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# Epistemic Commitments: A Lens for Heterogeneity in Science

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**Abstract:** Research about modeling emphasizes the importance of heterogeneity in science, yet also seeks curricular convergence. In response, we propose two constructs. *Heterogeneity-seeking curricula* emphasize multiple representations of phenomena, offering an image of science as messy and nonlinear. *Commitments* parallel epistemic cognition by focusing on values that shape students' modeling; however, rather than looking for disciplinary practices in students' modeling, we take students' values as a starting point to articulate commitments. Using commitments, we analyze six implementations of a heterogeneity-seeking 6th grade modeling curriculum, comparing commitments to epistemic criteria and considerations.

## Objectives and significance

Research about modeling in science classrooms highlights the importance of heterogeneity in science learning (Rosebery et al., 2010), emphasizing the complexity involved in developing scientific expertise (Pierson et al., 2021; Jaber & Hammer, 2016; Manz & Suárez, 2018). At the same time, a growing body of scholarship seeks curricular pathways for convergence of epistemic and representational practices (Barzilai & Chinn, 2017; Berland et al., 2016; Reiser et al., 2021). In this paper, we amplify the productive tension between heterogeneity and convergence with two constructs. *Heterogeneity-seeking curricula* emphasize multiple perspectives of phenomena across representational forms. Though we acknowledge shared understandings are essential for classroom praxis, in a heterogeneity-seeking classroom, knowledge products constitute an emerging, shared vocabulary that gives voice to students' ideas and questions rather than being end-points of inquiry. *Commitments* offer a lens for exploring the values that motivate and inform students' interactions with models and with one another. Our notion of commitments, paralleling epistemic cognition, focuses on students' values. However, whereas epistemic criteria (Pluta et al., 2011) and considerations (Berland et al., 2016) look for disciplinary practices in students' modeling, commitments take students' values as a starting point, mapping them to disciplinary resources that are sometimes overlooked in classrooms. These constructs offer lenses for noticing and capturing the discursive life of models in a classroom community by emphasizing students' values and ideas, problematizing how phenomena have been positioned as objective and external to students' modeling work (Reiser et al., 2021), instead showing them to be a production of the classroom's discourse.

## Conceptual framework

Though "commitment" has been used in varying ways (e.g., Chinn et al., 2011), we conceptualize commitments as fine-grained resources (Hammer et al., 2005) that shape how students use, value, and learn from models. From a resource perspective, commitments are activated and expressed by individuals in response to conceptual and social contexts (Elby et al. 2016). Yet, commitments do not reside solely in individuals; at a group level, emergent epistemologies are jointly constructed and reconstructed from resources within communities of practice (Goodwin, 2018). As a result, individuals can enact and display sometimes-conflicting commitments (Clark, 2006; diSessa et al., 2004), including those that represent their membership in multiple communities (Bang & Medin, 2010). We propose that commitments can function in some similar ways to the "ideals" of the apt-AIR epistemic cognition framework (Barzilai & Chinn, 2017), though their role for researchers and for students extends beyond epistemic cognition. As an analytic lens, epistemic cognition frameworks take disciplinary values as a starting point, searching for forms of these values in students' work (e.g., Berland et al., 2016). In contrast, commitments take students' values as a starting point (identifying students' values and mapping these commitments to disciplinary constructs). This perspectival shift opens analysis to a wider range of students' resources that may not align with science education's normative conception of disciplinary values. We distinguish between these lenses in three ways. First, because commitments emerge from students' modeling activities, they include material and phenomenological aspects that are backgrounded in research about epistemic ideals. Second, while some commitments in our data aligned closely with primary epistemic ideals, others would be considered "secondary," "vague," "nonepistemic," or "less sophisticated" using existing frameworks for epistemic criteria (Pluta et al., 2011) and practical epistemologies (Berland et al., 2016). Third, commitments played different roles for students' modeling than epistemic ideals; rather than only being used to evaluate models, commitments were also used (a)

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to explain why or how one model should inform another, (b) to position models as complementary, and (c) to relate models to broader contexts. In the context of this heterogeneity-seeking curriculum, we use a resource-focused lens to ask two research questions: What commitments emerged that influenced students' modeling? and, How can a lens of commitments help science education researchers identify and analyze students' values and their role in modeling?

## Method

We analyze data collected during a design study (Cobb et al., 2003) that iteratively refined a modeling curriculum about ecosystems. This study was conducted in a public middle school in a small suburban school district in the southeastern US in collaboration with a STEM teacher, Ms. S. Six of Ms. S's 9-week 6th grade classes participated (August 2018 to March 2020, 105 students total). From each class, 5-6 students were selected by the 6th grade teaching team as representative of their peers, and these students were interviewed about their experiences in the unit. All iterations of the curriculum foregrounded modeling. Throughout the unit, students were instructed to create diagrammatic, physical, computational, and embodied models. The unit was framed by two design challenges: students designed a biosphere, a closed-system physical model that included plants, snails, and guppies (a typical pet fish in the US); and they programmed a computational model that represented a larger ecosystem of plants, snails, guppies, and guppies' competitors and predators. Throughout the unit, the students gathered information and iteratively re-represented the guppies' environment with increasing complexity. We analyze focal student interviews and whole class discussions to identify students' commitments and how they shaped students' modeling using inductive coding (Charmaz, 2006). To identify commitments, we transcribed interviews and whole class discussions with turns of talk as the unit of analysis. We created initial coding categories in part based on students' language (e.g., "real world"). We compared these categories to studies of professional science and to research about epistemic ideals in science classrooms. In this paper, we have grouped commitments into categories (see Findings). This structure is not hierarchical (no commitment is considered more "sophisticated" than the others), and these commitments could be named and organized in a variety of ways; thus, rather than focusing on the relationship between these four commitments, we focus on the nature of these commitments and their role in a heterogeneity-seeking modeling curriculum.

## Finding: Commitments

In interviews, most focal students (26 out of 33) valued connecting their models to the **"real world."** This commitment maps to several epistemic criteria. From Pluta et al. (2011), it maps to the primary criterion of "accuracy" ("how faithfully the model depicts the target") and the secondary criterion of "realism" ("use the word real"). In prioritizing representing the real world, some students' responses also map to the primary criterion of "explains-2" (Pluta et al., 2011), because they value models that "show how and why" (Carlos: "how a giant biosphere works"). From Berland et al. (2016), valuing models that "show how and why" addresses the question, "What kind of answer should our knowledge product provide? (Nature [of account])" (p. 9). Explaining "how and why" suggests a mechanistic account, which Berland et al. have characterized as "more powerful" for constructing and evaluating knowledge" (p. 13) compared to a descriptive account (Carlos: "tell how it looks like"). In contrast, in our data, students did not always prioritize mechanistic accounts; for example, Caleb wanted to explore a descriptive question: how much oxygen a guppy needs.

A majority of focal students (24 out of 33) also valued models that could **"show"** phenomena to themselves or others. The commitment to seeing and showing phenomena maps to several epistemic criteria. Like the commitment to real-world, seeing and showing in some cases connects to "explains-2" (Pluta et al., 2011) and "Nature of Account" (Berland et al., 2016), because students valued models that showed mechanistic explanations (e.g., Nora: when algae are spread out, guppies die faster) although they sometimes also appreciated descriptive accounts (e.g., Nora: "more environmental" food web representation). This commitment also connects to "clarity" ("model is easy to understand;" Pluta et al., 2011, p. 496) and "audience" ("Who will use our knowledge products and how?"; Berland et al. 2016, p. 9).

Several focal students also valued models that enabled them to **"control"** variables by holding them constant or to "change" variables by manipulating them (15 out of 33). This commitment overlaps with several epistemic ideals about evidence; however, whereas these epistemic ideals are primarily evaluative, students in our classroom typically foregrounded controlling and changing variables when they were designing models. In a convergence-seeking curriculum, students might evaluate a model by considering the quantity and quality of evidence that was included ("quality of support" and "accuracy" in Pluta et al., 2011; "Nature of account" and "Justification" in Berland et al., 2016). In retrospective reflections, students' commitments functioned in a similar, evaluative way (e.g., Carlos: "it was kind of like testing soil differently"). Yet, as they were designing or using models, students more often emphasized affordances for investigations (e.g., David: "the computational model

won't go wrong unless you tell it too"). This forward-looking stance toward models positions models not only as "knowledge products" that can be evaluated but also as generative tools for exploring ideas.

Over half of the focal students (18 out of 33) voiced a sense of responsibility to **care** for the plants and animals in their biospheres or for the species or environments represented by their models. Caring for model components and their referents influenced how students thought about designing, using, and learning from models. There is no analogous epistemic ideal in Pluta et al. (2011) or in Berland et al.'s (2016) epistemic criteria or considerations. While Barzilai and Chinn's epistemic cognition framework includes affective and ethical dimensions (e.g., "caring about… epistemic performance" and "aspiring to epistemic justice;" 2017, p. 13) based on research that demonstrates that science learning is inextricably intertwined with students' *epistemic* affect and *epistemic* motivation (Jaber & Hammer, 2015), these aspects are narrowly focused on the production of (disciplinary) knowledge rather than broader axiological dimensions of learning.

## Discussion: Nature and role of commitments

In these classrooms, commitments functioned as resources (Elby et al., 2016; Sandoval, 2005). Students' commitments were pressing but unstable (interpreted and enacted differently by different students and by given students at different times). Commitments were also linked to models in a perspectival, rather than an inherent, way (took on different meanings for different students in relation to models). As a result, commitments were not a "property" of models or of students – they instead influenced how students valued and interacted with their models. In our data, commitments functioned in *some* ways like epistemic ideals by acting as evaluative resources during modeling. Yet, because each of these commitments connects to different, yet overlapping, aims, commitments were not hierarchically ranked. As a result, we would not expect to see students' progress toward "sophisticated" (Krist, 2020) or "primary" (Pluta et al., 2011) commitments, as they might with epistemic ideals. And because commitments were not stable across models, we also would not expect to see students develop a shared set of criteria that could be used to evaluate models generally, an activity common in convergence-seeking curricula (Pluta et al., 2011; Ke & Schwarz, 2021). Instead, a lens of commitments emphasizes making connections across multiple representations and ways of knowing (Warren et al., 2020).

First, students used commitments to justify one model informing another. For example, Karla suggested using the plant investigation to inform the computational model. She explained that students "did not really use [the plant investigation] as much as they needed to" to make the computational model "accurate with real life." In other words, she wanted to use the plant investigation to strengthen connections between the computational model and the ***real world***. In other cases, students saw the computational model as informing the design of "real" models. For example, Nataly used her computational model to imagine the guppy in her biosphere jar; her commitment to ***caring for*** the guppy helped her empathize with the guppies. Because she was concerned that the computational guppy looked lonely, she suggested her group include two guppies in their jar.

Second, students used commitments to position models as complementary–by connecting their own models (of different types, e.g., computational, food web), and also by connecting their models to their classmates'. For example, Lacie characterized all her models as "helpful because, like, you can find out different things." She described how she could ***change variables*** in the computational model ("make guppies do what you want them to do) and explained how she could ***show phenomena*** in the food web ("helps you show, like, what they're gonna eat"). Students also positioned models of the same type as complementary. For example, when Nora and Sean presented their food webs, rather than positioning one model as correct, they described how each group's model ***showed*** different perspectives of ecosystems (Nora's "energy pyramid" and Sean's "more environmental" model). Just as commitments were not ranked hierarchically, models were not seen as competing with or replacing other models. Instead, each model offered new perspectives that contributed to an assemblage of representations that became more valuable as models and perspectives were incorporated.

Third, students used commitments to relate their models to other experiences. For example, Wade wanted to give the plants "a chance at life," and Dolores and Hunter suggested that the biospheres could teach guppies how to "survive on their own in the wild." In these cases, a commitment to ***caring*** guided how students interacted with their models. Commitments also helped students think about why models might be used to investigate phenomena. For example, Micah explained that a scientist would need to "test the stuff on the computational model and do it in real life [in a biosphere] to see how the effects would turn out… so you don't mess up the river," explaining how the models could be used to protect ***(care for)*** populations in a river. As in these examples, students' commitments helped them consider the roles of models in the outside world.

In summary, while commitments aligned in some cases with epistemic ideals, their roles in these classrooms extended beyond those of epistemic ideals. Epistemic ideals are used to evaluate models. They support convergence-seeking aims by providing students with agreed-upon standards for developing and assessing knowledge. To this end, they guide students in creating mechanistic and "gapless" explanations (Ambitious

Science Teaching [AST], 2014, p. 3), producing abstract and generalizable knowledge (Berland et al., 2016), and justifying claims with evidence (Krist, 2020; Pluta et al., 2011). These are important goals for epistemic education (Barzilai & Chinn, 2017) that can help students appropriate powerful disciplinary practices. However, exclusively foregrounding these goals for epistemic education could limit the values that students use to navigate their STEM learning. Our data indicate that students can draw on a broad range of values to guide modeling, which sometimes resemble professional practices that are backgrounded in science education.

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