Designing for Shifting Learning Activities

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Existing approaches to instructional design each have a core focal unit of analysis; some focus on developing a specific tool, some focus on a sequence of tasks, and more recently, some approaches have focused more broadly on activities. However, we find that these don't go far enough as real-world implementations require that learners move through a shifting sequence of activities with teachers attending to these shifts. We therefore propose and illustrate an approach to design grounded in focusing on how the design of activities, including tools, necessarily need to shift over time to support learning.

Introduction

Existing approaches to instructional design each have a core focal unit of analysis; some focus on developing a specific tool, some focus on a sequence of tasks (Reigeluth & An, 2020), and more recently, some approaches have focused more broadly on activities (Kaptelinin & Nardi, 2012). Activity, in this context, builds on sociocultural theory (Danish & Gresalfi, 2018) to describe how a group of individuals aim to pursue a shared object or set of goals. Activity theory (AT) also explicitly recognizes how joint activity is mediated, or transformed by cultural artifacts including software, local rules, and other materials (Kaptelinin & Nardi, 2006; Wertsch, 2017). However, as new kinds of technologies emerge, and new approaches to design evolve, we have found that these prior approaches don't go far enough; they often treat activity as monolithic rather than recognizing how it shifts over time.

The need to focus on how activities can and do shift over time is particularly salient in embodied learning activities such as our work with the Science through Technology Enhanced Play (STEP) platform (Danish et al., 2020). In these kinds of embodied activities, participants often have agency to change how they act and interact, which shifts the activity and ways they are engaging with the designed learning tools. We argue that it is important for designers and educators to plan for and support this kind of fluidly shifting learning activity. Our approach to designing for shifting learning activities involves iteratively 1) identifying a high-level conjecture for how the sequence of activities in which learners will participate will support learning, 2) identifying the shared object that the learners will pursue in these activities, 3) designing the tools and other mediators to support these shifts, and 4) implementing the designed activity to explore how it supports the actual flow of activity that emerges. We will illustrate this process by describing some of the key design choices made during the development of the GEM-STEP mixed reality software platform. GEM-STEP, or the Generalized Embodied Modeling – Science through Technology Enhanced Play project, represents an extension of our prior work on the Science through Technology Enhanced Play or STEP project (Danish et al., 2015; Danish et al., 2020). STEP and GEM-STEP are mixed reality environments where learners control part of a model by acting out how it might move. For example, they might learn about pollination by pretending to be a bee flying through a field, while the software shows a bee avatar mirroring their movement in a virtual field. In exploring the design and implementation of GEM-STEP in several contexts, we aim to answer the following question: How do our designed sequence of shifting, mediated activities support learners in learning about ecosystems through embodied modeling?

Literature Review

Designing with Activity Theory

Scholars in a range of fields have suggested using Activity Theory (AT), sometimes referred to as Cultural Historical Activity Theory (CHAT), to guide their designs. The underlying assumption of AT is that human activity is both goal directed and culturally mediated (Kaptelinin & Nardi, 2006; Wertsch, 2017). Mediation refers to how different aspects of the activity system including tools, rules, community, and division of labor transform how learners perceive and pursue their goals (Wertsch, 1981). These mediational processes are all presumed to be bi-directional. That is, the tools we use shape our perceived object of activity, while the object of activity shapes our understanding of our tools.

While a number of scholars have argued for the value of AT in supporting design, there are also three core critiques that we have aimed to address in our approach. First, many scholars have argued that the focus on activity makes individuals less salient (Anderson et al., 1996). We believe this is a misinterpretation of the original theory. We build on the work of Engeström (2018) and others, which treats the two as dialectically connected — activity is made up of individuals and their actions, and at the same time helps to define and shape the actions, learning, and growth of those individuals. A second common critique of AT is that the attention to multiple mediators may be overwhelming, leading analysts and designers to feel as if "everything matters" and therefore there is no clear starting point (Witte & Haas, 2005). Our solution to this has been to focus on the object of activity as the crucial mediator, and then cyclically identify other mediators accordingly (Danish, 2014). Our logic, aligned with Vygotsky's (1978) notion of functional systems is that if learners are pursuing a specific object, a range of mediators may support them. However, the specific mediators won't matter if their goal is inconsistent with the designer's or the teacher's. Therefore, we begin by attending to what we believe learners will try and accomplish (the object) and designing the mediators accordingly.

Finally, there is much debate in the field about how we can bound the notion of activity, and identify when an activity starts or finishes. For example, some believe we can refer to a classroom task as an activity, while others believe it is necessary to focus on "schooling" as an activity (Witte & Haas, 2005). From our perspective, activities are always multiple and nested (Cole, 1999; Greeno & Engeström, 2014; Engeström, 2018). Therefore, rather than concern ourselves with defining an activity's bounds, we instead focus on how different aspects of activity become salient to learners. We assume that the multiple nested activities in which learners are operating will all influence them. For example, we recognize that while we can promote some norms specific to scientific inquiry, learners are also subject to the norms of their local classroom culture, as well as those of the school, their family, and society (Cole, 2017). Rather than deny this, we embrace it by attending to how different mediator designs may make each of these levels of activity salient in key moments and follow up by considering where learners were attending to so that we can adapt our framework as needed.

Designing for Shifting Learning Activities

Our design approach assumes that in developing a sequence of planned activities, we need to remain flexible enough to adapt to learners' ongoing engagement with our designs. To adapt flexibly, however, we believe it is important to have clearly articulated conjectures about how learning will progress so that we can evaluate and iterate on our ongoing implementations (Sandoval, 2004 & 2014). The steps of this approach are: 1) identify our high-level conjecture for change; 2) identify the learners' object of activity; 3) identify the other mediators; 4) look at the results and adapt.

1: Identify our high-level conjecture for change

The goal here is to articulate at a high-level how the overarching design will lead to learning. By "high-level" we mean a brief, easily communicated idea such as:

> Moving around and pretending to be a fish in a virtual ecosystem will help learners reflect on how the fish interacts with other elements of that system.

In a research project, this is the theoretical conjecture about how the design will support learning (c.f., Sandoval, 2004; Sandoval, 2014). This also helps us to identify the mediators we wish to focus on in our preliminary analysis and reflection. In the prior example, we focus our analysis on how students respond to the need to move their bodies, along with how the software makes the experience of being a fish salient to the learners. We have also found in classroom implementations that it is helpful to communicate this high-level conjecture to teachers because it helps them consider how to organize and reflect on their own interactions with learners.

2: Identify the learners' object of activity

The object of learners' activity shapes their experience and interpretation of the outcomes of that activity (Engeström, 1991; Greeno & Engeström, 2014; Engeström, 2018). However, as designers we can encourage and support specific objects. For example, if we encourage the learners to simply keep their individual fish alive, they may choose different actions than if they are excited to work with their peers to model how all of the fish can remain alive. It took only a moment for 5th and 6th grade learners in a recent implementation to recognize this tension; they quickly noted that when someone focused solely on their own fish's survival, they might eat as much as possible and thus survive. However, this kind of "greedy" behavior is detrimental to the object of keeping the ecosystem alive, as it can lead a single fish to eat so much food that there isn't enough for the other fish. Learners interested in the second object would, therefore, need to moderate their eating behavior.

Once the object has been identified, an important question to ask ourselves is whether there is value for the learners in shifting their object over time. If there is, then it is necessary to consider what shift is intended, and how it might be encouraged. We have found that taking on multiple objects in sequence can be a powerful method for encouraging learners to see a system from multiple perspectives (Danish, 2014). In our aquatic ecosystem example, this might mean attempting to alter our goal from trying to make the fish survive as long as possible, to trying to help the algae to also survive as long as possible. We then aim for learners to recognize that these are in fact complementary goals; having the algae survive longer can increase the chances of the fish surviving.

It is not easy to identify learners' objects or orient them to a specific object. Therefore, it is important to start with a conjecture theorizing a) what learners' object might be, b) how to help encourage the pursuit of their object, and c) how that object supports the high-level learning conjecture. However, we should never assume this will be learners' actual object. Therefore, it is crucial during implementations to try and identify learners' objects, consider its alignment with their planned object, and how this may lead to changes in the intended outcome.

3: Identify the other mediators of activity

Once we have identified the object of learners' activity, we then iteratively identify mediators that we believe, based on prior literature and experience, will serve to support learners in pursuing that object and implement them to align with our aforementioned conjecture. This is where more traditional forms of software and activity design fit within our framework as we aim to realize the conjecture. We continue to be guided by AT as we consider how a set of mediators may interact with each other to support our intended interactions. That is, each tool we introduce will be taken up in ways that are transformed by learners' object of activity, as well as other mediators such as the rules the teacher has implemented and the division of labor enacted through designed participation structures. In GEM-STEP, the limited amount of space within a typical classroom frequently means that not all children can embody a character concurrently, thus, we assign learners various concurrent roles and tasks such as observation, note taking, and offering suggestions to help their peers make sense of their embodied models. It is also important to explore how any shifting objects may benefit from changes in the other mediators.

4: Look at the results and iterate

As with many design approaches, it is crucial here to iteratively implement our designs, reflect on their successes, and revise accordingly. In this case, though, that means looking very closely at three elements which mirror the first three steps of the process: 1) the high-level conjecture, 2) learners' lived object of activity, and 3) the role of the mediators in supporting learners' ongoing activity. Simply put, if the activity doesn't work as we hoped, there may be an issue at any of these levels. Therefore, we aim to holistically consider each tier of the design to identify opportunities for adjustment.

Before we can evaluate our high-level conjecture, it is worth asking whether the activity looked as had been intended. Therefore we begin with the object and ask whether learners were in fact pursuing our intended object, or their own. Here we diverge somewhat from other design approaches that ask: if a learner is not doing as we had hoped, how can we get them to? Instead, we want to ask what object learners are pursuing, and how we might potentially re-design around that instead. Objects are deeply personal and arise from people's interests and motivations. Thus, while we can help people adopt new objects of activity, our approach is more learner-focused and aims to capitalize on what the learners wish to do in the first place.

Once we have understood the object, it is important to reflect on whether the mediators worked as intended, and how they aligned with the object that was taken up by learners. Here we may opt to shift the mediators to better support the learners' object based on the high-level conjecture. For example, if the high-level conjecture is that learners will gain new insights from acting as fish, we would look to see whether students a) moved, and b) gained insights from the process. If they didn't gain those insights, is that because we didn't make key patterns salient in the software or because they didn't move as intended? Naturally, we wish to remain open to the possibility that our high-level conjecture may also need revision.

The GEM-STEP Software Platform

To illustrate our approach in action, we will share two vignettes about our recent efforts to design the GEM-STEP embodied learning environment. GEM-STEP is a Mixed Reality (MR) environment that relies on a combination of motion tracking and computer modeling. Learners create a model by moving through the physical classroom. As they move, GEM-STEP tracks their motion and translates it as input into the computer model where characters, or avatars, represent the learners and mirror their physical movement in the virtual space. In the above examples, this means that learners pretend to be fish and see virtual fish move around the computer model in correspondence with their physical movements One thing that sets GEM-STEP apart from other MR environments is that it aims to support a whole classroom in engaging in activity all at once, rather than focusing on just 1-2 learners, which is what most commercial embodied technologies can support.

In our current iteration, we are integrating a scripting language into the GEM-STEP platform so that both the instructors and learners can programmatically modify and create models. Future publications will describe learners' experiences using this scripting technology. In the current study, this scripting enabled us as facilitators to quickly iterate on, vet, and refine our model designs between and often even during classroom sessions. Next, we will offer some vignettes illustrating our design and implementation of several new models for learners to explore including: an aquatic pond ecosystem that involves fish eating algae (described above), a garden ecosystem that incorporates bunnies eating plants, and the decomposition of organic waste, and a forest ecosystem which explores the evolution of moths during the industrial revolution.

Findings: Two vignettes from applying our approach

Vignette 1: Modeling Decomposition

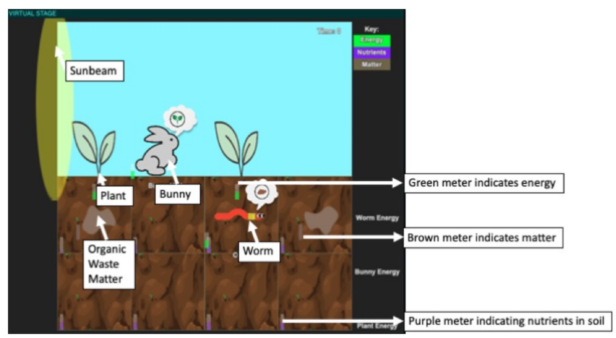
This model of an ecosystem was intended to help learners learn the Next Generation Science Standards (NGSS) of ecosystems: interactions, energy, and dynamics. Our high-level conjecture was that if learners had the opportunity to act as worms who were responsible for decomposition within an ecosystem, they'd be enabled to conceptualize the flow of energy through the ecosystem and explore the importance of decomposition in that process.

Initial design

Our initial design consisted of a visual of the ecosystem (see Figure 1) both above and below ground. The model includes a sunbeam which moves across the landscape. As the sunbeam touches the plants, it gives them energy, allowing them to grow. However, the plants only grow if there are adequate nutrients in the soil. The bunnies eat the plants, and gain energy and matter from them. Once they are full, they excrete organic waste into the soil. If the worms, controlled by learners, eat the waste they gain matter as well as energy. Once full, they can excrete nutrients into the soil. Thus we see the flow of energy and matter through the system from the sun to plant to bunny to waste to worm to nutrients in the soil, changing form as needed. Our instructional approach was to provide students with this default model so they could uncover the basic interactions that make up decomposition. Then we supported the students to modify the model so they could test different hypotheses about how it worked and strategize ways to keep the model in equilibrium.

Figure 1

The GEM-STEP decomposition ecosystem model.



A screenshot of the GEM-STEP garden ecosystem model for exploring decomposition. In this model we can see a beam of sunlight, plants, a bunny, organic waste, and worm agents in dirt. The energy in the system is represented in graphs measuring the worm energy, bunny energy, and lost energy.

Initial implementation

The first round of data collection occurred in the Fall of 2021 at an afterschool program where we pilot-tested the decomposition model during one 45 minute session with three fifth grade students (2 boys, 1 girl). All three students had used GEM-STEP in an earlier session exploring aquatic ecosystems and were familiar with the technology. The students appeared excited to explore the model, beginning as worms and moving quickly around until they discovered that the worms needed to eat the organic waste. They were then eager to try the role of the bunny in the system as well. Moving throughout the system, they soon recognized the need for the worms to not only consume the organic waste, but to deposit nutrients in the soil near the plants to support plant growth.

Reflection and design revision

Following this data collection, our whole team met once a week for several weeks to watch the video together and discussed observations with particular regards to the higher level conjecture previously stated. Following principles of Interaction Analysis (Jordan & Henderson, 1995), the team watched 2 -10 minutes of video in a session and discussed students' actions. They looked for key moments that emphasized movement and traced how students' activity and roles shifted in those moments.

Below we describe a key moment in the video that led us to add a new model into GEM-STEP. This moment occurred around 10 minutes into the session. By this point, these students had experienced four iterations of modeling with GEM-STEP and were strategizing ways to keep the worms alive for longer. In this fifth round, the instructor asked one member of the group to observe when organic waste appeared in the soil to help them notice that the bunny produced it. Girl 1 volunteered to observe and report her observations. Because she was observing, she returned the interactive tag to one of the instructors and stood in front of the TV screen to watch the model unfold while her peers were modeling as worms. When the model started, both boys stood in the soil block that contained an organic waste matter to eat it. Meanwhile, another instructor slowly moved the bunny across the screen so it ate the plants. The boys described themselves getting fat without knowing that they were consuming. Once the organic waste matter disappeared, they began moving around to obtain other pieces of waste matter. This is when Boy 2 realized the matter came from the rabbit. While they communicated their observations to the instructor, they intuitively followed the bunny to consume more waste matter and keep their worms alive. The conversation below occurred while the boys were walking around as worms:

1	**Boy 1:**	**I am fat (referring to the "full" state of the worm character)**
2	**Boy 2:**	**I feel like that's the rabbit's poop, because every time it jumps, I see something comes out of it**
3	Boy 1:	Like, the rabbit eats the plant and…
4	Boy 2:	Then probably when the soil, when the dots come out, the soil, the soil comes out
5	Boy 1:	and also that leaf right there…
6	Boy 2:	is dying so the rabbit will die

Once their worm characters died in the model, the instructor began to summarize all of the actions they described when Girl 1 jumped in and described the cycle:

1	**Instructor:**	**What are the earthworms doing?**
2	**Girl 1:**	**They are giving nutrients to the soil**
3	Instructor:	Where are they getting the nutrients from?
4	Girl 1:	From plants. So it's like a cycle, the worms are giving energy to the soil, and the soil is giving nutrients to the plant. The plants are giving energy to the bunny.

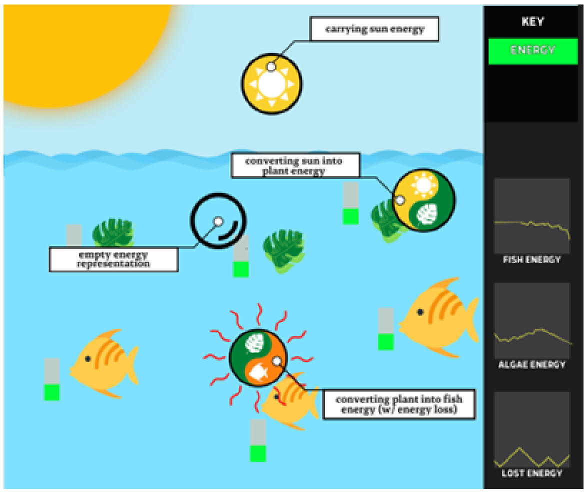
The team noted how this was the first time that one of the students described the energy and matter cycle in decomposition. However, in order to reflect on events occurring in the simulation she paused her movement. Although we saw evidence of the system making certain character interactions salient to the students, such as plants needing sunlight and nutrients from the soil to grow, the cyclical nature of an ecosystem only became salient when the girl in the black shirt stopped moving to observe the simulation unfolding. In other words, we set out to design a platform that drew on students' movement to foster development of energy models about an ecosystem, but we found that students needed to pause and observe the simulation to reach this point. We found that the same student spontaneously stopped moving several more times during this session to observe and add more ideas to her model.

This analysis led us to realize that our model design was not supporting students to use their movement to facilitate model development, which was the key high-level conjecture in our design. We needed to include an activity in which students experienced a cycle of energy and matter transfer through the system using GEM-STEP. We decided to create a model in which students represented energy and moved from one character to the next to transfer energy to them and close the energy transfer cycle in the platform. We further added a text bubble describing the mechanism that happened when they interacted with each character. For instance, when a student-as-energy walked over the sun, the text bubble said "producing energy" and when they walked away from the sun, their energy bar depicted that they were full with "sun energy." When they then walked over to the plant, their energy meter emptied, the plant grew bigger, and their text bubble read "Growing. Eat some!" Using this model, students needed to move in a circle to transfer energy through the model, embodying the cyclical nature of energy transfer in the system, and had an opportunity to notice and verbalize energy transformation as it occurred.

We recognized that students being energetic introduced a level of abstraction to the model that did not fit with our design principles of embodiment. While moving around to find food as a worm is an intuitive action, there is no intuitive motivation for moving around when representing energy. Thus, we included this model as a complement to the original model rather than simply replacing it. In the sequence of instruction, we had students go through this energy model after they experienced the original decomposition-as-a-worm model and we supported them by explicitly asking them to reflect on how energy transfers in this system. The students were then given the opportunity to again take the part of the worms and apply their new insights.

Figure 2

The GEM-STEP aquatic energy transfer model; learners embodied ‘energy’ representations (often referred to as ‘energy bubbles’) that visually indicated what type of energy was being ‘carried’ or converted (edited for readability).



A screenshot of the GEM-STEP aquatic energy transfer model showing the sun, algae, and fish agents in a body of water. Circles with images of the sun, algae, and fish agents represent energy transferring in the system. The energy in the system is represented in graphs measuring the fish energy, algae energy, and energy lost as heat.

This new model was implemented in the next round of data collection that occurred in a fifth and sixth grade mixed-age classroom of about 20 students who had the opportunity to first engage with the aquatic ecosystem model described above, then an energy version of that model (Figure 2), followed by the original decomposition model, and then the decomposition energy model. This shifting sequence from aquatic ecosystems to decomposition was intended to help students move through increasingly complex models, and also to begin recognizing that many different ecosystems have similar flows of energy and matter. This sequence appeared to support learners in appreciating the flow of energy in these systems. With the addition of explicit energy representations, students also seem to engage more deeply with the idea of energy transfer as they move rapidly around the system, and then carry this knowledge back to enacting the roles of worms and bunnies. When we asked students for feedback about this model, they admitted to it being more complex than the previous models, but not insurmountable. Moreover, we noted that students were discussing more strategies to improve energy transfer across characters.

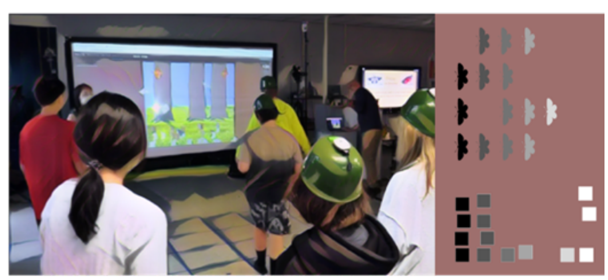
Vignette 2: Modeling Moth Evolution

Initial design

In another instantiation of GEM-STEP, researchers designed a 5th-grade curricular unit to meet NGSS standards on heredity and biological change. We used peppered moths as a grounding phenomenon, as it allowed us to explore generational change and external environmental pressures to evolve. Peppered moths are a prime example of environmental change impacting the traits of species. When the Industrial Revolution caused the trees in their habitat to darken, hunting pressures led peppered moths to have darker wings through natural selection. Evolution is a scientific phenomenon with little agency for those in the system (e.g., peppered moths do not choose to be light or dark, their color changes generationally based on their success at camouflaging and hiding from predators on the color of trees in their environment). As such, the high-level conjecture guiding our design was that embodying a multitude of perspectives in the scientific system would allow students greater agency in modeling evolution. We identified two objects of the activity for students: 1) to understand camouflage and evolution through movement and perspective taking and, 2) to collaborate to make sense of computational and scientific concepts. We identified a number of characters within the broader peppered moths system, including moths, moth babies, birds (predators), and trees (light and dark), then designed a sequence of models and associated curricular activities to be implemented over the course of 9 days.

Figure 3

On left, students prepare to start the second model, in which they embody guardian moths trying to camouflage baby moths on trees. On right, a generated histogram created after the model run with surviving moths on top and dead moths on bottom, represented as squares (edited for readability & to maintain anonymity).



On left, learners standing in front of a screen showing a GEM-STEP model of moths landing on trees. On right, a bar graph made out of squares and moth shapes ranging in colors of gray from black to white.

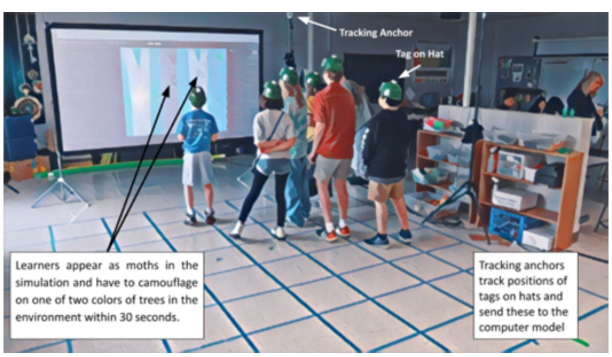
In the first model of our sequence, students took the perspective of birds (predators) hunting moths for a limited amount of time. Our intention was to have students come to know how the GEM-STEP system worked—where their projected character was in the simulation in relation to where their bodies were in the room—as well as introduce them to the moth's ecosystem, and a major player in its survival: its predator. As part of the rules of our system, light or dark moths resting on a tree of the same color were camouflaged and therefore inedible, while moths in motion were edible. At the end of the round, the moths that were eaten turned into squares that could be sorted into a histogram to demonstrate who survived and who was eaten (see Figure 3).

In the second model of our sequence, students took on the perspective of guardian moths, who were immune from being hunted, and were charged with the task of hiding "baby" moths onto trees to protect them from predators. The class could observe which babies survived and which were eaten by predators. Between rounds, students were prompted to consider the distribution of colors in the surviving population. Before the next round, the model generated a new set of moth babies based on the color distribution of surviving moths. The students played multiple rounds, converging on a new moth color over time. The lesson objectives for this model were to demonstrate that; 1) moths that camouflage with their environment better are more likely to survive and reproduce (natural selection), and so over generations, the color distribution of the population shifts towards more complete camouflage with the environment (adaptation); and 2) offspring are not identical to their parents (variation and mutation), so even after generations, some moths may not camouflage completely.

Initial Implementation

Figure 4

Image of learners using a GEM-STEP Moth model



Learners standing in front of a screen displaying a GEM-STEP model. One text box in the image explain that learners appear as moths in the simulation and have to camouflage on one of two colors of trees in the environment within 30 seconds. Another text box in the image describes that tracking anchors track positions of tags on hats and send these to the computer model.

The unit (30 min/day over 9 days) was implemented in each quarter of the 2021-2022 school year in a 5th grade teacher's science classroom in a mid-sized southern middle school. During implementation, a researcher would introduce the model then allow groups of 6-8 students to use interactive tags to control the movable agents in the models (see Figure 4). Students who were not actively participating in the models would be asked to observe or be given a low-tech activity to complete in parallel. After each model, students would be asked questions to prompt deeper engagement in the scientific concepts and ideas introduced in the model. Discussions were led by the classroom teacher, who additionally participated in guiding interactions with the models. Video, interviews, student artifacts, pre/post tests, researcher field notes, and design documentation were collected. For the purpose of this case, we examined design documentation, field notes, interviews, and video data to develop overarching patterns of design and student engagement.

During the first two quarters of the school year, two primary unexpected objects of the activities and sequence emerged, as identified in field notes and design documentation: 1) gamification that overshadowed the scientific content and, 2) skewed participation towards independent problem solving. To address the unexpected outcomes, the researchers revised the activity sequence to reduce the gamified elements and to increase collaboration by shifting the perspectives the learners could embody in the activity.

Reflection and design

In the unit, learners often expressed their thinking in relation to their experience with video games. While this allowed students to draw from their personal repertoires, for some models, the gamified lens prevented learners from accessing scientific knowledge. For example, when asked to make sense of population outcomes shown in a model, one student suggested, "Maybe the game is built in a way that lets a few black moths survive." They only reflected on scientific rationales with additional prompting. The game lens was particularly salient for students when playing as birds trying to catch moths. The "game" of competing to kill the most moths outweighed thinking about which moths were easier to see. The concept of camouflage did not resonate with students from a predator perspective. To adjust for this unexpected student object, the bird perspective was removed from the activity sequence.

The researchers additionally shifted the object of the sequence to focus on the way that students can collaboratively learn camouflage and evolution. To accomplish this new object, the researchers made several changes to the tool instantiations and sequence of the unit. First, we added a new GEM-STEP model in which learners must collaborate in order to succeed. In this model, the color of the moths is hidden from the learners and they must problem solve to safely camouflage on the two colors of trees. To scaffold their problem solving, student-controlled tree spirits were added to the model that could tell the moths the total number of moths correctly matched to trees. As such, in order to succeed, learners must collaborate to collectively match their moths to the associated color of the trees. In addition to the shift in the model, we designed classroom activities that required learners to work together and translate their thinking from embodied patterns of movement within the GEM-STEP system to a single inscription. For example, students drew cartoons and flow charts to indicate their understanding of how the moths and birds behaved, with the goal of helping a newcomer to understand the model. In these activities, learners are asked to shift from the perspective of moths to a global system's perspective.

Conclusion

In this research, we have demonstrated how effective classroom design necessarily needs to move beyond a focus on singular tools or activities, to a careful consideration for how our designs need to shift over time to support different learner perspectives. Furthermore, while it is crucial to design for learners' object of activity, it would be naïve to assume that we can always predict what learners will choose to pursue in advance. Rather, it is important to articulate our assumptions and then look to see what learners actually do. While our focus in the present analysis is on how the designers / researchers attended to these issues, we see a valuable parallel for classroom teachers as well. It will be important to help teachers understand how to look for these key shifts, and attend to learners' object of activity during implementations so that they too can shift their implementations on the fly, adapting to learners' activity.

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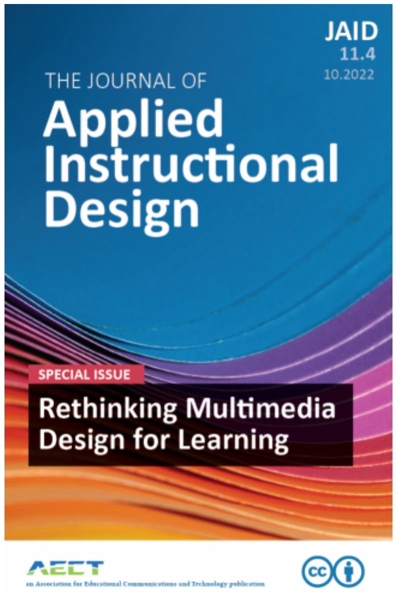

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