All Creatures Great and Small: Becoming Other Organisms through the EmbodySuit

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Abstract
The EmbodySuit augmented human system allows students to experience life from the perspectives of different organisms, by virtually and physically becoming birds, spiders, ants and even bacteria. Inspired by current advances in nanorobotics, Star Trek's holodeck and the Magic school bus, Embodysuit makes learning embodied and experiential. The student becomes a real organism, part of a real, natural ecosystem. The student's senses are adapted to those of the organism, and the student's actions map to the actions of an organism-sized robot inside a real environment. Our system is based on our projection of advances that will occur in the next 35 years in augmented reality, cybernetics and micro robotics. By about 2050 EmbodySuit type systems will be feasible to prototype, enabling us to address key research questions in classroom scientific inquiry; experiential and embodied learning; technology development; and design for 3D embodied cyber-systems.

Introduction
The field of interaction design for children is built on a long-standing assumption taken from developmental psychology that a child's development, particularly in the early years, depends on and is influenced by activity in the environment. In 1963 Held & Hein exposed the critical role of action in the development of vision with the twin kitten experiment [1]. Piaget also

posited as early as 1952 that even very young infants use their experiences of actions to shape their perception of the world [2]. Critically, children start to develop understanding of “other” and empathy through their own actions alongside their observation of others’ actions. What if they could experience the world and learn by not just observing, but by actually *being* the “other”? In this short paper and supplementary visual materials we describe how the novel EmbodySuit technology enables children of all ages to directly experience being another organism in order to learn experientially through embodied empathy.

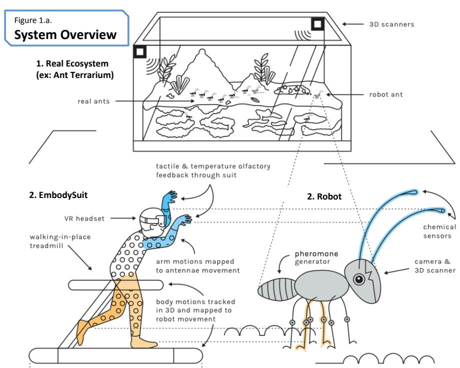

Figure 1.a. The system is composed of (1) real-life natural environments, (2) student-worn body suits, and (3) remote-controlled robots. In this example, children embody ants inside a classroom terrarium.

*****Larger images provided below*

Background

Theories of experiential learning, beginning with Dewey in 1938 [3], culminating with Kolb in 1984 and 2014 [4,5], have heavily influenced pedagogical research and practice in learning sciences and in educational technology -- not just for children but for lifelong learning. Dewey wrote that "successive portions of reflective thought grow out of one another and support one another". Through iterative cycles of *experience* and *reflection* a child participates in their own learning process through their body senses and their minds’ perceptual, interpretive, analytical and reflective processes. While there are many theories that describe what is needed for experiential learning to proceed, the specific mechanisms through which direct experience supports learning have not been clearly defined. Kontra *et al.* suggest that theories of embodied cognition provide the background through which we can understand how a child’s development unfolds, particularly the role action and experience in different environments have on the development of perception, empathy, thinking and reasoning [6]. For example, mirror neurons provide evidence that there is a direct link between our own brain body system and the brain body system of other individuals. Gee argues that a projected identity in video games enables embodied empathy for another human or system [7]. In addition, it prepares us for goal directed action-behavior. Players become not just systemic thinkers but ethical actors. We are not just learning *about* a system but learning how to *be within* that system. Barab mimics these ideas with his conception of reflexive play spaces [8]. One of his core principles is that learning environments should be designed so that content maintains its connection to the real world. We extend this idea so that the world is the environment in which scientific inquiry proceeds; students learn while being inside the Umwelt[1] of each organism, through interaction and reflection.

The EmbodySuit System

We envision a system of three tightly-coupled components (Figure 1.a). Learning activities will center on organisms that live inside a *natural ecosystem*, such as a terrarium hosted inside a classroom, or a larger environment hosting animals, insects and plants. The ecosystem is instrumented with 3D mapping capabilities (such as Kinect [9]). If a student is interested in a specific organism, the system can locate it and provide guided learning about that organism’s current behavior. A whole body *embody-suit* will be used to immerse the learner into the perspective of an organism inside that environment, by using several technologies. The learner’s visual and auditory senses will be immersed through a head-mounted device such as an advanced-version of Occulus Rift [10]; olfactory and tactile senses engaged through smell generation [11], haptics and temperature stimulation [12]; and

[1] https://en.wikipedia.org/wiki/Umwelt

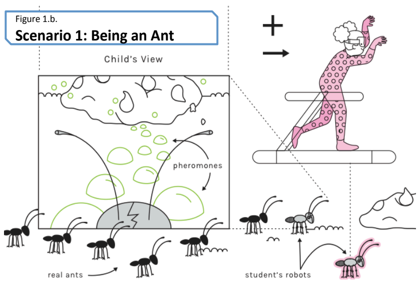

Figure 1.b. Being an Ant: Scenario illustration of two children being ants, leading a real ants to a cookie. *

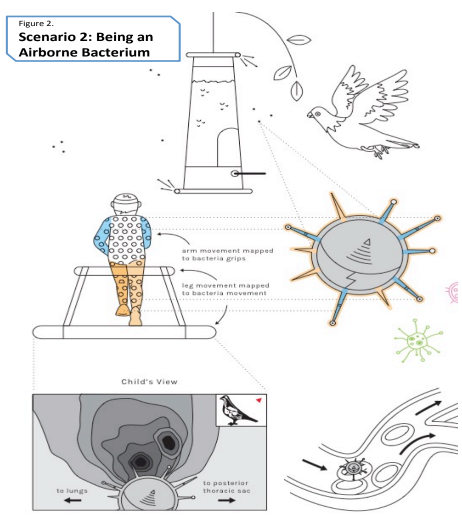

Figure 2. Being an Airborne Bacterium: Scenario illustration of a child being a bacterium traveling inside a bird's respiratory system. *

*Larger images provided below

students will be able to walk and immerse their whole body movements [13]. We envision that each school would have several suits allowing multiplayer connectivity. With current VR technology, such suits can be used to fully immerse students into a virtual learning simulation. In the future, such suits will immerse students into the real-life environment of small-scale ecosystems. Students will embody organisms of various shapes and sizes by using robots deployed in the ecosystem. With current technology it is possible to build remote-controlled robots 0.01m thin [14], and nanorobotics researchers have built molecular-scale transport devices [15]. In the future we should be able to build remote-controlled robots that look and behave like organisms of different scales, such as ants or bacteria. The body-suit will immerse a student into the scale and perspective of the robot, and the student will be able to use their body movements to control the behavior of the robot.

Usage Scenario: Being an Ant

By using our system, a child or a group of children, can become part of an ant colony existing in a classroom terrarium (Figures 1.a and 1.b). Imagine that a child places a cookie in the terrarium; then, they put on the embody-suit, which connects into a small ant-shaped robot inside the terrarium. Through the suit, the child now experiences the perspective of the robot – seeing the world as an ant, smelling pheromone trails through the robot sensors, feeling and hearing nearby ants through pressure and vibration sensors transferred to the suit. The child can move his/her body to reorient and control the robot motion; the child's hands can control the ant's antennae in order to sense smells in 3D space, and can even play preset ant behaviors through the robot. By being an ant in a real ecosystem, the child can learn about ant teamwork behaviors (e.g. leading ants on a path to the cookie food-source by using body contact with other ants [16]). They can learn about small-scale physics (e.g. allowing ant-children to lift leaves that are many times their ant size) or use pheromone-based communication [17] (e.g. allowing ant-children to detect or create pheromone smell trails), or participate in emergent system behaviors (e.g. participating in food foraging or habitat-construction activities with other ants) or experiencing empathy for small insects. This technology allows students to perform science experiments that are not possible even in today's biology laboratories. For example, in the above leader-follower example, the student who controls the lead ant can experiment with different variables such as varying walking speed or the length/complexity of their path, and observe if other ants have an easier or harder time following; or, multiple students can embody ants at the same time, all taking different paths, and studying how quickly the real ant colony optimizes to the shortest route.

Usage Scenario: Being an Airborne Bacterium

Through this system, students are also able to travel inside living organisms. In one application, multiple students' body suits will be connected to tiny bacteria-sized robots which reside in a bird feeder (Figure 2). When a bird approaches, the bacteria-bots are released in the air and breathed in by the bird. Students will experience a first-person perspective as the bacteria bot travels through the bird's respiratory system, allowing them to learn about bird lungs, which permit constant one-way airflow [18]. Once the robots reach the lungs, they will be transferred into the bloodstream with other oxygen molecules, and circulated inside the bloodstream through the heart, as students learn about bird circulatory system. Technically, since the robot's immediate environment will be dark, the student's view is based on a 3D scan of the real space based on the robot's sensors, augmented with additional learning content. The system can scaffold student learning while the robot travels through the living organism (e.g. the system can label each chamber of the respiratory system or the system can direct a student's attention to how bird antibodies attach to the structure of the invading bacteria). Additionally, when multiple students use this system together, it can be used to illustrate system-level concepts such as how different air particles progress at different speeds through the respiration system, or how the bird immune system reacts to multiple invaders at once.

Research Opportunities

The EmbodySuit project opens up several key research opportunities. Educators have long been challenged by finding the right balance of immersion in an experience and reflection; Ackermann's "stepping in and stepping out" [19]. Research will need to address formative learning design questions for understanding what novel classroom science-inquiry activities this technology enables, as well as how to create an effective interplay of experience vs. reflection; balancing between first person concrete immersion vs. higher level abstract overviews, and passive observation vs. interaction; as well as summative questions including: How does this style of learning change students' understanding of educational content? Does EmbodySuit lead to long term effects in student empathy, scientific inquiry, teamwork, and knowledge retention/transfer?

EmbodySuit also raises myriad questions for interaction and technology designers. For example, addressing the tension between the reality of being an organism vs. allowing students to easily control and understand the educational experience. Also, how to design mappings between organism's senses/motions and human senses/motions (e.g. ant chemical sensors mapped to human olfactory senses)? During real time 3D scanning, how can we reliably identify living creatures in the real environment? Does EmbodySuit generate uncomfortable physical sensations (haptic forces, temperature) or cognitive impressions (motion sickness, perceptual plasticity)? How can 3D printing allow robots to be reconfigured for different educator-authored learning activities? What are the limits to how large or small a student can become using the EmbodySuit (e.g. Can a student experience themselves as a tectonic plate; or an electron)?

This work also raises ethical questions related to experimentation on living creatures. Is it ethical to have a nanobot enter a living creature for the purposes of learning? How do we ensure children do not abuse creatures in the environment? What happens to the creatures when the system is not in use or needs to be recycled? And, are there negative psychological effects when children can embody living creatures?

Next Steps

Three research directions can be pursued in parallel in the near future: 1. Currently it is possible to use HMD displays with remote-controlled robots; researchers should focus on educational experiences for these contexts. 2. Research miniaturization of robots that can coexist with animals in real environments. 3. Research the integration of VR and walk-in-place treadmills in school environments, to develop the educational uses of immersive multi-user classroom experiences.

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Figure 1.a.

System Overview

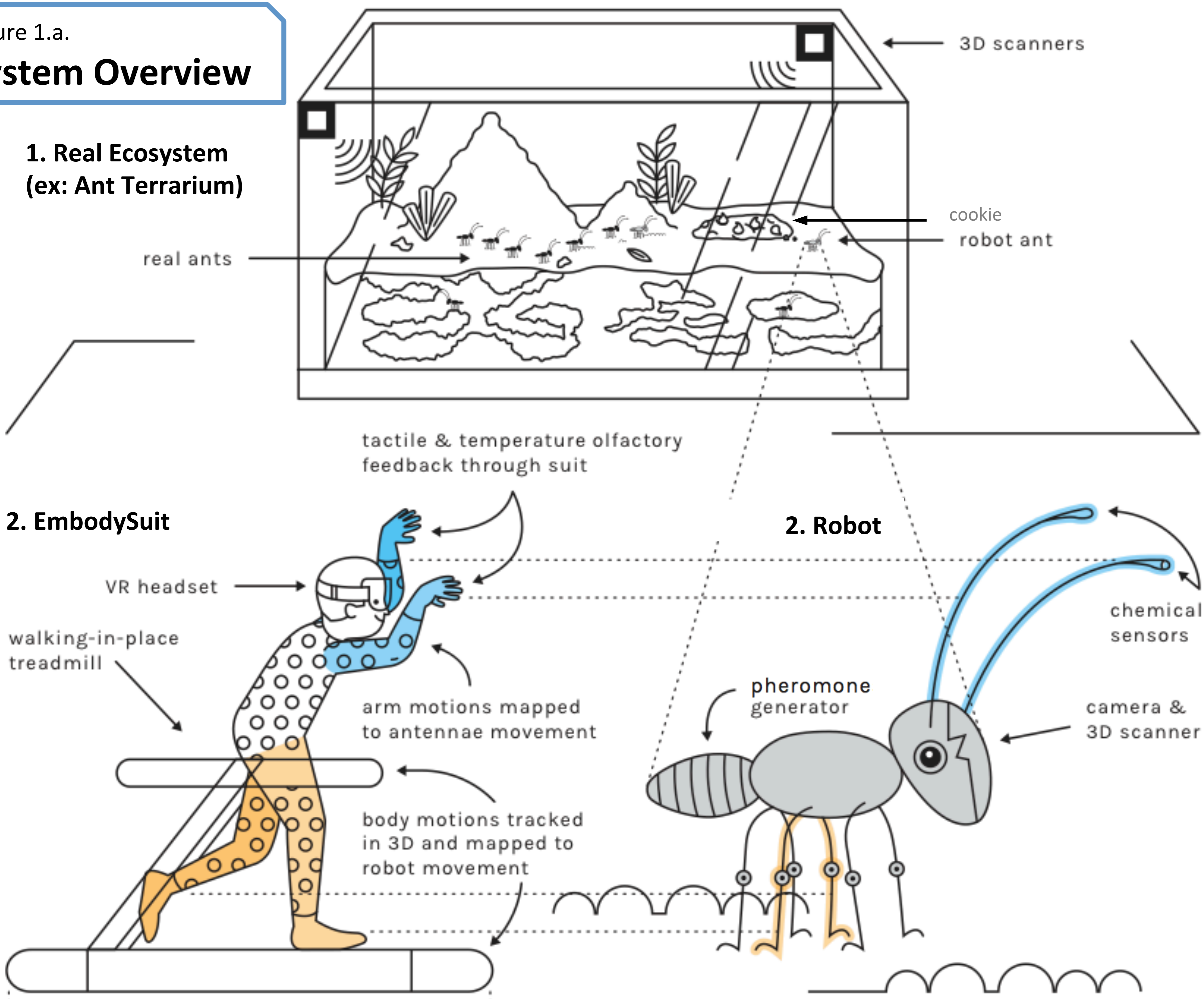

Figure 1.b.

Scenario 1: Being an Ant

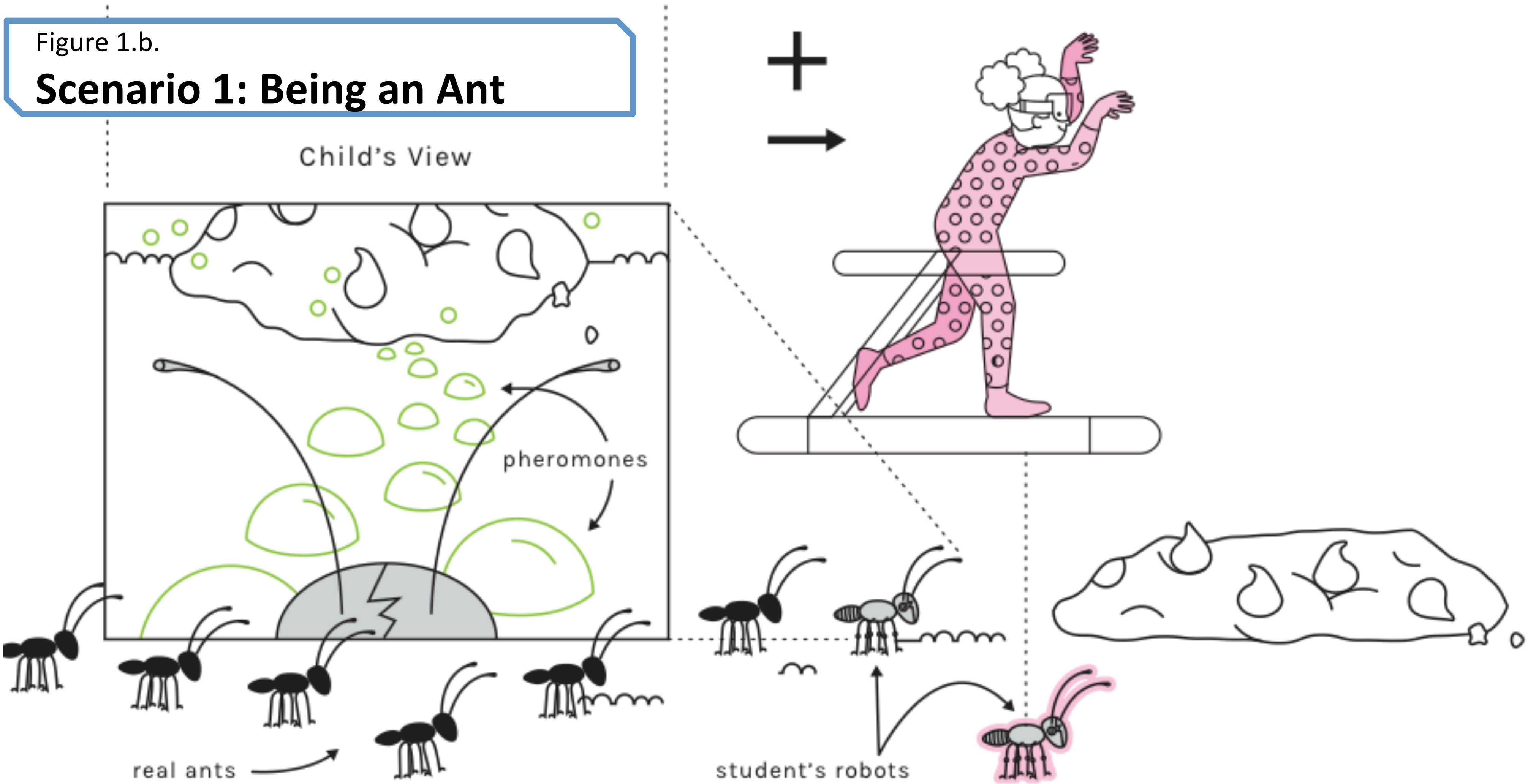

Figure 2.

Scenario 2: Being an Airborne Bacterium