BeeSim: Leveraging Wearable Computers in Participatory Simulations with Young Children

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ABSTRACT
New technologies have enabled students to become active participants in computational simulations of dynamic and complex systems (called Participatory Simulations), providing a "first-person" perspective on complex systems. However, most existing Participatory Simulations have targeted older children, teens, and adults assuming that such concepts are too challenging for younger age groups. This paper, by contrast, presents a design for a Participatory Simulation, called BeeSim, which makes use of wearable computers and targets young children (7-8 years old) to model the behaviors of honeybee nectar collection. In our preliminary user studies, we found that BeeSim contributed to systems understanding and more easily managed group dynamics.

Categories and Subject Descriptors
K.3.1 [Computers and Education]: Computer Uses in Education - *Collaborative learning.*

General Terms
Participatory Simulation

Keywords
Computer-supported collaborative learning, Children, Systems Thinking, Participatory Simulations, Wearable Computers

INTRODUCTION
Viewing everyday situations from a systems-based perspective is an important aspect of literacy for students and teachers as it creates a new and more effective lens for seeing, engaging, and changing the world [5]. However, despite the ubiquity of systems in our everyday experience, systems thinking is rarely the subject of instruction in and out of schools, in part because it is difficult for students to learn [6] [7]. One of the reasons that complex systems are so difficult to understand is that they can be viewed from several analytical levels simultaneously [4].

One successful approach to helping students overcome this challenge is to have them engage in Participatory Simulations. Similar to role-playing games, participants in a Participatory Simulation reenact the roles of single elements within a system, enabling them to forge personally meaningful understandings of their element's specific behaviors as well as its role in a greater whole [2]. Most prior work on Participatory Simulations, however, has targeted older children, teens, and adults because the complex systems concepts that they target have been so consistently challenging. This body of research fails to take into account, however, the alignment between Participatory Simulations and the play activities of young children, who are already apt to exploring topics of interest to them through play-acting and games, both of which are leveraged in the design of BeeSim.

In a recent study, it was demonstrated that young children (5-7 years old) could engage with complex systems using a range of activities, including computer simulations, physical embodiment, and rudimentary Participatory Simulations [3]. Building on this prior work, we present a Participatory Simulation, called BeeSim, which makes use of wearable computers and targets young children to model the behaviors of honeybees as they collect nectar. Through three short design iterations, we moved from using readily available materials, such as colored water and eyedroppers to represent nectar and the honeybee's proboscis respectively, to a more computational approach. As we will discuss below, these design iterations were implemented in an attempt to leverage the tools and activity structures in a manner that helped the students to engage with the increasing complexities of a system (e.g., honeybees have a limited range and cannot search for nectar indefinitely) and then reflect upon those rules in order to understand them. In our preliminary user studies, we found that BeeSim contributed to systems understanding and more easily managed group dynamics by structuring the students' activities in a more fluid and natural manner.

IDC 2010, June 9–12, 2010, Barcelona, Spain.

WHY HONEYBEES?

Honeybees were selected as a topic because they are familiar to young children and also represent a number of complex-systems related concepts. Most relevant to the current study is the way that honeybees communicate the location of flower nectar using a form of dance. Students begin with misconceptions such as the belief that the bees search for nectar individually without informing the other bees, or that there is some form of central organization in the hive where the Queen is aware of the nectar locations and directs the forager bees to them. This is what Wilensky and Resnick refer to as a "centralized mindset" [8]. The goal of the BeeSim activities was to help students to recognize both the difficulty of finding nectar and the value of communicating nectar sources to other bees.

EVOLUTION OF THE BEESIM GAME

The overarching goal of the BeeSim game was to illuminate the behavior of the individual bees with a focus on the challenge of finding nectar, the benefit of the dance as a form of communication, and then other variables such as nectar quality, nectar depletion, and a limited flight range. The BeeSim game was ultimately informed by two pilot iterations of the game without the use of computational technologies (Versions 1.0 and 2.0), which are briefly presented below. The various versions of the game represent a shift into constraining the children's activities via the computational affordances of the wearable computers to make visible more aspects of the system.

The first version of BeeSim (v1.0) was a game with very limited resources (pieces of cork) where the children searched for nectar in the yard in order to be able to discuss the challenges of finding it, and then "communicated" location to each other to convey the benefits of the dance [3]. In version 2.0, we began to introduce competition as a central motivation through gaming elements, including a limited range in terms of the number of flowers, and a limited number of flower selection choices before heading back to the hive that was enforced by an instructor. We also employed everyday objects to represent different elements of the system—colored water as nectar, Dixie cups to hide the nectar, eyedroppers as the bee's proboscis, and construction paper as flowers. Early pilot work was done with two groups of 20 students. The results of these early pilots verified that the resulting conversations about nectar collection were incredibly productive and insightful about how bees communicate within the hive. In particular, many of the students began to recognize the benefit of each bee dancing for the performance of the hive as a whole—a rudimentary recognition of the emergent properties of the system. However, the students' excitement to succeed made the enforcement of the rules challenging, and inauthentic. Furthermore, the teams who collected the most nectar were not necessarily the ones who communicated the best, but rather were the teams most apt with the eyedropper or the most able to peek behind the construction paper flowers at the hidden nectar in the Dixie cups.

These limitations with the materials distorted some of the children's appreciation of the local bee dance in affecting change at the aggregate level—faster nectar collection over time. This, in turn, jeopardized children's understanding of the relationship between the multiple levels within the system of nectar collection.

We then set out to prototype a solution using the LilyPad Arduino toolkit (BeeSim v3.0) that would monitor and model elements of the system more closely. Version 3.0 is structured similarly to v2.0, where eight children are split into two teams of dueling "hives", requiring teammates to work collaboratively to collect "nectar." However, the communication between computationally enhanced textile bee puppets, flowers and a hive, heightens the realism of bee behaviors and helps students to attend to the rules of the system.

Figure 1. Pilot users using ForagerBees to collect nectar from flowers and deposit at the BeeHive.

In this version, children have a finite amount of time (45 seconds) to collect and deposit nectar and a finite storage capacity (3 units). During the allotted time, a child runs from flower to flower and tries to collect nectar (see Figure 1). A child can collect one unit of nectar from any given flower (if the flower is not empty) and will also be informed as to how much nectar remains inside the flower. A child may collect nectar from the same flower more than once. Once the child's nectar stomach (represented via a LED array) has been filled, he or she returns to the hive and deposits the stored nectar. If time runs out prior to depositing nectar, the nectar is lost and is not counted. When a child's turn is over, marked either by running out of time or by making a successful deposit, the glove is passed to a teammate. (Ultimately, we hope to provide each child with a glove in future implementations.) As the child relinquishes the glove, the child may attempt to inform the next bee, through nonverbal language of the location of any high-yield flowers. After all children have had a turn, the team with the most nectar wins, as they are most prepared for winter. These constraints were all designed to help the children reflect upon the constraints that real bees face as they collect nectar, as well as the benefits of the solutions that honeybees have evolved to these constraints (e.g., the bee dance to convey nectar sources).

The BeeSim 3.0 Design

The current version (v3.0) of the BeeSim game uses the LilyPad Arduino platform, a microcontroller board designed specifically for use with e-textiles, developed by Leah Buechley and made commercially available through SparkFun Electronics [1]. The LilyPad, which can be programmed with the Arduino programming environment, features large conductive pads with holes through which conductive thread may be sewn and connected to wearable objects, such as LEDs, power supplies, and a variety of sensors.

The BeeSim puppet, called the "ForagerBee", consists of one LilyPad Arduino Micro-Controller, one XBee 2.5 2mW Wireless Module and LilyPad XBee Breakout Board, two sets of 3 LEDs, one Tri-Colored LED, one regulated power supply, one resistor, and two pieces of conductive fabric shaped into a child-sized glove (see Figure 2). The XBee Wireless Module allows for wireless communication between the glove and another XBee attached to a computer embedded within a giant cloth BeeHive. During gameplay, students wearing the bee puppets could monitor through a set of three LEDs the amount of nectar currently stored on the glove, while an accompanying set of LEDs displayed the amount of nectar in each flower. To represent the finite energy levels of bees as they travel between the hive and a flower, a Tri-Colored LED was used as a timer, moving from green to red to indicate to students when they needed to return to the hive. The Pseudo Code is provided below:

Pseudo Code for Forager Bee:

```
Start
  Start Timer Count Down
Loop
  Display Current Nectar Amount
  Read Voltage Value From Flower
  Send Voltage Value To BeeHive
  Receive Nectar Amount from BeeHive
  Display Nectar Amount for Flower and current
amount of nectar in honey stomache using LEDs
  Check Time Left:
    If Time Left: Continue
    Else: Stop and Reset at BeeHive
```

Pseudo Code for BeeHive:

```
Start
  Set Nectar Amounts For Flowers
Loop
  Get Flower Voltage Value From ForgarerBee
  Map Flower Voltage Value to Flower ID
  If Nectar in Flower:
    Decrement One Unit in Flower
    Return ForagerBee Nectar amount incremented by
  one and Flower Nectar amount decremented by one
  Else:
    Return Code for Empty Flower
```

To simulate a field of flowers, a unique resistor was embedded in eight fabric flowers with two pieces of conductive fabric attached to the ends of the resistor. An additional resistor was placed at the BeeHive. When the fabric from the glove came into contact with the fabric of the flower, the LilyPad on the glove measured the voltage across the resistor. Each flower had a unique resistor and therefore a unique voltage. This voltage was used in our software to identify which flower the glove was touching. As the child collected nectar, the computer noted the time and flower ID of the collection. If the child returned to the hive before time ran out, the total amount of nectar for the team increased by the amount of nectar currently stored on the bee. As the amount of total nectar increased, a webpage displayed the new changes (see Figure 3).

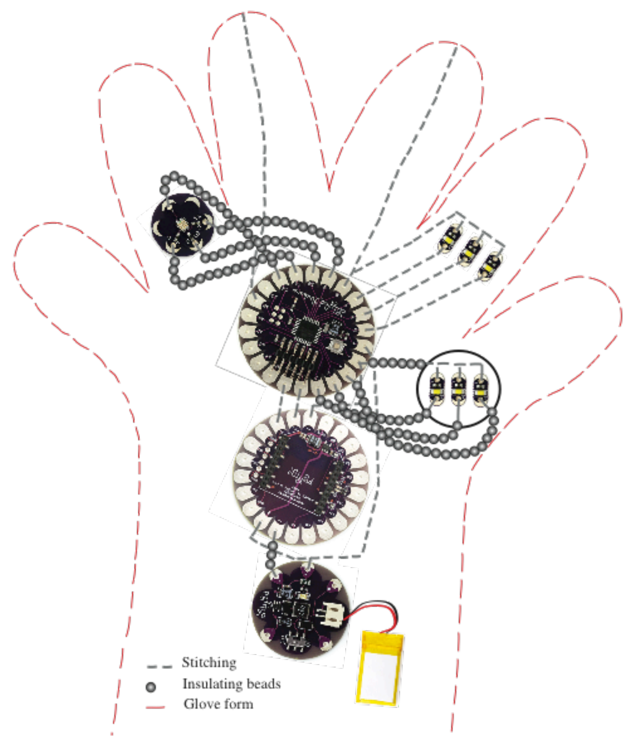

Figure 2. Layout of the ForagerBee Glove

PRELIMINARY USER STUDIES OF BEESIM 3.0

Building an electronics-based version of the BeeSim game gives the instructor more freedom and better access to data than in previous incarnations. Furthermore, the students' interactions were both more natural and more authentic. For example, in previous studies, the honeybees' range had to be monitored by a research assistant with a stop-watch who notified the children that they had to return—something that they often ignored or resisted by looking at "just one more" flower. Because of this, the participants often failed to consider the range to be a real constraint for bees, because it was not a real constraint for them. In fact, several students even believed it would be beneficial to navigate to more distant flowers to avoid having the other team spy on them despite the increased time required to collect nectar. In contrast, the computational textile bees embedded the bees' energy into the game in a natural and familiar manner such that the children in the role of the bees had to attend very carefully to it, or suffer the consequences (lost nectar). This resulted in far more attention to details important to understanding the system.

Figure 3. Partial Screenshot from the BeeHive Interface

In addition to the bee range, the computational textiles also helped to model limited amounts of nectar collection, flower variables such as random nectar depletion and the difficulty of determining if a flower has nectar without visiting it, and supported easier tracking of how much nectar was collected. In the prior iteration, for example, students were sometimes distracted by their efforts to fill the eyedropper with nectar, rather than focusing on the importance of communicating the flower location so that other bees could then find it. With these new computational limits, however, ideas such as the value of completing the bee dance to communicate the nectar location to one's peers took on new import for the children.

FUTURE RESEARCH POSSIBILITIES

Building a wearable, fabric-based electrical/ computational device works well for children running throughout an indoor space and interacting with other electrical components. By sewing the device onto something wearable, the object then becomes tactile and part of the children's play space. Additionally, by making use of commercially available tools, the construction of the device can be made by classroom instructors with little to no advanced knowledge of electronics. Coupled with the kinds of success in teaching young children about systems thinking that we have seen with these tools, our hope is that wearable devices will become central in helping to bring Participatory Simulations into more classrooms in an effort to support youths' understandings of complex systems.

In plans for future iterations of BeeSim, we have devised a way of easily reusing the wearable computers in the bee costume by reprogramming and adding a new skin to explore other complex systems that would be attractive for this target group. This work will then lead to creating "patterns" of wearable experiences that can be reused and adapted in similar contexts, helping to foster general practices and conceptual building blocks that youth can leveraged to understand a large number of complex systems, including other natural biological systems such as ants and termites, as well as systems in other domains of science.

ACKNOWLEDGMENTS

This work was supported by a collaborative grant (CIS# 0855868/0855773/0855886) from the National Science Foundation Kylie Peppler in collaboration with Yasmin Kafai of the University of Pennsylvania and Leah Buechley of the High-Low Tech Group at the MIT Media Lab as well as a grant from the John T. and Catherine D. MacArthur Foundation's Digital Media and Learning Initiative to Kylie Peppler. Special thanks to our anonymous reviewers that were helpful in shaping the ideas presented in this paper.

REFERENCES

1. Buechley, L., and Eisenberg, M. *The LilyPad Arduino: Toward wearable engineering for everyone.* Wearable Computing Column in *IEEE Pervasive*, *7*, 2, (2008), 12-15.
2. Colella, V., Borovoy, R., and Resnick, M. Participatory Simulations: Using Computational Objects to Learn about Dynamic Systems. *Proceedings of the CHI '98* (Los Angeles CA, April 1998).
3. Danish, J. A. BeeSign: a Design Experiment to Teach Kindergarten and First Grade Students About Honeybees From a Complex Systems Perspective. In Proceedings of the annual meeting of the American Educational Research Association (San Diego CA, 2009).
4. Hmelo-Silver, C. E., & Pfeffer, M. G.. Comparing expert and novice understanding of a complex system from the perspective of structures, behaviors, and functions. *Cognitive Science,* 28 (2004), 127--138.
5. Jacobson, M. J. & Wilensky, U. Complex systems in education: scientific and educational importance and research challenges for the learning sciences. *The Journal of the Learning Sciences, 15,* 1 (2006), 11-34.
6. Mandinach, E. B., & Cline, H. F.. Classroom dynamics: Implementing a technology-based learning environment. Lawrence Erlbaum Associates, Hillsdale NJ, 1994.
7. Resnick, M., & Wilensky, U.. Beyond the deterministic, centralized mindsets: New thinking for new sciences. Presented at the annual conference of the American Educational Research Association (Atlanta GA, 1993).
8. Wilensky, U. and Resnick, M. Thinking in Levels: A Dynamic Systems Perspective to Making Sense of the World. Journal of Science Education and Technology, 8, 1 (1999), 3-19.