

# Introducing Bifocal Modeling Framework in Elementary School Learning Science Using Concrete Modeling Tools

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**Abstract:** In this study, we implemented a Bifocal modeling unit on diffusion with physical models instead of computational models, using two different tools: 1. Paper modeling, 2. Modeling with micro-robot toy. We worked with 5<sup>th</sup> grade students for a period of 5 hours. After running experiments, students developed physical models and then interacted with a virtual model. Using either tool, students significantly improved their conceptual understanding of diffusion, but engaged differently in the modeling processes.

## Introduction

Scientific models foremost serve to explain natural phenomena; they gain their meaning in juxtaposition with the real-world data (Duschl & Grandy, 2008). However, much of the research on model-based instruction has focused on the support of students in the construction and exploration of models as ends by themselves (VanLehn, 2013). Little work has focused on how to get students to *think with* models *about* natural phenomena, in order to explain observations, etc. This is the focus of the Bifocal Modeling Framework (BMF), which integrates real-world experimentation and computer modeling in the same representational space, enabling students to compare real-world data and virtual models explicitly and in real-time (Blikstein, 2012). While BMF can be effective for science learning (Blikstein, 2012; Fuhrmann et al., 2014), programming computational models remains challenging for students and teachers, and the practice impedes science learning (VanLehn, 2013). In this study, we explore alternative media for modeling, which do not require programming and entail only minimal logistical considerations. We implement a BMF unit on diffusion with 5<sup>th</sup> grade students, using two distinct modeling methods: “paper modeling” with pen and paper; and the “micro-robot model,” which represents a tangible, agent-based model of diffusion. We focus on the following research questions: 1) How conducive is each tool in helping students develop a conceptual understanding of diffusion? 2) Do students using these different tools engage differently in the modeling activity?

## Modeling tools

We selected the modeling tools based on two types of criteria: access, affordability, and types of cognitive engagement utilized during modeling. We ended up choosing two tools: 1) pen and paper; 2) Hexbugs. Hexbugs are off-the-shelf, toy micro-robots that exhibit random movements similar to the Brownian motion of molecules. In the paper-model condition, students had to draw an explanatory model using paper and colored pens. In the Hexbug model condition, students were given a limited set of objects to interact with (two boxes, a sticky mat, 25 hexbugs). The two tools differed in terms of medium (two-dimensional versus three-dimensional), temporal representation (static versus dynamic), and the degrees of freedom for conceptual decisions to be made: in the paper-model activity, students had to make decisions about all aspects of the model, whereas in the Hexbug model, many of these decisions were offloaded onto the model.

## Methods and materials

The study was conducted with two 5<sup>th</sup> grade classes in a K-12 urban charter school (85% low-income, 68% ESL). The classes, both taught by the same science teacher, were randomly assigned to either condition (paper-model: 25 students; Hexbug: 28 students). The total Bifocal Modeling unit on diffusion took 5 hours across multiple days. The unit started out with *physical experimentation*. Students followed an activity guide to design and run experiments to study the rate of diffusion, using blue food coloring, water of two different temperatures, thermometers and stopwatches. This was followed by *physical modeling*; students were prompted to design a model that would explain their physical experiment using materials of their corresponding modeling conditions (see previous section). The unit ended with the exploration of a *virtual model* of diffusion in NetLogo (Wilensky, 1999) designed by the authors. Students had to compare the virtual model’s behavior with that of their experiments, and use the model to explain their empirical observations. We applied a mixed-methods approach, utilizing several different data sources. We evaluated students’ content knowledge with pre-, mid- and post-tests, which included multiple choice items (Blikstein, 2012). We analyzed the students’ modeling processes based on video recordings of the physical modeling activities. We binned each video into 4 time sequences and coded each sequence according to the level of “Collaboration” (students working together), “Active” (students being

physically engaged), “Planning” (students reflecting discursively prior to action), “Focus on task” (students doing task-relevant work); each category was ranked on a scale of 0, 1 or 2.

## Results

Students in both conditions significantly improved their conceptual understanding of diffusion, with a significant main effect of test phase (Figure 1),  $F(2,86)=36.6$ ,  $p<.001$  (repeated measures ANOVA on test scores, nested within student). We found no significant interaction between condition and phase overall,  $F(2,86)=1.4$ ,  $p=.3$ . Looking at mid- and post-test only, we did find a marginally significant interaction effect,  $F(1,43)=3.2$ ,  $p=.08$ . Students’ learning gains from the physical modeling activity were similar for both conditions, but the Hexbug model condition had higher learning gains with the virtual model than the Paper model condition. Looking at the coding of learning processes (Figure 2), we find that most of the groups in the Hexbug model condition had higher rank-averages for “Collaboration” and “Active”, but lower ones for “Planning” than the Paper model condition.

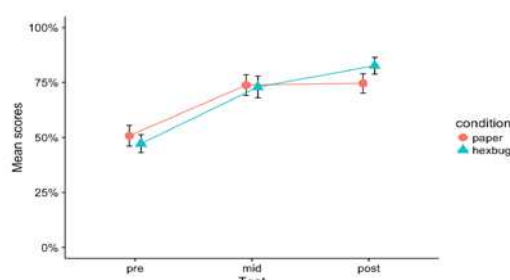


Figure 1. Proportional test scores by phase and condition.

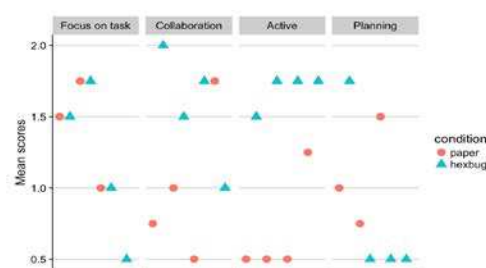


Figure 1. Avg. rank of each group per coding.

## Discussion and conclusion

The two tools – Hexbug and Paper model – influenced student engagement and learning differently: the Hexbug model condition produced more learning from the virtual model during the last activity; the Paper model yielded more planning, but appeared less collaborative and active. We cannot make conclusive causal claims because of the many differences between the tools. One key distinction is that the Hexbug model was an interactive, analogous representation of the final virtual model. Another distinction is that the objects of inquiry are tangible in the Hexbug condition, while the paper-based representation is intangible. Further investigations are needed to examine how the tools influence student engagement in the modeling processes. However, we argue that the differences between the tools have complementary beneficial effects for learning; thus, the question is not necessarily which approach is the better to use, but rather how best to combine them. For example, the paper condition might be beneficial to elicit students’ prior ideas about a phenomenon and make them explicit in the form of external representations. Tangible, interactive models like the Hexbug model provide another representation of the target phenomenon, which could help highlight key aspects that teachers want students to focus on.

## References

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