Making Students' Ideas Visible through Coding a Scientific Computational Model

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Abstract: This study investigates the ideas of 5th-grade students while creating computational models for diffusion. Results illustrate that translating ideas into code can be a strategy to make them explicit. However, there is tension between designing blocks and learning; limited numbers of blocks interfere with students' expressing their ideas, while an open environment can make it hard to converge into acceptable explanations. We argue that creating domain-specific-blocks for modeling needs to be a thoughtfully designed process.

Introduction

Designing computer models is a promising approach to science learning. It combines the advantages of traditional modeling with computational literacy, opening new possibilities for inquiry-based learning (Weintrop et al., 2017; Wilkerson et al., 2015). Nevertheless, developing a computational scientific model can be a demanding task for teachers and students in elementary and middle school. In the past decade, many new environments have been designed to allow kids to create their own models using block-based programming languages and other innovative user interfaces such as NetTango (Horn et al., 2014), Deltatick (Wilkerson et al., 2015), StarLogo Nova (Klopfer et al., 2009). Drawing on these ideas, this paper introduces the designed nine domain-specific blocks of the scientific phenomenon of diffusion as a Scratch extension.

This study aims to explore what ideas students have about diffusion and how they were translated into code during an activity based on the Bifocal Modeling approach (Blikstein, 2016; Fuhrmann et al., 2018). We use the term "ideas" to refer to the understanding that students have developed about the natural phenomena of diffusion of ink in hot and cold water. Students' ideas are challenging to identify, and many times invisible to teachers. In this sense, designing a model with domain-specific blocks can be a valuable way to disclose students' ideas about the scientific phenomenon of diffusion while students are still in the midst of an inquiry activity.

Methods

The study was conducted with seven students in grade 5 through individual Zoom sessions that lasted approximately one hour. The sessions were based on the Bifocal Modeling approach split into four “mini activities” where students created a program to model the process of diffusion after observing an experiment using the designed domain-specific blocks. Data sources included seven hours of video recording and seven computational models.

Results and Discussion

Data illustrates that students had diverse ideas to explain the process of diffusion. Two main types of ideas were observed: ideas that could be tested with the available blocks - for example, the idea of “speed” - and ideas that could not be expressed with blocks - for example, the idea of “melting”. A summary of students' ideas is presented in Table 1, alongside quotes that explain their reasoning.

Table 1: Students’ ideas regarding diffusion

Category	Description	Sample quotes	Tested with blocks
Number of particles	There are more particles in hot water than in cold water.	*In hot water, I guess there are more particles.*	Yes
Motion	Water particles move more chaotically than ink particles	*In hot water, water molecules are more chaotic than the food color particles*	Yes
Speed	In hot water, particles are faster than in cold water	*They move faster in hot water probably, because you can see that they spread out more.*	Yes
Collision	When particles collide, they change	*When they touch each other, they don't go over*	Yes

	their direction	*each other, they bounce back.*	
Melting	In hot water, ink particles melt	*In hot water, the food color melts. In the cold water, it stays the same*	No
Density	In hot water, bubbles make the particles lighter, cold water is denser	*Hot water particles are maybe lighter. Maybe the bubbles have something to do with it, and the cold it's just denser*	No
Proximity	Hot water particles are separated from each other, in cold water they are closer.	*In hot water, everything separates. (...) The particles are together in cold water.*	No

Conclusion

Our data illustrates that observing students designing a model can be a good strategy to explore their prior ideas and how they evolve over time. Ideas about diffusion that are usually invisible to both the students and the teacher in a traditional lesson become visible, concrete, and sometimes testable using the blocks. When students designed their diffusion models, they needed to understand many details regarding the phenomenon and to “unpack their thinking” since each step revealed a “piece” of students' prior conceptions (diSessa, 2018), which later can evolve to understanding the broader phenomenon of diffusion. However, a key challenge was that some of the students’ ideas were not easily representable using the pre-designed blocks. if the goal of engaging students in the coding of scientific modeling is to allow them to explore their ideas, the ways the blocks are designed might interfere with that goal. Even though blocks make coding easier, they also limit some possibilities. As more and more developers and researchers create domain-specific block-based modeling tools, we warn that the smoother learning curve could come at a price: limiting students’ explorations that radically diverge from the “official” explanation. Opportunities to implement domain-specific blocks are numerous, and follow-up research is invited to determine more pedagogical affordances and new areas for improvement.

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Acknowledgments

This work was partially supported by the grant Projeto Ciência na Escola - 441066/2019-4 from the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) in Brazil. It was also partially funded by the NSF DRK-12 Award #P2010413.