Designing Interactive Scaffolds to Support Teacher-Led Inquiry of Complex Systems Concepts

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Abstract: This study examined the design of interactive scaffolds to support teacher-led inquiry into complex systems concepts. The goal was to both develop a brief instructional unit with minimal resource requirements, and to examine students' initial understanding of complex systems concepts based on this unit. Early elementary students (aged six to seven) were randomly assigned to six mixed-ability groups of five students (N=30) who participated either in a scaffolded, teacher-led inquiry session with the BeeSign simulation software or a teacher-led book reading session, both centered on honeybees collecting nectar. Statistical analysis of a direct measure and transfer measures indicated that while students in both conditions developed initial understanding of systems related concepts, those in the BeeSign inquiry condition significantly outperformed their peers. Video analyses reveal that designing the simulation around teacher-scaffolded inquiry prompts led to more student articulations of their ideas and opportunities to examine prior misconceptions.

Introduction

Recent research has consistently indicated the value of teaching students to view the world using complex systems related concepts (c.f, Hmelo-Silver & Pfeffer, 2004; Resnick & Wilensky, 1998). The BeeSign project (Danish, 2009; Danish, Peppler, Phelps, & Washington, 2011), a simple computer simulation that depicts honeybees in two different hives collecting nectar has also demonstrated that with robust teacher-scaffolded inquiry, young students were able to explore honeybees collecting nectar from a complex systems perspective (Figure 1 or http://joshuadanish.com/beesign.html). The present study aims to build on this prior work in three ways. First, we aimed to extend the prior examination of elementary students' understanding of complex systems concepts by explicitly examining both direct and transfer measures of learning based on items from the complex systems inventory developed by Goldstone and Day (2010). Second, the goal was to explore the potential for designing a short intervention with minimal resource requirements. This was intended to both vet the possibility for supporting a broader range of teachers in teaching complex systems related concepts, and to begin documenting how a first experience with a system might support student understanding. For that reason, inquiry with the BeeSign software was contrasted with students collectively reading a book about honeybees with their teacher, the manner in which most students would likely encounter this content currently. Finally, to continue exploring the role of teacher scaffolds for supporting student engagement with inquiry into the systems content, these scaffolds were supported by prompts integrated into the BeeSign software, which also supported the first goal by limiting the necessity of prior teacher knowledge of systems concepts, instead building upon their understanding of how to support inquiry more broadly.

Theoretical and Design Framework

The final design is a simple web-page framework designed to scaffold the teacher and students' use of BeeSign (Figure 1). Our design was guided by activity theory, and by the scaffolding framework proposed by Quintana and colleagues (2004). Specifically, activity theory helped us to attend to the relationship between the software (tool), the intended division of labor, and assumed rules for the classroom environment as we identified scaffolds to include.

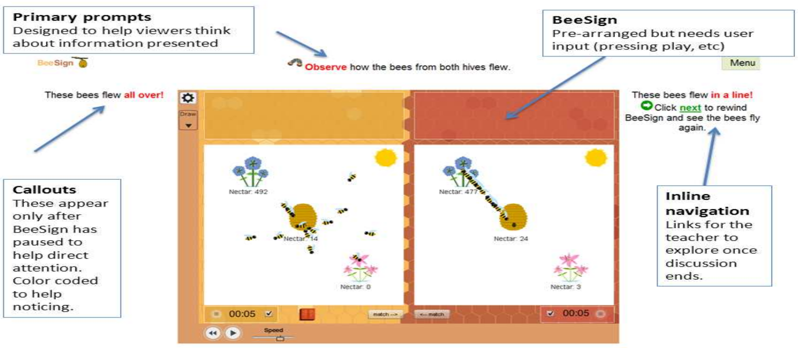

Figure 1: The BeeSign framework

Methodology
The participants were 30 students (six to seven years old) in a mixed-age classroom (first and second grade) in an elementary school in a small midwestern city. Students were randomly assigned to the BeeSign experimental or the book control condition (n=5, three groups per condition) with an effort to balance groups in terms of teacher-identified ability level. Each condition took approximately the same amount of time (30-40 minutes). All conditions were videotaped for later analysis and students participated in an interview-based post-test to measure their conceptual understanding. These results were coded in terms of accurate mentions of feedback loops, emergence, and iteration. One researcher coded all of the interviews and another coder then coded a randomly selected 30% of the data for inter-rater reliability and achieved an overlap of 90%.

Results
Group results were compared using two *t*-tests with a Bonferroni-adjusted alpha of .025 (.05/2), two-tailed. Students in the BeeSign condition (M = 8.79, SD = 4.66) performed significantly better, $t(16.99) = 9.92$, $p = 0.003$, than the control condition (M = 4.21, SD = 1.85) on the direct measure. The students in the BeeSign condition (M = 3.93, SD =1.82) also performed significantly better, $t(25.26) = .652$, p = 0.012, than students in the control condition (M = 2.21, SD = 1.53) on the transfer measure. To explain the differences in learning gains, we examined video of the classroom activities. We hypothesized that the BeeSign activity promoted a more targeted, rich discussion, providing opportunities for the teacher to guide students through conversations related to how and why the bees behaved, and what the implications of the bee behavior were. The framing of the activity as inquiry also supported the teacher in asking questions to make student thinking visible, and offer opportunities to confront common misconceptions. Video analyses corroborated this hypothesis; the teacher in the BeeSign group typically began the activity by asking students to read what was projected on the whiteboard screen and describe their observations and predictions. He then encouraged them to reflect upon the reasons behind these and solicited multiple competing hypotheses so that they could each be discussed and resolved using the simulation. The teacher frequently challenged the students to analyze and assess their prior predictions. These discussions of specific processes helped students understand the relationship between the bee dance and increased nectar collection.

Discussion
Our design represents a first step in exploring alternative methods for helping schools to integrate cutting edge content into their curriculum in a non-resource-intensive manner. While long-term curricular innovations coupled with professional development are important, the economic reality is that there will be new content that need exploring without a curriculum overhaul. Thus, it is valuable to explore scaffolded design models that leverage existing capabilities to engage teachers and students with this new content with minimal additional cost. Our design was effective precisely because it relied upon the teacher's expertise in leading effective group inquiry. By assuming that the teacher would effectively promote student inquiry, we were able to instead focus upon which questions and aspects of the content to make most visible for the teacher and the students to explore together.

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