Quantitative Reasoning Learning Progression: Rasch Analysis

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Abstract

NSF funded Culturally Relevant Ecology, Learning Progressions, and Environmental Literacy Project (DUE-0832173) which we called **Pathways** established **learning progressions for environmental science in grades 6 to 12**.

- Quantitative Reasoning (QR) research team studied impact of QR on environmental science progression
- QR essential for environmentally literate citizen to make data informed decisions.
- More needs to be known about the progression of students' QR development in STEM

The development of learning progressions requires an **iterative research design** that explicates progressions of learning over long periods of time. The purpose of this study is to **develop and verify a hypothesized learning progression for QR with environmental sciences as a context**.

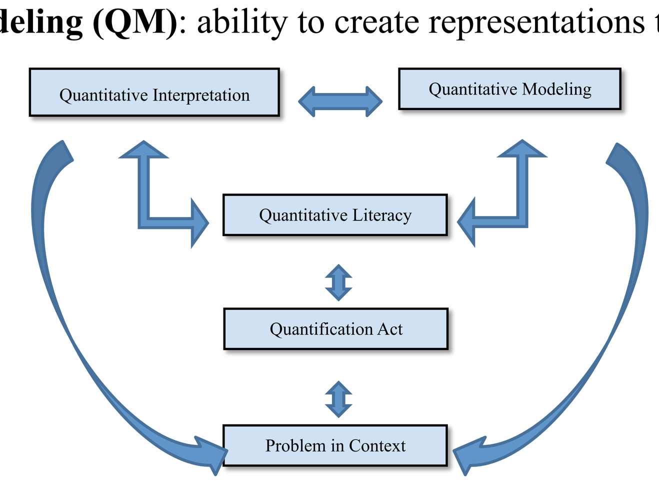
Theoretical Framework

The definition of QR used in this study, derived from the literature and informed by QR student interviews:

Quantitative reasoning is mathematics and statistics applied in real-life, authentic situations that impact an individual's life as a constructive, concerned, and reflective citizen. QR problems are context dependent, interdisciplinary, open-ended tasks that require critical thinking and the capacity to communicate a course of action. (Mayes, Peterson, & Bonilla, 2013)

We propose that QR has three fundamental components:

1. **Quantification Act (QA)**: mathematical process of conceptualizing an object and an attribute of it so that the attribute has a unit measure, and the attribute's measure entails a proportional relationship (linear, bi-linear, or multi-linear) with its unit. QL is an element of QA
2. **Quantitative Interpretation (QI)**: ability to use models to make predictions and discover trends, which is central to a person being a citizen scientist
3. **Quantitative Modeling (QM)**: ability to create representations to explain a phenomena



Research has suggested that learning progressions can help inform curriculum design, professional development, as well as advance effective adaptive instruction teaching techniques (Duschl, et al., 2007; Corcoran, Mosher, & Rogat, 2009).

Research Questions and Goals

The **purpose** is to establish a learning progression for QR within the context of environmental science for middle and high school students (6th to 12th grade).

Central research question:

How do students develop QR in the context of environmental science across 6th–12th grade?

Procedural questions :

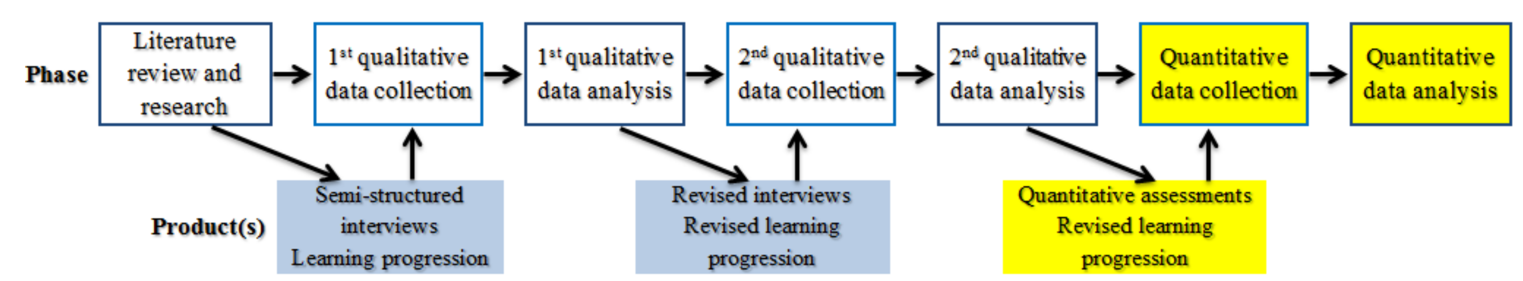
What are the QR progress variables (dimensions of understanding, application, and practice) that support the development of an environmentally literate citizen?

What level of QR within the context of environmental science do students bring to the discourse at the sixth grade level?

What are the key QR conceptual stepping stones to moving from a novice to environmentally literate citizen? How do these inform a QR learning progression?

What are the QR tasks students at a given learning progression level should be capable of performing?

Research Method



Creating learning progressions (LP) involves grounding the **lower anchor** in domains accessible to sixth graders. In addition, **intermediate levels of understanding** need to be identified through which they pass on their way to attainment of the upper anchor. The **upper anchor** is based on expert views of what QR a scientifically literate citizen should know and be able to do by the 12th grade. This is done through an iterative research process where LP is informed by student interviews and closed-form assessments.

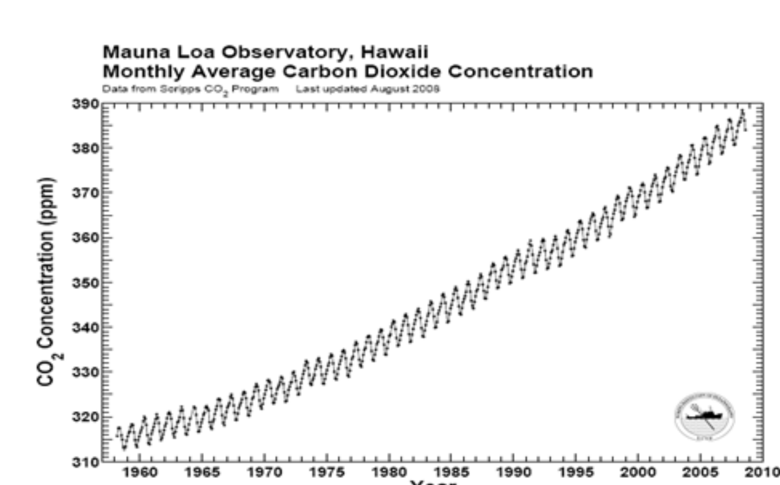
Semi-structured Interview: hypothesized LP was first tested empirically via semi-structured interviews

Closed form Assessments: based on interview analysis, 3 closed-form assessment versions for **Quantitative Interpretation (QI)** were developed, one for each **science strand** in Pathways (Biodiversity, Carbon, and Water) across three different **scales of environmental science** (Macro scale - personal experience of the world, Landscape scale - global generalizations, Micro/Atomic scale - hidden mechanisms). These assessments focus on four components of QI that we have identified: **trends, predictions, translation, and revision**.

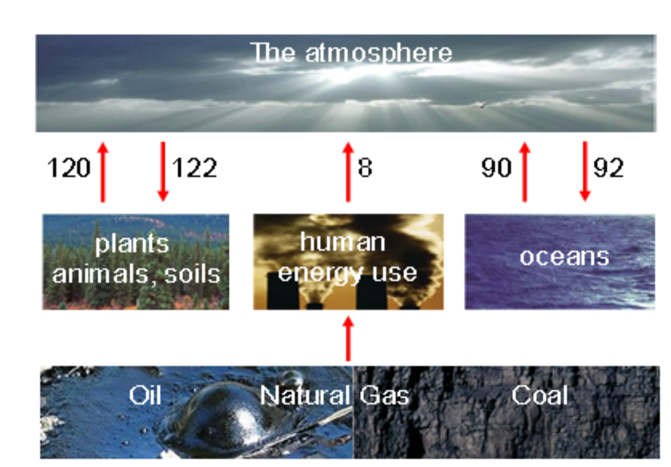
Over 500 students from 3 states completed a version of the closed form assessments online using Qualtrix. Rasch Analysis was used to analyze the assessment data, both to improve the assessments and determine QI trends from grade 6 to 12.

The following is an example of a QI assessment item for trends.

The graph and table below show the concentration of carbon dioxide in the atmosphere in parts per million (ppm) for every year since 1958. The box model gives the exchange of CO_2 during the years 2000-2005 in gigatons of CO_2.



Carbon Cycle Box Model



Year	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
CO_2	316.9	320.0	325.7	331.1	338.7	346.0	354.4	360.8	369.5	379.8	389.9

1.	Trends cannot be determined from the box model.	Very strongly disagree	1 2 3 4 5	Very strongly agree
2.	The change in CO_2 concentration is not linear or curvilinear, it just randomly varies across time.	Very strongly disagree	1 2 3 4 5	Very strongly agree
3.	The amount of CO_2 concentration is increasing.	Very strongly disagree	1 2 3 4 5	Very strongly agree
4.	Trends cannot be determined from a table.	Very strongly disagree	1 2 3 4 5	Very strongly agree
5.	The single point in 1995 can provide the CO_2 concentration, but cannot explain trends in CO_2 concentration.	Very strongly disagree	1 2 3 4 5	Very strongly agree
6.	The amount of CO_2 concentration is increasing and the rate is not constant or linear.	Very strongly disagree	1 2 3 4 5	Very strongly agree
7.	The CO_2 concentration trend is best represented by a quadratic function, not a linear or exponential function.	Very strongly disagree	1 2 3 4 5	Very strongly agree
8.	The function $y = 0.012x^2 + 0.83x + 314.33$ is a possible model for this data, indicating that the increase of CO_2 is more every year.	Very strongly disagree	1 2 3 4 5	Very strongly agree

QR Learning Progressions Framework

QR Progress Variable	
Achievement Level	Quantitative Interpretation
Level 4 (Upper Anchor)	**4a Trends**: determine multiple types of trends including linear, power, and exponential trends; recognize and provide quantitative explanations of trends in model representation within context of problem **4b Predictions**: makes predictions using covariation and provides a quantitative account which is applied within context of problem **4c Translation**: translates between models; challenges quantitative variation between models as estimates or due to measurement error; identifies best model representing a context **4d Revision**: revise models theoretically without data, evaluate competing models for possible combination (Schwarz)
Level 3	**3a Trends**: recognize difference between linear vs. curvilinear growth; discuss both variables, providing a quantitative account **3b Predictions**: makes predictions based on two variables, but relies on qualitative account; uses correlation but not covariation. **3c Translation**: attempts to translate between models but struggles with comparison of quantitative elements; questions quantitative differences between models but provides erroneous qualitative accounts for differences **3d Revision**: revise model to better fit evidence and improve explanatory power (Schwarz)
Level 2	**2a Trends**: identify and explain single case in model; recognize increasing/ decreasing trends but rely on qualitative account or change in only one variable **2b Predictions**: makes predictions for models based on only one variable, provides only qualitative arguments supporting prediction **2c Translation**: indicate preference for one model over another but do not translate between models ; acknowledge quantitative differences in models but do not compare **2d Revision**: revise model based on authority rather than evidence, modify to improve clarity not explanatory power (Schwarz)
Level 1 (Lower Anchor)	**1a Trends**: do not identify trends in models **1b Predictions**: avoids making predictions from models **1c Translation**: fail to acknowledge two models can represent the same context **1d Revision**: view models as fixed, test to see if good or bad replicas of phenomena (Schwarz)

Results

Rasch approach is a modern latent trait model that allows examination of both item statistics and person statistics using the same linear scale. Removed persons were not simply those representing extreme measures, but those representing improbable response patterns relative to item measures and other participants.

	Biodiversity	Carbon	Water
Rasch Iteration 1	122	114	126
Rasch Iteration 2	99	89	98

Person and Item Summary: The mean scores for three assessments on average 64% of the possible points

	Biodiversity Assessment				Carbon Assessment				Water Assessment			
	Person		Item		Person		Item		Person		Item	
	Total	Infit	Total	Infit	Total	Infit	Total	Infit	Total	Infit	Total	Infit
Mean	309.9	-0.3	319.6	0.0	307.6	-0.6	285.2	0.0	303.7	-0.6	310.0	0.0
S.D.	27.3	3.2	27.3	1.5	23.3	3.9	19.3	1.5	21.4	4.2	24.4	1.4
Max	390.0	5.4	414.0	4.5	367.0	9.3	345.0	5.5	368.0	9.6	357.0	3.5
Min	274.0	-7.5	267.0	-3.8	261.0	-9.5	231.0	-2.6	269.0	-9.9	266.0	-3.7
Reliability	0.85				0.80				0.72			

- An infit standardized z score greater than 2 indicates a suspicious score, either where the odds were too perfectly met (too predictable) or there is too much noise (unpredictable). Mean OK, S.D, Max, Min concern.
- All three assessments have alpha levels above 0.72 indicating relatively high reliability
- Item fit statistics, when combined with difficulty and ability measures suggest closer examination of items for revision, as well as breaking up the 96 item administration into shorter sets of items to help increase participant focus.
- Rasch ruler indicates for the biodiversity assessment 14 person measures exceeded all items, indicating they had better than a 50% chance to get all items correct. Person measures are higher than the item measures, a number of item measures do not overlap with person measures on the lower end of the scale, which tends to increase error for both item and person measures.