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Learning Natural Selection through Computational Models in a High School A.P. Biology Classroom

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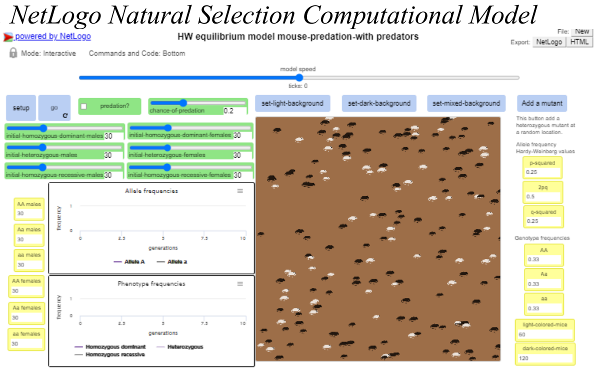
Abstract: Science education communities understand the importance of computational thinking but lack empirically tested learning materials. We report the implementation of a computationally driven natural selection unit in an A.P. high school biology classroom. Epistemic network analyses of student responses indicate that computational tools can facilitate learning of natural selection, and to varying degrees. We interpret these results to show that attention should be given to the fit between computational tools and natural selection concepts.

Introduction and Methods

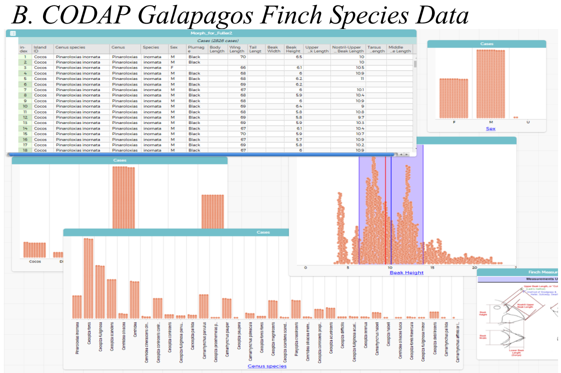
Computational tools and methods have restructured the nature of science. In response to this paradigm shift, and others, computational thinking (CT) has surfaced as a national and scholarly research interest. Due to CT's relative novelty, much of the research on CT has focused on the design of standards and curricular frameworks. Less attention has focused on empirically testing learning materials and exploring CT's ability to promote K-12 science learning (Grover & Pea, 2013). In this paper we report the implementation of a computationally driven unit to address these gaps. Moreover, we extend from previous work involving students' computational modeling of evolutionary processes (Dabholkar et al., 2020) to address the well-established and considerable difficulties students have in learning natural selection (Rosengren et al., 2012). Students in this study (N=35) interacted with four computational tools across an 8 week, 7-lesson unit on natural selection in an A.P. high school biology classroom within a large public school in the U.S. Midwest. We report two tools below in Figure 1: A computational model of natural selection (Dabholkar et al., 2020) developed in NetLogo (Wilensky, 1999) and an interactive data environment about Galapagos finches developed in the Common Online Data Analysis Platform (CODAP, 2014). The following research question guided our work: "How do computational tools facilitate learning of natural selection concepts?" Three researchers used a coding guide (Peel et al., 2019) to code unit questions and student responses. Interrater reliability was high across all codes ($K_{avg} = 0.91$). We analyzed student responses to two questions embedded in the unit that correspond to distinct computational tools and therefore distinct opportunities to investigate the influence of computational tools on student reasoning. We conducted epistemic network analyses (Shaffer, 2017) to understand (1) student use of natural selection in reasoning about speciation and (2) the effect of computational tools on student use of natural selection concepts.

Figure 1

A. NetLogo Natural Selection Computational Model



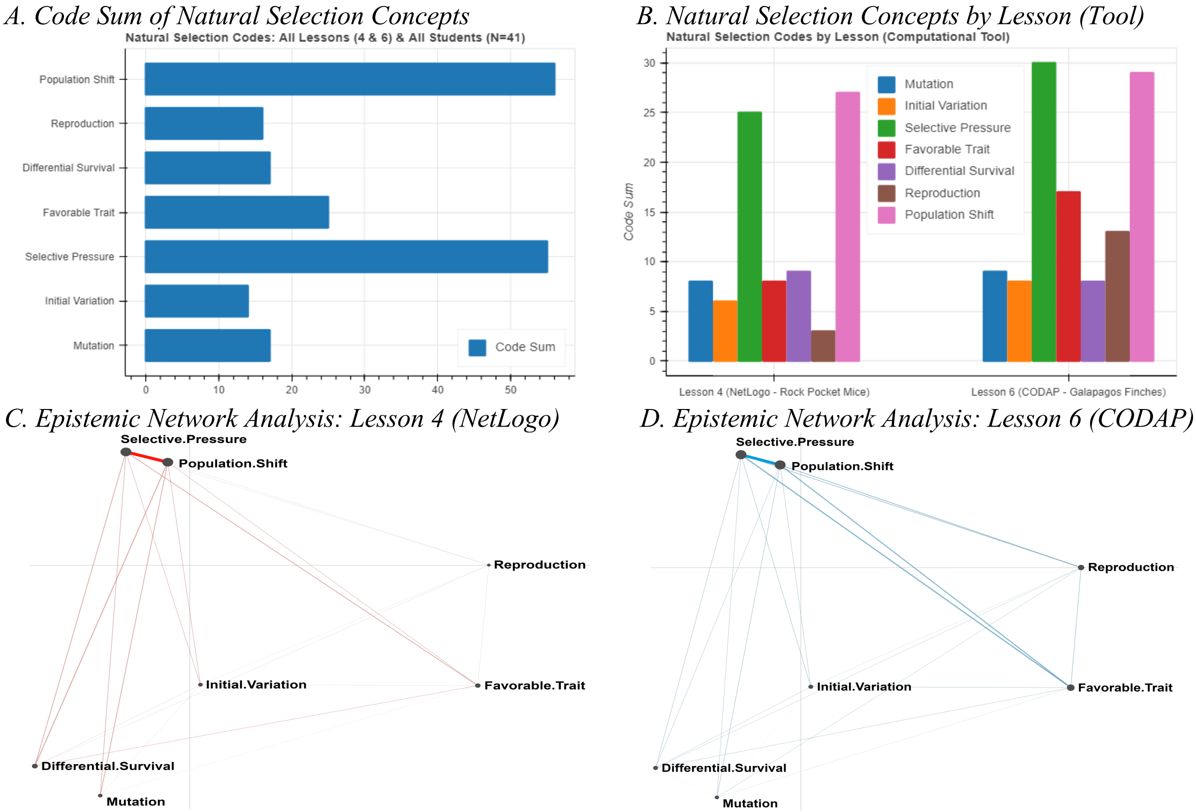
B. CODAP Galapagos Finch Species Data



Results

In Figure 2A we report the sum of natural selection concept codes for all students and both questions. In Figure 2B we disaggregate the natural selection concept codes by question and associated computational tool. Figures 2C and 2D show comparative epistemic network graphs of student demonstration of natural selection concepts with the NetLogo computational model (Figure 1A) and after the lesson with CODAP (Figure 1B).

Figure 2



Discussion

Analyses indicate that computational tools can facilitate learning of natural selection, and to varying degrees. For example, in lesson 4 students used selective pressure and population shift concepts to explain natural selection in rock pocket mice, but fewer of the five remaining concepts (Figure 2B). Students then applied knowledge of natural selection to explain speciation of finches in the Galapagos and exhibited greater knowledge of favorable traits and reproduction (Figure 2B). We suspect this difference reflects the foregrounding of favorable traits and reproduction in the CODAP environment, which indicates that the explicitness of natural selection concepts in computational tools may lead to deeper learning. Comparative epistemic network analyses (Figure 2C and 2D) further support this interpretation and show that the NetLogo model elicited cooccurrences with differential survival, a key design principle of the model. On the other hand, student reasoning relied more on reproduction in the CODAP environment. Both tools surfaced initial variation and mutation concepts to lesser degrees, corroborating prior challenges found in teaching and learning evolution (Peel et al., 2019; Rosengren et al., 2012). Taken together, these results indicate that future work should investigate the fit between computational tools and natural selection concepts so that designs may better facilitate student learning.

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