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# Ontological Alignment: Investigating the Role of the Teacher in Supporting Computational Modeling in Science Classrooms

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**Abstract:** Though the medium of computational modeling presents unique opportunities and challenges for science learning, little research examines how teachers can effectively support students in this work. To address this gap, we investigate how an experienced 6th grade teacher guides her students through programming computational, agent-based models of diffusion. Using interaction analysis of whole-class videos, we define a construct we call *ontological alignment* in which the teacher facilitates discourse to surface, highlight, connect and seek supporting or contradictory evidence for student ideas in ways that align with the level of analysis available in the modeling tool. We identify two practices reflecting this construct; the teacher 1. primes students to orient to interactions between particles and 2. strategically selects evidence to help discern between student theories. We discuss the pedagogical value of ontological alignment and suggest the identified practices as exemplary for supporting students' learning through computational modeling.

## Introduction and background

Modeling is a central practice in scientific work and involves explaining a phenomenon by representing its key elements and their underlying behaviors, relationships, and interactions. Computational modeling, and specifically, domain-specific agent-based modeling (ABM), has emerged as an important practice that can simultaneously support students in science and computing (e.g., Kahn, 2007; Wilkerson-Jerde et al., 2015).

Teachers play a critical role in facilitating student engagement with modeling (Ke & Schwarz, 2021). However, uncertainties and challenges persist around teachers' roles in supporting students' computational modeling work. As with any modeling work, teachers must navigate between modeling as a practice for content learning vs. a practice for generating, exploring, and validating or refuting yet unknown scientific knowledge (Guy-Gaytán et al., 2019). As a relatively new representational medium and practice, computational modeling offers unique opportunities and challenges that merit more focused research. Many aspects of programming computational models can be challenging for students, as it requires them to identify relevant content, manage programming structure and syntax, and map content onto the ontological structure of code (Basu et al., 2016). Teachers need to respond to these challenges with tailored support. Incorporating any new epistemic tool or practice into a classroom can be a complex task; teachers and students require time and space to negotiate between their goals and the tool's functionality (Wilkerson et al., 2022) before settling on productive engagement practices. However, despite the central role of teachers in guiding modeling activities, most existing research focuses on the efficacy of diverse teaching approaches using *pre-built models* (Hmelo-Silver et al., 2015) rather than on how teachers can support students in *computational model building* for learning.

In this paper, we investigate how an experienced 6th grade science teacher guides her students through a computational, agent-based model-building unit about diffusion. Specifically, we pursue the following research question: *How does an experienced science teacher support students in expressing and representing their ideas through a computational modeling unit?*

Based on our analysis, we identify a construct called *ontological alignment* that we define as a lens the teacher adopts in facilitating discourse to elevate student ideas that align with the level of analysis available in the tool (in this paper, particle-level behaviors and interactions). We see ontological alignment as important to supporting discourse when using new epistemic tools and practices in science classrooms.

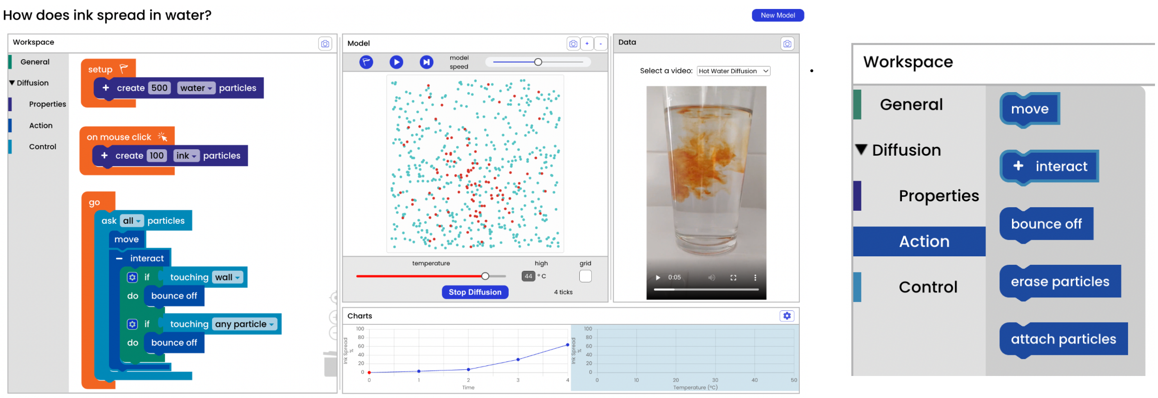
# Methods

## Materials

The computational modeling unit studied in this paper was enacted in MoDa, an agent-based, domain-specific, block-based environment that puts a computational model side-by-side with real-world data of the target phenomenon (Fuhrmann et al., 2022; Wagh et al., 2022). MoDa includes a coding workspace, a space to run simulations, and a real-world data area with video of the phenomenon (Figure 1, left). The code library for this unit includes blocks to define particle-level interactions such as “bounce off” and “attach” (Figure 1, right).

Over 5 days (1 hour/day), students investigated how ink diffuses in water. They ran an experiment comparing the diffusion rates in hot and cold water (Day 1), drew models to explain observed differences (Day 2), and presented their ideas to the class (Day 3). They used MoDa to program models representing their theories about diffusion (Days 3 & 4) and compared their computer models with video data (Day 5).

**Figure 1**
*MoDa with coding, modeling, and data areas (left) and diffusion-specific code blocks (right).*




## Data collection & analysis

Ms K is a 6th grade teacher at a public school in the Bay Area, CA. She was selected for this analysis based on her 8+ years of experience teaching computational modeling curricula in which students explored pre-built models. This was her second year teaching a computational modeling unit using MoDa in which students programmed their own models. Of Ms K’s two classes, one class was randomly selected for analysis. Data sources include observation notes and whole-class video recordings.

Based on observation notes and video review, we identified 4.5 hours of video of teacher-led, whole-class discussions in which Ms K introduced, reviewed, or contextualized the computational modeling activity. Following interaction analysis methods (Jordan & Henderson, 1995), members of the research team reviewed the videos independently and collaboratively to identify the teacher’s high-level pedagogical practices around supporting her students’ computational modeling work. In mapping the relationships and goals of those pedagogical practices, we developed the construct of *ontological alignment*, which we define as facilitating discourse in ways that surface, highlight, connect and seek supporting or contradictory evidence for student ideas that align with the level of analysis available in the tool (in this case, particle-level behaviors and interactions). Through discussion and comparison, we clustered the initial set of pedagogical practices into two moves critical to establishing ontological alignment, presented below in the Findings.

# Findings

We present two ways ontological alignment was visible in Ms K’s facilitation of classroom discourse: 1. underscoring student ideas about particle-level interactions and how those relate to ABM; and, 2. strategically selecting evidence to discern between student theories about interactions.

## Underscoring ideas about particle interactions and how they relate to ABM

Ms K emphasized particle behaviors and interactions in ways that aligned with the representational infrastructure of MoDa, an ABM platform. On Day 2, she organized students’ paper models into five groups of “theories” about how ink spreads in water. Words representing MoDa blocks are bold; words used by students in discussions and drawings are underlined: 1. “The water particles are infecting, consuming, soaking in, capturing, dissolving the ink particles"; 2. "Water and ink particles are mixing but not **attaching**"; 3. "The water particles are **bouncing off** the ink particles to cause the spreading of the ink"; 4. "The water particles are combining, growing or coming together, **attaching** to the ink particles"; and, 5. "The compactness or density or space between the particles affects the spread of ink in water." Each theory either highlighted an interaction between particles (e.g., #2 or 3) or flagged the kind of outcome students would expect to see when they run their model (e.g., "not attaching"). Notably, the language for these theories came from students and reflected the block library available in MoDa (e.g., "attach" and "bounce").

In the whole-class presentations that day, Ms K supported students in thinking about how to translate their ideas into computational models. For instance, during Parker's presentation of his paper model, Ms K asked students to consider how they might code their explanation:

> *Parker: In this one, the ink was far apart. In a little bit more time, it was closer together.*
> *Ms K: Did the ink particles increase or break apart? How did there get to be more ink particles?*
> *Parker: It slowly increased because the ink particles were splitting apart.*
> *Ms K: So that'll be super interesting to think about when you make this computer model, like how can you take an ink particle and split it apart?*

Parker explained that the ink spreads in water because the ink particles split apart, but there is no block in MoDa for splitting particles. Aware of the challenge of translating this explanation into a computational model, Ms K asked students to think about how they would represent that idea in their computational model.

On Day 3, after student pairs programmed their first MoDa models, Ms K pulled up four student models representing those theories or combinations thereof. Introducing one pair's model, Ms K said "They're doing kind of an interact and **attaching** theory. So watch what happens to the particles here [*plays simulation*]" (emphasis added). Here, Ms K labeled a student model (#4) and supported students in noticing how the model represented this interaction. Specifically, she instructed students to "pick an ink and water particle and watch what happens to them." After a few moments of watching the simulation, one student commented, "What the heck, the particles are **attaching**" while another student noticed that "only the water seems to be **attaching**, not the ink." In these instances, students saw how each theory, even ones they may not have programmed, could be programmatically encoded and simulated.

## Strategically selecting evidence to discern between student theories

When using MoDa, students support or refute the explanations encoded in their models by running the simulation and comparing it to video data of the target phenomenon. By Day 4, the "infect theory," the idea that ink particles change the color of water particles to cause the spread, was popular in the class but could not be invalidated using the video data available in MoDa. Outside class, Ms K discussed at length with the third author what kind of evidence would help students refute the infect theory. On the last day, Ms K asked students how they could test their idea that "the water has been fully infected." Students suggested that "you could evaporate it" or "you could use a microscope." On a projected slide, Ms K showed the class an experimental setup in which water mixed with blue dye was evaporated from a dish covered with plastic wrap (which she referred to as "Saran wrap"). When she asked students to discuss with their partners what color the water on the plastic wrap would be, some students predicted it would be blue.

> *Ms K: Ok, it would be blue if the infection theory is correct. If the water is not blue on top of the Saran wrap, what does that mean?*
> *A few students: That that theory is incorrect.*
> *Ms K: That the infection theory is incorrect. (Shows next slide with clear droplets on Saran wrap)*
> *Ms K: What color is the water?*
> *Multiple students: Not blue.*
> *Ms K: It's not blue. It's clear. So does the ink infect or get captured by the water?*
> *Multiple students: No.*

Ms K strategically brought evidence that helped students discern between their ideas and brought in new evidence to invalidate a theory that could not be disproved within MoDa itself. Here again, Ms K operated from an understanding of the strengths and limitations of the computational modeling possible within MoDa and found ways to support students where the code and simulation fell short. She situated computational modeling as one tool for scientific sense making and exemplified for students how to best pair that tool with other science practices and techniques to advance their theory-building work.

## Discussion and Conclusion

This paper addresses a pressing gap in the literature about how teachers can support computational model building in the classroom. It defines a construct, *ontological alignment,* to characterize the teacher's work of guiding discourse to highlight the representational infrastructure and level of analysis in the computational tool being used. We present two manifestations of ontological alignment in Ms K's practice: 1. underscoring student ideas about particle-level interactions and how they map onto ABM; and 2. strategically selecting evidence to discern between student theories about particle-level interactions. Collectively, these practices required the teacher to adopt an ontological lens of particle-level interactions and, throughout the unit, to elicit student ideas about interactions, support them in translating these ideas into a computational medium, and find evidence that would help students discern between the different theories. Space constraints exclude our ongoing analysis of how students take up these practices. The paper contributes to research on teachers' roles in computational modeling by illustrating how ontological alignment can guide a teacher in supporting classroom discourse around computational modeling. The focal teacher's understanding of MoDa went beyond simply knowing how to use it; she was intimately aware of its strengths and limitations, which informed how she guided students in her class. Ultimately, our findings highlight the importance of teachers seeing computational tools as supporting the expression and refinement of particular forms of students' existing ideas and facilitating discourse from that perspective. We see ontological alignment as important to supporting discourse when using new epistemic tools and practices in science classrooms.

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