Designing computational models as Emergent Systems Microworlds for learning biomaking digitally

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For high school students to develop a holistic understanding of synthetic biological systems, researchers must design educational tools that will allow them to learn about the emergent nature of synthetic systems. In addition to knowing how individual biological parts (e.g., a gene or a sequence of genes that produce a consistent functional characteristic) work, *making* with biological parts requires designers and engineers to learn how complex biological systems function as a whole (Smolke & Silver, 2011). We address this challenge by designing computational tools for learning called Emergent Systems Microworlds (ESM) (Dabholkar & Wilensky, 2019). Emergent complex systems perspective involves understanding how simple interactions between autonomous elements can result in complex emergent patterns at the system level (Jacobson & Wilensky, 2006). Computational models have proven effective to help science learners understand natural phenomena (Yoon et al., 2018).

As we design newer educational tools for synthetic biology curricula, computational tools need to be designed to complement experimental curricula authentically. We designed an Emergent Systems Microworld, *iTune Computational Lab*, as an educational aid to be used with a synthetic biology curriculum called iTune Device (iTune Device, 2020). *iTune Computational Lab* uses a model of a synthetic genetic circuit based on the Lac-Operon regulatory mechanism (a canonical feedback loop that is often taught in genetics courses). The computational model can be accessed at the following website: http://tinyurl.com/itunecomplab (Figure 2). This model is specifically designed to support students in virtually exploring, and investigating a synthetic genetic circuit. Students can conduct computational experiments to collect and analyze data of enzyme activity of a biochemically synthesized product.

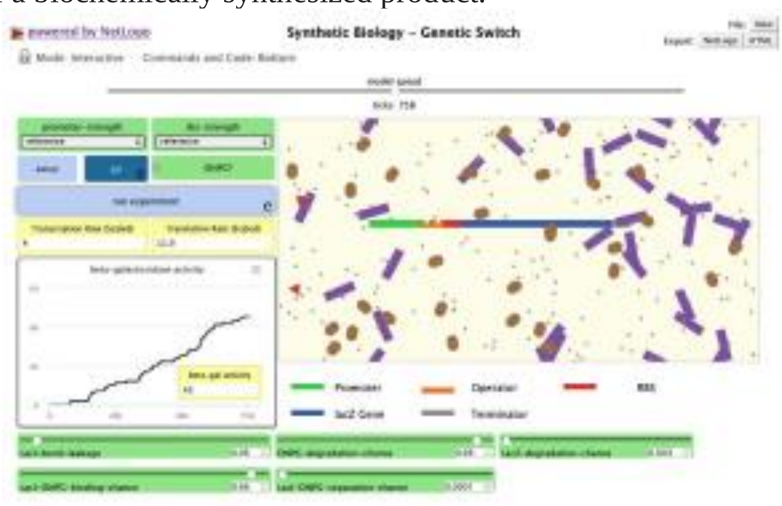

Figure 2: A screenshot of Synthetic Biology - Genetic Switch Model

Co-designing with teachers and practitioners is an effective approach for developing educational tools to support learning of advanced ideas (Kyza & Georgiou, 2014). To co-design this curriculum, we partnered with two synthetic biology researchers who also actively facilitated the iTune Device curriculum (iTune Device, 2020). we conducted a professional development workshop session for teachers to demonstrate the pedagogical use of the model. Additionally, a co-design partner and synthetic biology researcher, Brianna*, facilitated a session in a two-week-long outreach program focused on Biomaking. Qualitative analysis of anecdotal and interview data from practitioners revealed the importance of certain design features for student learning. For example, a teacher said, “Students can see that the molecules move randomly inside the cell,” when he discussed how students can learn about predictable patterns arising from random interactions. This was also supported by Brianna’s observations of student interactions in the class. Students could observe changes in system level parameters and think about reasons for variability which is fundamental to biological processes.

As we design technologies for students to learn advanced ideas in synthetic biology, it is important that the tools allow them to engage in authentic disciplinary perspectives. This work helps us understand how the emergent complex systems approach can be used to co-design pedagogically effective computational learning environments.

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