Exploring how a collaborative board game can be used as a scientific model within the classroom

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Abstract
Current K–12 science education reform identifies three dimensions integral to science education, including scientific practices. One core practice is that of developing and using models. Models are the distilled, conceptualized systems that form the framework of simulations, which can be present in games. We evaluated teacher and student interactions with a collaborative board game that includes a scientific model of the genetic and environmental influences of honey bee behavior. The findings from this study have implications for the continued research of game-based learning and participatory simulations in the classroom as possible avenues for meeting the science learning goals of the NGSS. We view this exploratory research study as a starting point for further investigations of using games and participatory simulations to incorporate three-dimensional learning envisioned in the NGSS into classrooms.

References
1. NGSS Lead States. (2013). Next Generation Science Standards: For states, by states. Washington, DC: The National Academies Press.
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3. Berland, M., & Lee, V. R. (2011). Collaborative strategic board games as a site for distributed computational thinking. International Journal of Game-Based Learning, 1(2), 65-81.

Additional Resources
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- Khoury, D. S., Myerscough, M. R., Barron, A. B. (2011). A quantitative model of honey bee colony population dynamics. PLoS ONE, 6(4), e18491.

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Introduction

Scientific practice of "Developing and Using Models"[1]

Models
- include "diagrams, physical replicas, mathematical representations, analogies, and computer simulations"
- are the distilled, conceptualized systems in frameworks of simulations
- can be present in various types of interactive media, including games

(See reference document on table for full description of this practice)

Science education researchers' interest in games for learning

In "role-playing games" or "participatory simulations"[2] students
- take on the role of one or more characters
- are immersed in a well-defined world or scenario
- can affect or be affected by the game/simulation directly

In collaborative games, players express ideas aloud while communicating strategies and building a common understanding of the game[3]

Research Questions

RQ 1. In what ways can a game align to the scientific practice of "Using and developing models?"

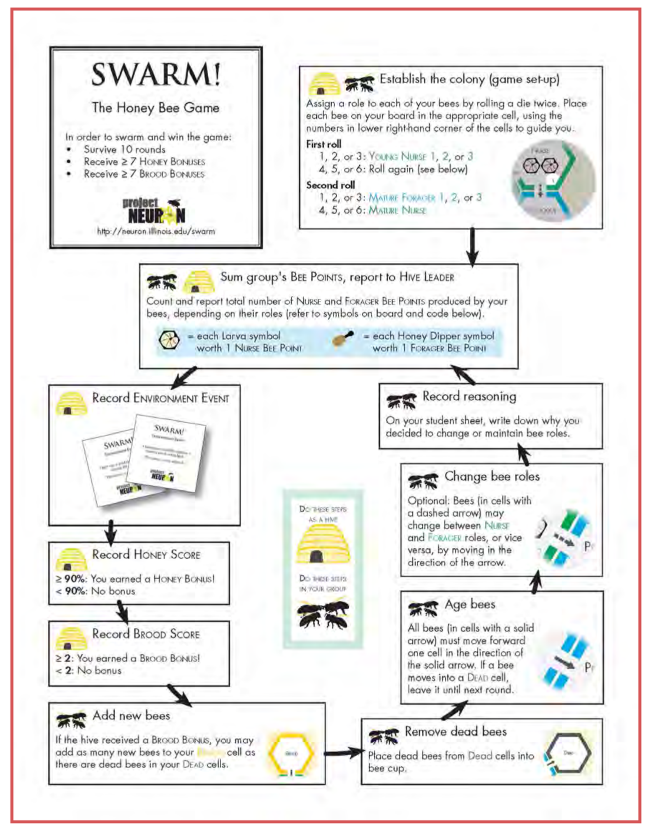
RQ 2. How do teachers and students use and evaluate a game as a scientific model within authentic classroom settings?

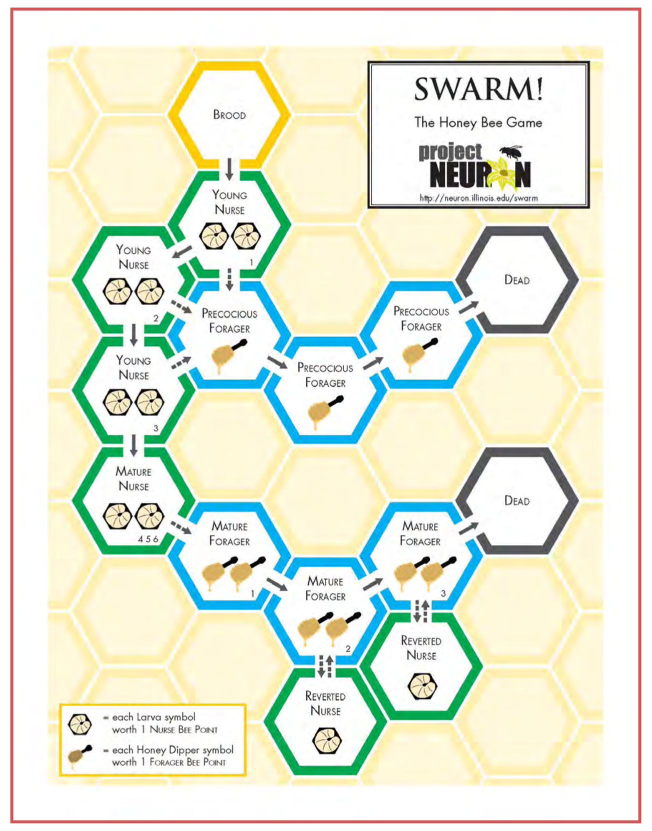
Curriculum & Game

What makes honey bees work together? Curriculum Unit

- Lesson 1: What do honey bees do?
- **Lesson 2: Why do honey bees have different jobs?**
  - Students explore genetic and environmental influences of behavior through primary research literaure and *Swarm!* game
- Lesson 3: How do honey bees heat the hive?
- Lesson 4: What is the genetic basis for the evolution of eusocial behaviors?

Figures 1 & 2. The "Quickrules" document (left) and individual student boards (right) guide the class as it works together as a colony to collect honey and care for brood by balancing the roles of their forager and nurse bees. (See reference documents on table).





Methodology

Summary of Participants and Collected Data

Table 1. This study evaluated classroom audio, teacher responses, and student surveys from the classrooms of three teachers.

Teacher	Taylor	Kacey	Alex
School	• Rural public high school • 500 total enrolled students		• Urban public high school • 1000 enrolled students
Teaching Experience	7 years	1 year	2+ years
Implmnt. Support	• PD workshop • Developer in classroom	• PD workshop	• Developer in classroom
Classroom Periods & No. Students	**Biology II** Fall 2013 • P1: 17 stdnts • P2: 19 stdnts • P3: 21 stdnts **57 Total Students**	**Biology II** Fall 2014 • P1: 27 stdnts • P2: 28 stdnts **55 Total Students**	**AP Biology** Spring 2014 • Per 1: 19 stdnts • Per 2: 10 stdnts Fall 2014 • Per 1: 25 stdnts **54 Total Students**
Classroom Audio	Yes	Yes	Yes
Interviews	No	Yes	Yes
Student Surveys	No	No	N=35*

*Teacher adapted curriculum so that debrief was collected as students' written responses rather than an oral discussion during class time.

Data Analysis

- Data were transcribed, coded, and scored using instruments derived from the NGSS learning progression of the practice "Developing and using models"
- For classroom data, codes were applied for three time chunks:
  - Introduction of the game
  - Set-up and ten rounds of gameplay
  - Debrief (reflection and formal evaluation of game as model)

Instruments

Code categories used for evaluating the alignment of the game/curriculum, teacher instruction, and student understanding to the scientific practice "Developing and using models."[1] (See reference documents on table).
- Instrument 1. Codes for the **qualities** of models that students are developing and/or using or that are emphasized by the curriculum, game, or teacher.
- Instrument 2. Codes for the model **interactions** that students engage in or are encouraged to engage in by the curriculum, game, or teacher.

Figure 4. A discussion while playing the *Swarm!* game at a workshop on the curriculum unit *What makes honey bees work together?*

Results

RQ 1. Game alignment to "Developing and using models" practice

Overall, aligns best to Level 3 (Grades 6–8): Strongest in representation of a complex system; weakest in student use of multiple models

RQ 2. Teacher and student use and evaluation of game as a model

Rely heavily on curriculum (rarely exceed game/curriculum scores)

Table 2. Scores for the **qualities** of the model (using Instrument 1)

	Abstraction			Purpose			Represent.			Certainty		
	Intro	Play	Debrf.	Intro	Play	Debrf.	Intro	Play	Debrf.	Intro	Play	Debrf.
Game	3			2			4			3		
Taylor	0	0	0	0	0	0	4	4*	0	0	0	0
Kacey	0	0	0	1*	0	0	4	0	0	0	0	3/4
Alex	0	0	0	0	0	2	4	0	0	0	0	0

Table 3. Scores for the students' use and **interactions** with models (using Instrument 2)

	Use			Limitations			Multiplicity		
	Intro	Play	Debrf.	Intro	Play	Debrf.	Intro	Play	Debrf.
Game	3			3			0		
Taylor	0	3*	3	0	0	2/3	0	0	0
Kacey	0	0	3*	0	0	3	0	0	0
Alex	0	0	3	0	0	3	0	0	0

Discussion

Using games as scientific models within the classroom

- Well-designed and accurate games can be a valuable way to engage students with models, especially if compared to other models
- Introduction
  - Thoroughness important for efficient gameplay
  - Favored time for teachers to review content knowledge
  - May be good time for explicit instruction on scientific models
- Gameplay
  - Good communication is key for students to "debug" the game as a model
- Debrief
  - Essential for meaning-making and evaluating game critically

Next Steps

Complete evaluation of integrated dimensions

Cross-Cutting Concepts (Instrument 3, provided in reference document)
- "Systems and system models"
- "Cause and effect"

Disciplinary Core Ideas (Instrument 4, provided in reference document)
- "Social interactions and group behavior"
- "Variation of traits"

Revision of curriculum and/or game

- Integrate comparison with mathematical models (high school level)
- Explicit support for teacher learning and instruction
- Digital game for flexible implementation

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