarding student facility and/or knowledge.
- While the ordering of waypoints is the same across the ARG constructs, we found that, for all three waypoints, ARG-SOM appears to be relatively more difficult than ARG-ECO. Research continues.

Future works

- We will collect students' responses to all new and revised items and provide empirical validity evidence for all the construct maps we developed.
- More ARG and PAT items will be created or revised to cover the three disciplines: physical sciences, life sciences, and earth sciences.
- We will continue to work with researchers and teachers to collect their feedbacks and ideas on our construct maps and items, e.g., how students progress in the waypoints defined in the construct map.

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