Scaffolding Children's Understanding of the Fit Between Organisms and their Environment In the Context of the Practices of Science

Kathleen E. Metz, UC Berkeley
Stephanie Sisk-Hilton, San Francisco State University
Eric Berson, Uyen Ly, UC Berkeley

Abstract: This research project applies the learning progression perspective to the teaching of the conceptual underpinnings of evolution for 2nd and 3rd graders. We frame the progression from the epistemic perspective that understanding a scientific idea encompasses *using* that idea, in prediction, interpretation and explanation of the natural world. The progression foregrounds the question of the fit between organisms and their environment. This paper reports on the first step of the project, our teaching of the curriculum in an urban summer school and the analysis thereof. We analyze students' reasoning during prototype instructional activities and in comparison of pre- and post-interviews. We have had success scaffolding children's understanding of differential survival advantage of different traits. While we have existence proofs of children coming to understand the impact of this differential on changing distributions across generations, this next step of understanding appears to be much more difficult.

Evolution remains widely misunderstood at all ages. Preschoolers and adults alike manifest teleological reasoning in thinking about the biological, *albeit* with changing cues as to when it is applied (Keleman, 1999; Lombrozo & Carey, 2006). Across this same wide age-span individuals manifest 'biological essentialism", assuming that a species is determined by a defining essence (Gelman, 2003; Medin & Atran, 2004), while ignoring the within-species variation so crucial to understanding the mechanism of natural selection (Shtulman, 2005). Indeed even earlier biologists fell prey to these same misconceptions, as reflected in Ernst Mayr's (1988) tracking of teleological reasoning across the history of biology and Stephen Jay Gould's (1996) attribution of early evolutionary theorists' devaluing of within-species variability to their "essentialist tendencies".

In this continuity of challenges to understanding evolution, we envision an intriguing potential of starting instruction about the conceptual underpinnings of evolution at the second and third grade level. While these findings indicate that these conceptual challenges are robust and difficult to transcend for students of all ages, this continuity in the conceptual challenges leaves open the possibility that some form of early intervention might have an advantageous impact. We make no claim that these conceptual issues could be easily resolved if addressed much earlier in the K-12 curriculum. Rather, in accordance with the idea of *learning trajectory*, we posit that strategically taking up the conceptual underpinnings of evolution at this level could support a basic understanding of some facets of the theory and enable a deeper understanding of evolution at subsequent grades.

This research agenda accords with the new NRC report, *Taking science to school: Learning and teaching science in grades K-8* (Duschl, Schweingruber, & Shouse, 2007). This report emphasizes the fundamental importance of the interplay of instruction, experience, and maturation in the competence that children can achieve. Its conclusion that "*what children can do is in large part contingent on their prior opportunities to learn"* points to the key role of the learning trajectory in instructional design and analysis of children's capabilities. Finally in place of the problematic dichotomy of content and process, it recommends framing K-8 science learning in terms of four interrelated strands: *a)* Know, use and interpret scientific explanations of the natural world; *b)* Generate and evaluate scientific evidence and explanations; *c)* Understand the nature and development of scientific knowledge; and *d)* Participate productively in scientific practices and discourses. This research is grounded in this conceptualization of science learning.

This paper reports on our project, striving to scaffold young children's understanding of the fit between organisms and their environment. We present the instructional approach through description of the learning progression and design principles that informed the construction of the curriculum. We analyze the children's understanding of the fit between organisms and their environment and how this changed over time, through: *a)* comparison of pre- and post-test one-on-one interviews; and *b)* children's thinking wrestling with the targeted ideas in the context of prototype lessons. The research is small scale, limited to two cycles of research within a summer enrichment program (over which the team will have complete control of student placement and instruction) and two years of the classes of three second and third grade teachers in a diverse, urban school (reflecting the complex environment to which any viable intervention must adapt). This paper reports on the first cycle of the summer enrichment program.

The Scaffolding of Children's Understanding

The Learning Progression

Above and beyond consideration of where children begin and the long-term end-point in the conceptualization of a learning progression, we aimed to conceptualize the conceptual terrain of the progression such that it supports increasing explanatory power *from the students' perspective*. Most elementary school science curricula violate this criterion, with content that will only prove to have some explanatory power when linked to concepts reserved for older grades – a curricular pattern that fails to reflect the power or purpose of science or the heart of its practices. We aimed to construct the learning progression in evolution in such a way that the concepts within this grade-band have explanatory power in and of themselves, while also strategically grounding more powerful and complete explanatory models to be taught in subsequent grade levels.

The learning progression is framed in terms of *increasingly powerful explanations of the fit between organisms and their environment.* We focus on phenomenology and change at the time scale of microevolution. An ecological perspective is limited to that needed to understand this relationship; *e.g*., the survival value of different inheritable traits of a population within a particular environment. The cellular level is excluded, as well as speciation and genetics above and beyond the idea of inheritance.

Our current version of the learning progression consists of seven levels. We assume that children will come to school with some understanding of the two most basic levels: the simplistic idea that organism*s Live where they belong* (Level I) and the more adequate idea that organisms *Live where they can get what they need* in Level 2. While children come to school with some ideas about what organisms need, the curriculum aims to develop these understandings. Variation in organisms' structures/ limiting factors embodies the idea that organisms are able to get what they need in very different environments --- with different limiting factors --- due to variation in their structures. At this level we can build on some understandings that children have of structure/ function, but also need to substantially elaborate the structure/ function idea and the scope of the context to which it is applied. *Survival value of specie's trait* (Level 4) conceptualizes fit between organisms and environment in terms of the survival value of a particular trait (e.g.; the survival value of the Grey Whales' migration between Baja and the Arctic or the ridge on the male crickets' wing that enable them to chirp). Whereas survival value or cost-benefit analysis may be intuitive at some level and some contexts (*e.g.*; is it worth trying to get my ball back now from the playground bully), we doubt children have ever considered animal or plants' traits from this perspective. *Within-population variation and differential survival advantage* (Level 5) takes up the idea of differential survival advantage of different traits of the same characteristic within a given environment. *Natural selection* (Level 6) is conceptualized as the idea that, over many generations, inherited traits that help organisms' chances to survive and reproduce in that environment become more common there. Traits that hurt their chances become less common. The traits that hurt its chances become less common. The last level (Level 7) encompasses the outcome of the mechanism of natural selection, namely *Organisms well-adapted to where they live.* A secondary progression, supporting understanding of life cycle, resemblance of parent and offspring, and inheritance supports the primary progression building increasingly powerful explanations of the fit between organisms and their environment.

Pedagogical Design Principles

Given space constraints, we present the pedagogical design principles here in brief:

1) Understanding a scientific concept entails *using* the concept in the practices of science, including interpretation of the natural world, making prediction, and developing explanations.
2) Build children's conceptual understanding through a range of scientific knowledge-building practices, including thought experiments, field-based and laboratory-based empirical inquiry, and text-based research.
3) Immerse children in exploration of a phenomenology and the puzzling patterns therein *prior* to introducing the corresponding explanatory abstraction.
4) Leverage strategically selected in-depth cases of phenomenology and their interpretation as a basis to build generalizations and abstractions.
5) Capitalize on fruitful preconceptions.
6) Build from contexts that we anticipate will be less likely to evoke buggy reasoning before having students apply these new ideas to contexts that we anticipate will be vulnerable to buggy reasoning.

7) Emphasize the metaconceptual and metacognitive knowledge that support children's understanding of the power of the targeted ideas in explaining the fit between organisms and their environment.

The Curriculum Modules

We have developed two curriculum modules, to scaffold children's advancement on the learning progression, in accordance with these design principles. One of the modules develops these ideas in the children's study of botany, the other in the realm of the children's study of the animals and their behavior. Each module is approximately 30 hours in length, about the length of a relatively long "replacement unit".

Measures of Student Understanding

Pre- and Post-Interviews

We developed a structured interview instrument to measure student progress on the learning trajectory. In accordance with our conceptualization of what understanding of a concept entails, items elicited children's using the targeted ideas in predicting, interpreting and explaining biological phenomena. The instrument consisted of 7 extended items. One item was framed in terms of one of the particular organisms the class studied (Brassica rapa on the part of the botany class and crickets for those in the animal class). All the others were transfer items, a characteristic of the instrument that we realized made it extremely difficult. The instrument included items without any kind of scaffolding, as well as two items with dynamic scaffolding and two items with what we conceptualized as empirical scaffolding, in the form of empirical feedback following the children's generation of a prediction and the explanation thereof. The instrument assessed the conceptual terrain through: *a)* two items involving children's thinking about why particular organisms (otters and kelp) lived where they lived and consideration of where else they could or could not live; *b)* four cases of microevolution, involving predictions and explanations about a population after an environment change, followed by explanation of what actually happened (*e.g*.; changes in the coloration of male guppies, following arrival of predators); and *c)* explanation of change in a characteristic over time (e.g.; the question, drawn from this research literature, of why cheetahs today are so much faster than their ancestors).

On-Line Student Negotiation of Curricular Activities

Above and beyond analysis of gains in understanding from before and after the instructional intervention, we are also interested in understanding how the curriculum functioned to support conceptual development and how we might iteratively improve it for these purposes. For the purpose of analyzing the interplay of instruction and learning, we videotaped all instruction and developed a complete database of student written work and easel pad record notations from class discussions (used in place of the white board to support the inclusion in the written artifact data base.) We also designed embedded assessments into the curricular plan.

Analysis of Children's Understanding

We conducted structured one-on-one interviews with almost all of the 40 children in the summer program. These interviews were videotaped to enable close analysis. We are currently formalizing the coding process to apply to the full set of interviews. While we will report statistics about all 40 children and their changes from pre- to post at the conference, the results we report are only preliminary and formative, and based on the 13interviews we have studied to date. (These * are all the children from the animal behavior class who participated in all days of the program, minus one child with Down's syndrome who did not participate in the post-test interview.

Advancements From Pre- to Post-Test and Enduring Conceptual Challenges

Even before the curriculum, the majority of the children we have analyzed (9 out of 13) had some understanding of the differential survival value of some traits, at least in the relatively straightforward and familiar instance of camouflage; *i.e*., organisms that stick out in an environment with a predator, as opposed to those that blend in, are more likely to be eaten. This in-coming level of understanding emerged in our framing of an item based on the classic case of the shifts in peppered moth coloration following severe pollution due to industrialization, as well as another item based on Endler's (1980) study of microevolution of male guppy coloration as a function of the presence of predator fish. For example, in an item asking children to make predictions and explanations thereof of the color of moths following heavy soot darkening their landing places, most of the children realized the survival value of dark coloration. For example: "They [the birds] can find the light ones because they're not camouflaged. But the dark ones, they're camouflaged. But they won't find the dark ones."

In the single non-transfer item, 12 of 13 children reflected some degree of conceptual advancement from pre to post-test. Thus, for example, the animal curriculum cohort had studied a case of microevolution of crickets on Kauai (Tinghitella, 2008, 2009): the appearance in the island cricket population of a slightly different wing structure such that cricket could not make a chirping sound, followed by arrival of maggots that lay their eggs in crickets that they can locate through their chirping. Post-instructional intervention, 92 % of the children in the animal curriculum cohort analyzed to date not only appreciated the differential survival advantage for the particular population currently living *(i.e;* those crickets that chirped were more likely to be found by the maggots and thereafter soon die from the development of the maggots in their body), but also considered the impact of this differential survival value -- combined with some rudimentary understanding of inheritance-- on the relative frequency of the trait in the next generation. For example, Ellen appropriately predicts an increase in the proportion of non-chirpers, but qualifies her prediction with noting that chirping is both a risk and an advantage. On the one hand, she views chirping as a survival disadvantage, in her words, "The fly will only go for the chirping cricket". On the other hand, she also notes the survival value of chirping, "They [indicating male crickets with changed wing structure] don't chirp, so that mates won't be attracted to them." As she explains her prediction of an increase in non-chirpers and decrease in chirpers (as represented in iconic symbols for chirpers and non-chirpers in the next generation), "a lot of the chirping crickets got eaten by the fly, the fly. And then most of these guys [non-chirpers] gave some birth to offspring."

Analysis of the transfer items revealed that 69% of the children also considered the impact of the shifts in survival value of traits to changes in the relative frequency of the traits in subsequent generations to contexts they had not studied in class. For example, consider Wally's post-test reasoning about the case of microevolution of male guppy coloration post arrival of predator fish. He predicts there will be more "black" or "grey ones" (camouflaged) and fewer "yellow ones" (colorful), on the grounds that:

> The black guppies can blend in more than the golden guppies... The yellow ones are getting eaten, because they can't blend in so good. And the gray ones... most of them, they can survive and then they give babies. There will be more and more gray ones... The yellow guppies, they'll get eaten so when they give babies, they won't have as much, and when they get eaten, there will be less and less.

In short, these interviews documented second and third graders' wrestling with questions of microevolution. The post-instruction interviews revealed conceptual advancements on the part of many students in a context they had studied, success on transfer tasks on the part of some, as well as multiple enduring conceptual challenges. In the sections below, we consider the functioning of the curriculum vis à vis these challenges.

On-Line Student Negotiation of Curricular Activities and Embedded Assessments

Children's Thinking in the Context of the Botany Curriculum

The botany curriculum included an instructional sequence of an empirical investigation followed by a thought experiment designed to support the children's wrestling with several ideas central to the learning progression, including within-kind variation (LP5), differential survival advantage (LP5) and a change in the prevalence of traits in subsequent generations (LP6). These investigations engage students in applying these ideas in the context of making predictions and developing explanations. Students are also immersed in a phenomenology to establish the basis from which to reason scientifically. The investigations build on prior investigations to develop these abstract ideas in a phenomenology that is familiar to students.

This instructional sequence begins with the students' close analysis of a population of aster seeds, identifying subtle differences between seeds. Students noticed that some seeds were slightly bigger than others and some had slightly bigger parachutes. They made predictions about which of these differences might matter for the distance that the seeds might travel in the wind. Students developed an experiment to test their predictions, comparing the distance bigger seeds and smaller seeds traveled.

To extend their empirical exploration of traits that support dispersal potential, we designed a thought experiment to scaffold students thinking around differential survival value and subsequent generations. We adapted the thought experiment from a case in the research literature of microevolution of the aster seed structure following the arrival of the seeds on ocean islands (Cody & Overton, 1996). As part of the thought experiment, we asked students to make predictions about the survival advantage of different aster seeds on the island and the distribution of size within the population of aster seeds in future generations. In this limited space, we focus on the interplay of instruction and evidence of students' thinking along the learning progression as reflected in the thought experiment.

We framed the microevolution thought experiment in terms of a population of aster seeds (large and small) that landed on an island. In this thought experiment, students (a) made predictions about where the next generation of seeds might land; (b) explained their predictions in terms of the survival advantage of the seeds that land on the island; (c) made predictions about future generations of seeds on the island and their differences with respect to size; and (d) compared their predictions to empirical data from the scientist. The students worked together as a class on each part of the thought experiment, but recorded their own predictions and explanations separately on written templates functioning as independent, instructionally embedded assessment. An analysis of the classroom video of the thought experiment and written assessments reveal that most children had some understanding of survival advantage of the larger seeds and that the larger seeds would be more prevalent in the next generation (LP6).

Consider the interplay of task and student thinking in the context of this thought experiment. Shown a sample of seeds that landed on the island, the teacher challenged the class to make predictions about where the next generation of seeds might land (Figure 1). As part of the classroom discussion, many students shared similar predictions. For instance, "What I think will happen is that most of the heavy seeds will land on land and the light seeds will likely land on water" and "What I think will happen is that the light seeds will be more likely to land in the water because they fly farther." Based on analysis of student work, all of the students represented more heavy than light seeds in their predictions of which seeds would land on the island in the next generation.

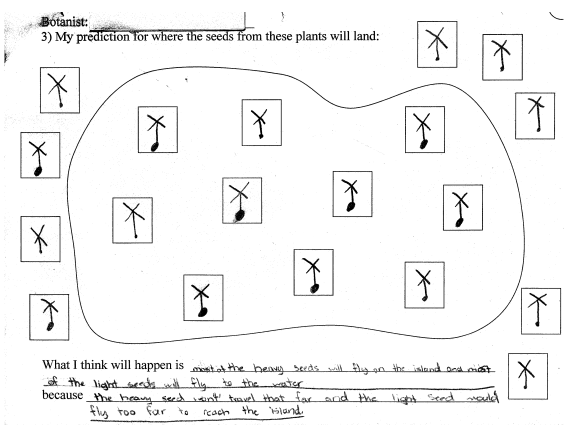

Figure 1. Sample of prediction of regarding where seeds with different traits will land.

The teacher asked the students to explain their prediction in terms of survival advantage, using a written template to scaffold their explanations. Analyses of these assessments reveals that 12 of 17 students appropriated the class discussion about the impact of seed size on distance traveled and used this as a rationale for explaining the differential survival advantage of heavier seeds. These students explained that the heavier seeds had a survival advantage relative to the lighter seeds. They reasoned that the lighter seeds tended to travel too far and would land in the water, whereas the heavier seeds didn't travel as far and would be more likely to land on the island, e.g.:

> [*Written prompt:* The heavy/light (circle one) seeds will have a survival advantage because…] …[circled "heavy" above]… the big ones will travel on land and the light ones will travel too far so they might fall in the water.

Students subsequently made predictions about what the scientist saw when she went to study the seeds on the island, many years after the seeds first arrived. Many students noted that while there will likely be MOSTLY bigger seeds on the island, there may still be some smaller seeds, for example:

> I predict that most of the…there won't be that much little ones that will be on the island. But I think the heavy ones will be on the island, because they have the advantage because they are heavier and they don't go as far…

In the final part of the thought experiment, the teacher presented the students with empirical data from the scientist and asked the students to explain what the scientist saw, how that might have happened and how their predictions matched what the scientist saw. Consider, for example, how one student compared her prediction to the empirical data (below). After summarizing the scientist's observations, the student explains these observations by reasoning that the lighter seeds were less plentiful because they had flown off of the island. She then concludes that her prediction fit with the scientists' observations based on a relative distribution of small to big seeds.

> *What did the scientist see?* A bunch of big seeds and a few little.
> *Why do you think that happened?* All the little seeds flew off the island.
> *How does your prediction fit with what the scientist saw?* That my prediction fit in because I drew three small seed and a lot of big seeds.

Note she appropriately predicted a decrease in light seeds and an increase in big ones, she may not fully attend to the generational nature of the mechanism over long periods of time.

Analysis of students' work indicates that 12 of 17 students demonstrated an understanding of survival advantage (LP5). However, generational thinking was still problematic for many. Nonetheless, by immersing students in the seed phenomenology and by engaging in the practices of science under these instructional conditions, students were able to reason about the differential survival value of traits and how the value can change with the change in the environment (arriving on the island.) The curriculum subsequently built on this emerging understanding to further develop student reasoning along the learning progression. In subsequent investigations, students continued to build on these ideas in a more independent context of partner work focused on using empirical data from their plant populations growing in the classroom to make predictions about plant characteristics in future generations following an environmental change.

Children's Thinking in the Context of the Animals and Their Behavior Curriculum

The idea of multiple generations also proved particularly difficult for students as they reasoned about shifting survival advantage of a trait in relationship to an environmental press in the context of the animal behavior curriculum. In the Kauai crickets thought experiment, the first point at which the curriculum scaffolded students to work through the process of natural selection most students (88% based on analysis of individual students' worksheets)readily worked into their repertoire the idea that a particular trait could have *survival value* for an individual (LP 4), and also that within a population, individuals with a certain trait could have a *survival advantage* over those members of the population without the trait (LP 5). Likewise the idea that offspring usually had traits similar to the parents was non-problematic according to students' comments in the class discussion and as shown universally on student workseets (although students over-attributed identical traits to offspring, since the curriculum did not explore genetics). Some students were able to use these ideas to reason about the likelihood of a trait being passed from one generation to a single subsequent generation. For instance, at the beginning of the Kauai Crickets thought experiment, Maria explained the ideas of her partner, Carlos, regarding which type of male crickets had a survival advantage: "the chirping ones because um, the chirping ones could find a mate, and then when they had their babies they could also chirp." However, almost all students encountered significant difficulty in reasoning about the impact of an environmental press over many generations. In their written records, 23% predicted that variation would simply cease to exist in the next generation (the trait with survival advantage would be present in all individuals), 29% predicted an increase in the population of non-chirpers but were unable to describe their reasoning, and 23% were unable to construct a response at all. Of the 23% who predicted an increase in the population of non-chirpers and gave a reason, all focused on the fate of an individual or a single generation, for example, "the chirping crickets get caught by the fly." Students had difficulty creating a chain of reasoning that moved beyond the second generation and considered the impact of differential survival value *survival, reproduction, and traits present in subsequent generations.*

In the animal behavior curriculum, a single external representation used multiple times throughout the series of investigations appeared critical in scaffolding children's multi-generational reasoning (see figure 2). Evidence suggests that this form, in the context of the curriculum's thought experiments, helped students develop evidence-based predictions about the shifting distribution of a trait over many generations. The representation was first used in the Kauai crickets thought experiment, where it did not have an obvious impact (see above). However, in subsequent thought experiments, when students returned to the representation they were better able to make generational predictions. For instance, in students' final projects, in which student pairs predicted changes to a population of an animal of their choosing in response to a real environmental press, the teacher observed only 2 pairs reasoning about a potential shift in trait distribution due to differential survival based on traits. Upon bringing back a version of the generational chart seen in figure 2, all pairs were able to construct such an explanation (with differing degrees of direct teacher intervention). The generational representation scaffolded students' development of a multi-generational prediction regarding shift in the distribution of a traitin three key ways, discussed briefly below in the context of the Kauai crickets example.

First, the representation *required students to represent the members of a population as individuals with or without a key trait and on this basis make predictions about whether they were likely to survive and reproduce.* After students discussed the survival value of chirping for male crickets prior to the arrival of a predator, the teacher presented a small sample population to represent the initial trait distribution, in this case 10 male crickets in which 7 were chirpers and 3 were non-chirpers. The teacher then described the arrival of the predator fly, and several students co-constructed the idea that non-chirpers, previously at a disadvantage in attracting a mate, now had a survival advantage because they would be less likely to be victims of the fly. However, the seemingly simple question of "would there be more or fewer chirping crickets in the next generation" met with little response. The teacher then asked students to predict using actual numbers: out of the 10 crickets represented on their page, which five would survive and reproduce. Underneath the first representation were 5 boxes in which to place the reproducers. They then filled in connected boxes to show the traits of their offspring. Students repeated this process for two subsequent generations before making predictions about the population 15 generations later. Manually "moving" representations of individuals from members of the population as a whole into a sub-group of those that reproduced allowed students who were unsure of the question when initially asked to develop well-reasoned responses. For instance, Tyrone, who adamantly insisted that neither chirpers nor non-chirpers had a survival advantage when the predator fly arrived, when forced to make a decision about which individuals to place in the "reproducer" boxes, placed more non-chirpers than chirpers, and wrote [italics refer to provided prompt]: "*Now I think* the non-chirping *male crickets have a survival advantage because* the fly would not eat them." In class conversation and on his representation sheet, he contended that 15 generations later, there would be *no* chirpers. While this is not entirely accurate, his reasoning showed a move from not accounting for survival advantage to predicting individual survival based on a trait to making predictions about trait distribution in the population as a whole.

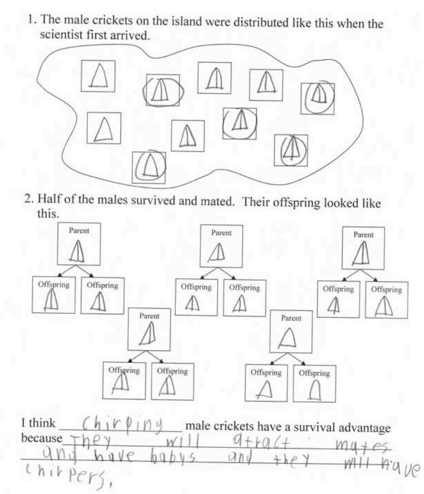

Figure 2. Sample of simplified visual representation of shifting distribution of a trait over generations.

Second, this format provided a simplified representation of *next generation as involving the offspring of organisms present at the onset of the investigation.* The representation physically linked traits of offspring to traits of parents. Students then transferred only the offspring into a new box labeled "Generation 2." Of course, this is a simplification in many ways. The representation limited offspring per parent, mandated number of reproducers in a generation, and assumed offspring always had the same trait as the represented parent. Most importantly, the representation prompted students to reason about the fate of individuals, although the goal was to get them to reason about the shifting distribution of a trait within a population. However, for many students, as in the example of Tyrone above, reasoning at the level of the individual appeared to be a necessary step to move from the claim that it was impossible to predict future distribution toward reasoning that accounted for differential survival advantage resulting in some members of a population being more likely than others to survive and reproduce in each generation (LP 6).

Finally, the generational representation provided a simplified visual that scaffolded students' understanding of the *shifting relative concentration of a particular trait in a population across generations.* By looking at the scattered icons representing the predicted population by trait in each generation, students easily discussed the shift in prevalence of a trait over multiple subsequent generations. Some students described the shift using the actual numbers of the greatly simplified population drawing, for example, "here there's seven that chirp, but now there's just four so there's more that don't." Others were able to make more generalized statements about how traits become more or less prevalent across generations, still referring to the simplified representation. For instance, Martin stated, "[in generation 15] there'll be mostly non-chirpers because if they had to mate… and if they had babies, then they'd have to be non-chirpers." Many students continued to need this representation to scaffold their predictions and explanations for the remainder of the curriculum, even those who were able to construct more generalized explanations of shifting trait distribution. As discussed above, 7 of the 9 student pairs used the representation in constructing an explanation for their final project in the curriculum.

Conclusions

The understanding of evolution poses challenges for high school and colleges students. Our project aims to support understanding of this key theoretical frame by beginning early: with second and third graders. We have conceptualized a learning progression in terms of steps of increasing power and complexity in explaining the fit between organisms and their environment. Analysis of structured interviews, classroom discussions, and instructionally embedded assessments reveal children wresting with key aspects of natural selection in cases of microevolution. Predicting changes in relative frequency of a trait from one generation to the next appears to pose less substantial challenge than extrapolating shifts in distributions across a broader scope of generations and time.

We have three more rounds of the educational design experiment, including a second summer school with many of the first summer's second grade participants as third graders in the other domain (switching from study of botany to animals and their behavior or visa versa) and two semesters in regular school year classrooms. This gives us the opportunity to continue to rework the curriculum to more adequately scaffold the conceptual issues that prove most difficult. Our goal is to iteratively refine the instruction, as we closely examine the power and limitations in children's understandings of evolution that emerge under these instructional conditions. This process will best position us to try to differentiate robust limitations of children this age from limitations due to suboptimal learning opportunities.

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