Rethinking Assessment Formats: Development of a New Measurement Strategy for Assessing Scientific Sensemaking

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Instrument Design & Methods

- The assessment was constructed using a modified SSM framework that was developed from two previous instruments focused on life sciences.
- Unlike past iterations, this instrument is more interactive and the context focuses on physical science, specifically, space science and the search for habitable planets, using real data from NASA’s Kepler mission.
- This particular physical science context was chosen because space was ranked highly among middle school students as an area of general interest.

Facets of Scientific Sensemaking (SSM)

Evidence
- Student evaluates evidence in light of the question and in general for what counts as evidence. Use of data as evidence:
  - 3. Extracts relevant data for research question.
  - 2. Analyzes and interprets graphs, tables, and data accurately and with intention.
  - 1. Interprets the outcomes of controlled and comparative experiments to answer question(s).
  (Toulmin, 1958; Erduran & Limes-‐Alexandre, 2009; Sampson & Clark, 2006)

Explanations
- Mechanism open ended assessment
  - Student: 1. Constructs mechanistic explanations of phenomena.
  - 2. Provides claims and evidence that illustrate assumptions.
  - 3. Situates his/her own understanding in social context of competing alternatives while coherence seeking.
  - 4. Understands the justifiability relationship between claims, evidence and reasoning.
  (Russ et al., 2008; Carey, 1995; Kosolwicz, 1995; Staudt et al., 2007; Kemper et al., 2007; Erduran, Simion, & Osborne, 2004; Sismondo, 2004)

Questions
- Student: 1. Recognizes and generates appropriate questions.
- 2. Poses investigative questions or identifies investigable problems.
  (Schirra & Steiner, 2000; Chiu & Osborne, 2008)

Pilot Study

This simulation was administered to twenty-three 7th and 8th grade students who attended a summer camp serving public school students of color who excel academically and come from low-income backgrounds.

Coding Schemes

Responses were coded according to three coding schemes. Two of the schemes, the Mechanism Coding Criteria & the Argument Coding Criteria (Nagy Catz et al. under review) featured hierarchical, mutually exclusive codes for assessing the mechanism and argumentation in students’ responses. A third coding scheme for mechanistic reasoning (Russ et al., 2008) codes for understanding evidence of mechanistic reasoning, but the levels are not mutually exclusive.

Implications for Design

- Providing an interactive experience to students with the actual science content necessary to succeed embedded in the assessment proved to be successful. The students constructed complex arguments and mechanistic explanations using a real world current science problem.
- By using two different coding schemes for the three open ended mechanism items, we were able to compare what each scheme afforded. The Russ et al. (2008) scheme provided more information about the actual mechanistic reasoning occurring, but our schemes did not correspond, i.e., more mechanistic reasoning codes (Russ et al., 2008) also got higher scores (Nagy Catz et al., under review).
- Traditional curricular design focuses on experiences within our own solar system in middle school; however, we designed our assessment around the search for habitable planets outside our own solar system. In this pilot, we found that some students used examples from within our solar system, but were able to apply these principles to the planets in our scenario while constructing an evidence based argument.

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Sample responses, with codes:

<table>
<thead>
<tr>
<th>Mechanism open ended item with student exemplar</th>
<th>Argument open ended item with student exemplar</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does the distance of a planet from its star affect the temperature? Please explain how distance affects temperature.</td>
<td>From the list pick which planets you think could have liquid water, and write a letter to NASA telling them which of these planets they should point the new telescope at, and explain why.</td>
</tr>
<tr>
<td>Mechanism Coding Criteria (Russ et al., 2008)</td>
<td>Argument Coding Criteria (Russ et al., 2008)</td>
</tr>
<tr>
<td>Chaining, analogies, and animated models identifying organization of entities</td>
<td>Chaining, analogies, and animated models identifying organization of entities</td>
</tr>
<tr>
<td>Mechanistic Reasoning Coding Scheme (Russ et al., 2008)</td>
<td>Mechanistic Reasoning Coding Scheme (Russ et al., 2008)</td>
</tr>
<tr>
<td>(5) Claim connected to reasoning and evidence</td>
<td>(5) Claim connected to reasoning and evidence</td>
</tr>
<tr>
<td>(4) Mechanism (the HOW) and cause/effect relationship explained</td>
<td>(4) Claim with unlinked reasoning and evidence</td>
</tr>
<tr>
<td>(3) Concrete cause and effect relationship</td>
<td>(3) Claim with reasoning or evidence</td>
</tr>
<tr>
<td>(2) Vague cause and effect relationship or checklist of different causes</td>
<td>(2) Claim only or unwarranted evidence</td>
</tr>
<tr>
<td>(1) No cause and effect relationship or general statement</td>
<td>(1) Solutions or personal</td>
</tr>
<tr>
<td>(0) No explanation or off topic</td>
<td>(0) No Claim or off topic</td>
</tr>
</tbody>
</table>

Preliminary Results

Students’ responses generally confirmed that the simulation and survey provided students rich opportunities to make sense of which extra-solar planets might support life. Comparing the responses and codes across the students, we have begun to notice nuanced differences in how students are approaching the task. Some were approaching it more like a “school” task, using canonical vocabulary without much evidence of making sense of physical mechanisms, while others seemed to do quite the opposite. Here we highlight three students who have slightly different approaches to answering the questions. We qualitatively characterize their approaches, citing evidence from their responses.

Three Interesting Cases

Appealing to canonical knowledge
- The student’s responses go beyond the confines of the scenario by using examples from prior experience and planets within our own solar system. The questions that she generates are about habitability, but in relation to the planets she knows, not the planets in the scenario. Her questions about habitability seem to be motivated by her desire to understand her own solar system. She approaches the argument question with a planet in mind (Neptune), not the one we gave her, and uses the factors shown to be relevant in the scenario to reason through how it could be habitable.

Appealing to prior knowledge, taking ownership
- The student’s responses are more rooted within the experience of the simulation, although they also appeal to prior knowledge, by making reference to our solar system. They answer questions about mechanism by interpreting what occurred in the simulation when manipulating its hands-on features. They recognize the importance of relevant factors, such as the size of a planet and its distance from a star. However, they characterize these factors as individual entities and do not construct a cohesive mechanistic explanation as to how these factors are interconnected.

Students:...