Myco-kit

Towards a design for interspecies creative learning

Isabel Correa
Department of Mathematics, Science, and Technology.
Teachers College, Columbia University, New York, NY USA
mic2130@tc.columbia.edu

Nathan R. Holbert
Department of Mathematics, Science, and Technology.
Teachers College, Columbia University, New York, NY USA
holbert@tc.columbia.edu

ABSTRACT

This paper explores the design of tools and pedagogies for bio-design understood as a space for children to create and challenge the nature-culture dualism that underpins the environmental crisis. By blurring the boundaries between the learning practices of making and growing, bio-design allows learners to imagine what it means to produce artifacts at the frontier of natural and artificial. We propose the concept of interspecies creative learning to advance in the understanding of learning experiences that engage humans and other living systems in a joint space of creative discovery. Using design-based research, we share the work-in-progress design of Myco-kit, a bio-design toolkit to support interspecies creative learning and advance in the understanding of this concept and its implications for ecologically conscious education.

CCS CONCEPTS

• **Education**; • **Interactive learning environments**; • **Hardware**; • **Emerging Technologies**;

KEYWORDS

Environmental education, ecology, creativity, learning technology design, toolkit design, biodesign, maker education, interspecies creative learning

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1 INTRODUCTION

The environmental crisis is rooted in a profound dualism between humans and nature. The idea that humans and nature are essentially different is distinctive of modern Western thought [14, 20, 24, 28]. The earth, no longer considered alive and sentient, is dismissed as passive matter to be mastered by the human mind. This ontological schism between humans and nature legitimizes commercialization and industrialization of alleged "natural resources" and ongoing extraction, mining, draining, deforestation, and pollution.

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This dualism permeates every realm of modern society; it is embedded in science and technology [24], pushed by dominant economic and political systems [29], and systematically reinforced by standardized education [17]. However, alternative human-nature relationships are possible and necessary. A renewed valorization of indigenous knowledge in education [2, 27] coupled with increased attention to agency beyond humans in learning environments [16, 18, 33] is part of growing efforts to challenge settled anthropocentric paradigms. Along with these efforts, we explore bio-design as a potentially rich and active space for students to conceive and create new forms of relationships with companion species [13].

In this paper, we examine the concept of interspecies creative learning (ICL) as a framework for the design of learning tools and pedagogies that engage humans and other living systems in entangled creative discovery. Through a brief analysis of prior work, we discuss to what extent existing bio-design tools support ICL. Finally, we share the methods and work-in-progress design of a toolkit explicitly designed to support ICL in the context of elementary grade interdisciplinary art and science education.

2 BACKGROUND

The last decade has seen the blossoming of bio-design [7]. In bio-design, living organisms–such as fungi, algae, bacteria, silkworms, among others–work with designers to build and grow into the shapes of clothing, furniture, foods, packaging, and more. Beyond biomimicry or bio-inspired approaches to fabrication, bio-design integrates living systems as essential components of the design's function [30], politics, and aesthetics.

As a new field of exploration, bio-design is only recently finding its way into educational spaces. Some efforts focus on equipping students with biotechnologies that are defining our times [21, 22]. Also, bio-design can be seen as a space for students' personal expression, future career training, or STEM learning [35]. Informal learning environments such as community lab spaces [4–6, 11, 23] have expanded access to specialized equipment and materials. Still, because working with living organisms requires tedious sanitation protocols and interaction with instruments and materials optimized for scientific rather than creative and learning purposes, bio-design development happens mostly in secluded laboratories in industry and academia.

The integration of biology with creative fields tends to make the nature of our relationships with "companion species" [13] apparent and open to debate [15]. Design as a discipline emerged from rationalistic, functionalist, and industrial traditions, and its creative purposes are often intertwined with economic and utilitarian values [10]. When designing with life, it becomes apparent that these values are not neutral. And yet, integrating biology with genres of design that embrace political and ethical concerns and invite to speculate new ways of being have the potential to push back on these capitalist and rationalistic ideologies and illustrate alternative relationships with life [8, 9].

Bio-design may offer valuable opportunities for children to imagine and embody new forms of human-nature relationships and reflect on their critical implications. An analysis of bio-design practices can also provide insights into potential forms in which humans can relate with nature in less oppressive ways.

3 THEORETICAL FRAMEWORK

We propose the concept of ICL to define pedagogical practices where humans and other living organisms or ecosystems engage in mutual creation and development. The goal is to craft a learning experience–with the support of appropriate facilitation, guidelines, tools, and technologies–for learners to engage physically with a living system in search of mutually enhancing creative collaboration and symbiosis.

In ICL, creativity is understood not as an exceptional capacity of the human mind but as an emergent property of life itself. Drawing from Hallam and Ingold [12], we see the ever-novel designs of both natural and human worlds as the outcomes of ongoing engagement and skilled response to a mutually responsive material environment. In words of Ingold: "Where the organism engages its environment in the process of ontogenetic development, the artifact engages its maker in a pattern of skilled activity. These are truly creative engagements in the sense that they actually give rise to the real-world artefactual and organic forms that we encounter" [19]. Skilled makers know their materials and work along with their possibilities and affordances in order to keep creation going. Likewise, thriving organisms know their medium to keep life–self-creation or "autopoiesis" [25]–going. In this view, creativity is not an invisible phenomenon but a worldly engagement with matter.

ICL is thus a joint space for a learner and a partner organism to create by engaging with a given material through mutually responsive actions. It is an intentionally tight and entangled space where humans create by manipulating the material and the environmental conditions for the organism also to create itself and contribute to the recursive transformation of the material. ICL may afford close analysis of interspecies power dynamics and reveal an array of possible modes of human-nature relationships such as collaboration, negotiation, symbiosis, domestication, exploitation, or even other forms that we are yet to name. Understanding ICL can help us lead students towards preferred ways of relating to nature while becoming aware of conflicting power dynamics. To that end, we extract the following three fundamental theoretical and design principles of ICL:

- Joint space: Interspecies creative processes occur at joint spaces where humans and other forms of life can affect the unfolding transformation of the materials in the space. ICL is thus the attentive craft of explicit encounters between humans and other organisms to participate in action with each other.
- Generative: Ingold [20] describe creativity as a generative process that gives rise to phenomenal forms. In this view, people, living organisms, and the earth continually create themselves and create one another at different time and space scales. ICL should support mutually enhancing generative actions in humans and organisms, striving for symbiosis over oppression while respecting the differences in style, scale, rhythm, and timeframe of organic and human design processes.
- Relational: Interspecies creativity is relational "in that it is continually attuned and responsive to the performance of others" [12]. Because of this entangled dynamic, in ICL, learners should be supported in getting to know the organism, discerning its behavior, and tunning creative responses to it.

These principles have significant implications when we design for interspecies creativity. They can be embedded in design features of tools and technologies and implicit in the rhetoric used by facilitators, supporting materials, and learning context. Within this context, careful attention should be given to foster respectful, curious, and reciprocal relationships between learners and the life at hand.

4 PREVIOUS WORK

Before we outline our efforts to develop a kit for ICL, it is worthwhile examining how the few bio-design kits currently available support or hinder interspecies relationships through their features and afforded interactions.

4.1 Toolkits for synthetic biology

At the moment, most bio-making developments focus on educational tools for synthetic biology. Wet lab kits such as DNA playground, BioBits, Bento Lab, and others are designed for DNA analysis and cell fabrication [1, 3, 19]. These kits offer low-floor hands-on interaction with biological procedures. Students can, for example, engineer bacteria to display pigments or fragrances using the tools and (living) substances included.

Through the lens of interspecies creativity, these technologies maintain an instrumental approach to life inherited from rationalistic science and mechanistic engineering. An overview of supplemental educational materials reveals how human control is reinforced through its wording; Cells are presented to children as small "factories," and possible interactions include "programming" or "controlling genetic circuits." Borrowing terminology from engineering and computer science to describe organic processes ultimately reduces the complexity and intelligence of life [22]. Also, the invisibility of the organisms in these kits does not help make their individuality and agency graspable to experience. The joint space gets lost given the organisms' microscopic scale and their enclosure within instruments and mechanisms for control and analysis.

4.2 Toolkits for bio-fabrication

Aside from synthetic biology, the development of toolkits for bio-design is scarce. Learning is mostly driven by DIY (do it yourself) methods and improvised tools shared through online communities. While not specifically designed for education, one available kit

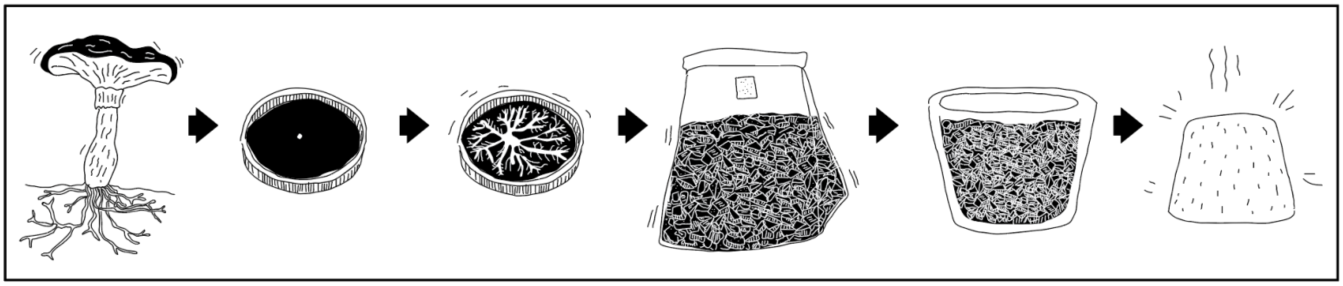

Figure 1: Biofabrication with mycelium starts by cutting a section of a mushroom and placing it over a nutritive agar plate. After the mycelium grows it can be transferred into a bag of substrate and nutrients to increase the volume. Finally, the mix is cast into a mold and unmolded after the mycelium grows. Ecovative's DIY kit consists in a bag of pre-inoculated and dehydrated woodchips ready to be molded after adding water and nutrients to the bag.

is Ecovative's mycelium for bio-fabrication [31]. The kit consists of a plastic bag of organic substrate (woodchips) inoculated with dehydrated mycelium (fungal networks) that designers cast and provide certain environmental conditions for the organism to grow and take the shape of the mold (see figure 1). After unmolding, the resulting artifact is normally heated to inhibit further growth.

From an ICL perspective, Ecovative's toolkit offers more explicit interspecies collaboration. The organism provides an appropriate scale for users to appreciate its behavior. Furthermore, to create anything, the designer must provide the conditions for the organism to grow, which highlights relational dynamics. On the other side, when casting, the organism's growth is black-box inside the mold hiding the joint space. Also, the act of casting as a relational dynamic implicitly reinforces the idea that mycelium is no more than a pile of matter waiting to be shaped according to human will. While bio-fabrication with mycelium affords ICL to some degree, the practice needs refinement to afford an explicit joint space and scaffold generative and responsive interactions.

5 METHODS

We use design-based research (DBR) as a method to advance the development of a theory of ICL through the design of learning practices and tools to support that framework [36]. DBR provides a systematic yet flexible method to advance both theory and design through iterative cycles of analysis, design, development, and implementation [36]. An overview of our DBR process–still ongoing for this work-in-progress–is below:

- Analysis. The first iteration of analysis consisted of examining the literature to define the concept of ICL, which anchors our design process. It also included the analysis of previous work presented above and analysis of interview data from expert bio-designers.
- Design. The ongoing design process involved experimentation with several organisms, which led to the selection of mycelium as an optimal organism to design the first toolkit for ICL. After experimentation with the properties, behavior, and constraints of the organism, we defined the three design choices shared in this paper as ways to scaffold the principles outlined in the theoretical framework.
- Development. The next steps include the design, development, and refinement of the toolkit described in the design section. Furthermore, we intend to develop and study strategies and guiding materials to deploy the kit within informal and formal learning environments.
- Implementation. Initial rounds of research implementation will involve elementary-aged children in the context of informal ICL workshops facilitated by the first author in a local community lab. After refinement of the toolkit and supporting learning experience, we expect to implement ICL in a local elementary public school in collaboration with art and science teachers to align the experience with curricular standards. Implementations will last approximately three weeks, with interventions twice a week to support personal engagement with mycelium while allowing apparent growth between sessions.

6 DESIGN

In this section, we share the in-progress design of Myco-kit, a kit to support ICL between elementary school-aged students and mycelium. The kit design will enable learners to engage hands-on with this living system in search of mutually enhancing creative collaboration and symbiosis. Learners will need to provide the necessary conditions for mycelium to thrive and guide its growth and development towards a personally meaningful outcome. Through this process learners will develop their own skills as caregivers and partners in creation, grow their understandings about the intelligence, agency, and creativity inherent to life, and expand their preconceptions about human-nature relationship. What follow are three preliminary design choices for the development of the kit.

6.1 Mycelium as a partner organism

After experimenting with several organisms, we choose mycelium as a partner organism for the toolkit for ICL. Mycelium is a multicellular organism that looks like a meshwork of threadlike tissues and lives underground or beneath decaying wood or leaves. Mushrooms

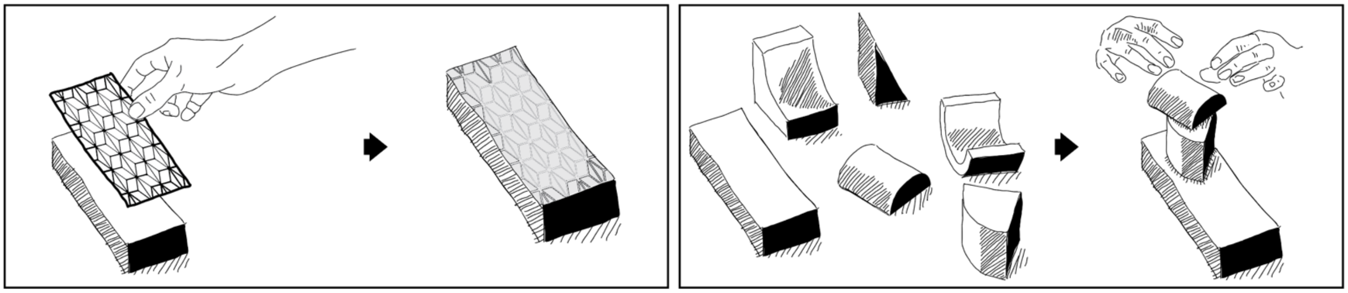

Figure 2: Left: Placing a physical pattern over a mycelium pre-grown block to obtain a texture over the surface. Right: Connecting pre-grown shapes using mycelial welding property.

are fruiting bodies of this organism. Mycelium grows from the hyphal bud, which is the tip of each thread as it searches for water and nutrients. In this unfolding process, mycelium is "creating itself as it searches through the world of its creation" [26].

Mycelium can also be cultivated indoors by inoculating an organic substrate (wood chips or grains) within a certain temperature and humidity range. Bio-designers take advantage of mycelial capacity to fuse pieces of organic matter by allowing the organism to grow within the shape of a mold (see figure 1).

From an ICL lens, mycelium has an appropriate space and time scale to afford a joint space for creative collaboration. This brainless organism's striking intelligence and creativity [26] challenges settled understanding of nature as passive matter and may incite curiosity and awe if adequately facilitated. Other reasons to choose mycelium are the organism's accessibility and ubiquity–given its key role in all ecosystems–, and a growing public interest in mycology [34] coupled with a lack of tools to support creative engagement and learning.

6.2 Generative templating

To describe relationships between natural and human design processes the MIT Mediated Matter Group proposes the concept of templating [32]. According to Oxman, "while the biological world expresses form and function from the bottom up through self-organization, cell differentiation, growth, remodeling and regeneration, design practice operates from the top down, establishing constraints that inform or guide form generation and construction" [32]. In other words, templating is akin to the design of constraints–such as physical scaffolds or environmental forces–to shape organic processes [32].

While we do not necessarily seek strict differentiation between top-down and bottom-up processes, the concept of templating can help refine the relational dynamics between organisms and learners. A mold can be considered a form of templating that constrains growth through a physical barrier. Laser-cut or CNC mill patterns placed over the surface of a growing mycelium block can also act as physical constraints. The organism will tend to grow differently through the pattern generating textures (see figure 2). Alternatively, we can think of templates that do not restrict the organism but instead provide differential nourishment. For example, 3D printing a pattern made from nutritive or humid substrates may afford mutually enhancing collaboration.

6.3 Mycelial welding

Mycelium's capacity to bind together pieces of organic matter is the basis for bio-fabrication. However, there are virtually no explorations on how this property–that we call mycelial welding–can be used at strategic moments during the process to connect or weld pre-grown modules. By streaming the casting process and providing pre-grown blocks, we can draw learners' attention to mycelium's capacity to connect not woodchips, but entire structures, as in playing with a living Lego set (see figure 2). This method may support relational interdependence. Interspecies creativity becomes explicit when the learner critically needs the organism to grow in order to connect a set of blocks while the organism needs the learner for nourishment and care.

7 FUTURE WORK

The next steps in the first iteration cycle include developing the design choices presented, integrating ideas into a prototype, and implementing the design. Other considerations include a more holistic approach to the whole learning experience beyond the toolkit itself, in view of the developmental needs of elementary school-aged students, teachers' preferences, and curricular expectations. This includes the design, study, and development of a learning context that frames interactions with the kit in ways that foster critical reflection and open-ended exploration of answers through the design of artifacts that represent alternatives forms of human-nature relationships. Special attention should be given to the discourse embedded in supplemental material and facilitation guidelines to avoid instrumentalization and promote respectful ways of referring to all forms of life.

Throughout the implementation we will conduct research to advance our theoretical understanding of the possible ways in which humans and living systems can create together. Rather than assuming all forms of interaction as collaborative, we are interested in depicting different power dynamics between human and non-humans and the impact they could have in the resulting designs and in students' environmental consciousness.

8 CONCLUSION

We propose ICL as a framework to advance the understanding of how humans, and specifically young children, can learn to create and collaborate with other organisms by enhancing the inherent creativity of life processes. In order to bring this concept into practice, we present the work-in-progress design of a toolkit that aims to support key principles of the concept such as the design of joint spaces for interspecies exploration and the affordance of mutually generative and responsive interactions. Future work includes the development and implementation of the toolkit to advance our understanding of ICL and its potential to engage learners in imagining new ways of designing alongside natural dynamics.

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