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have shown promise for reversing summer learning loss and increasing educational equity.

Positive and Healthy Youth Development

Although much recent attention on summer learning has focused on connections to academic support, summer learning programs continue to offer a broad range of active and intellectually stimulating experiences that promote positive and healthy youth development.

Generally, summer programs tend to be more effective in improving outcomes supporting academic achievement, such as social–emotional skills, rather than specific markers of academic achievement. Because youth spend the vast majority of their time outside the school context, academic success is inextricably linked to these academic support experiences and outcomes.

As the passage to adulthood becomes prolonged and more complex, the demands on youth to be active and engaged citizens are pressing and multifaceted. Summer programs present a unique opportunity and resource to forge ahead with efforts to meet these demands and to better educate the “whole child.” Because youth and their parents expect summer learning experiences to differ from traditional academic year opportunities, program staff can be more inventive and flexible in their methods and curriculum. In addition, the growth of school–community partnerships in summer programming represents a progressive and innovative approach in the education of youth by combining the resources of schools and community organizations toward a shared focus on the healthy development of children. Bringing together educators with community partners who have a specialized expertise in the arts, technology, sports, music, and youth development showcases the potential for summer learning programs to be multidimensional settings for applied and meaningful learning. Furthermore, such partnerships strengthen youth connection with their community and expose youth to opportunities for personal and professional opportunities.

Other areas of youth development, such as media literacy and civic engagement, represent additional potential targets for summer learning focus and impact. As summer programming models are strategically designed to best align with the fundamentals of a positive youth development perspective, the potential for the summer context to encompass and affect multiple challenges facing youth today becomes significant.

Armed with a deeper and more nuanced understanding of the impact of summer programs on diverse populations of youth, researchers, practitioners, and policy makers can harness the potential of the summer months to better meet the social–emotional and academic support needs of all youth and most notably of those youth who face the greatest challenges to their positive and healthy development.

Georgia Hall

See also Access and Equity in Out-of-School Learning; After-School STEM Programming; Community Outreach Programs; Educational Camps; School-Based Programs; Summer Camps

Further Readings


Systems Thinking

The world we live in is increasingly interconnected in ways that affect our lives. There are social and
emotional connections between people; physical connections between animals, people, and the environment; and economic connections between companies, cities, and nations, to name just a few. Scientists and mathematicians often refer to groups of interconnected elements (e.g., animals and plants within the environment) as a “system” and have made great strides in explaining how the elements of a system interact with one another.

While this might seem at first blush to be the kind of content best studied in formal classrooms, many of the most successful approaches to learning about systems, such as embodied play and game design, are quite popular in out-of-school environments. Through informal approaches such as these, and other more formal approaches such as agent-based modeling, educators have worked to help students identify common mechanisms or behaviors across these complex systems so that they can better understand how the world around us works.

For example, the notion of feedback—the idea that one element within a system can affect others in a consistent and predictable way—can be used to explain both how grades in the classroom affect a student’s performance and how honeybees within a hive work together to find and collect nectar. While systems can be quite complicated, researchers and educators are particularly interested in those that are referred to as “complex.” In addition to being made up of many complicated interacting elements, complex systems are made complex by a series of properties that cannot be intuited at a quick glance.

Educators have shown that students can engage deeply with complex systems in a number of content domains and topics such as the fish within a pond, honeybees collecting nectar, the water cycle, chemical equilibrium, traffic patterns on the freeway, and how the stock market fluctuates. This line of work shows how it is possible to help learners of all ages see the mechanisms behind the inner workings of these systems and to explore new systems in productive ways. This entry looks at why it can be difficult to understand complex systems and some of the key principles of systems thinking. It then describes some successful approaches to learning about systems and how systems thinking can be supported in out-of-school learning environments.

Understanding Complex Systems

Complex systems are distinct from other complicated systems in that they contain various dissimilar components across multiple levels. These components are often difficult to see as a whole, coherent system and can sometimes be misunderstood as simply collections of unrelated parts. Furthermore, learners do not always see the value or necessity in exploring a system in detail, and this lack of motivation can lead to superficial studies and thus common misconceptions.

To overcome this motivational challenge, those working with learners can help them identify systems and systems principles that are relevant in their own lives and then scaffold their process of learning about these systems so that the barrier of entry is not too high. Similarly, learners may engage quite deeply with complex systems in the form of video games or other aspects of youth culture without ever realizing that there are deep, underlying principles they might attend to that would enhance both their gameplay and their understanding of the world around them. Researchers have begun to identify the effective ways of scaffolding youth engagement with systems concepts. When learners’ activities are scaffolded in this way, they both enjoy learning about systems and come to appreciate their nuances. This is true of students even as young as those in kindergarten.

Before exploring how researchers have scaffolded young learners in complex-systems learning, it is useful to identify some of the key principles that researchers hope these students will learn, and to elaborate on why these principles are actually quite challenging. This section briefly examines three of the most commonly addressed principles: (1) thinking in levels, (2) feedback, and (3) emergence.

Thinking in Levels

Thinking in levels involves looking at a complex system from multiple perspectives and recognizing how these perspectives are related. For example, an exploration of an ecosystem within a pond or lake might start with the fish and vegetation, or with the chemicals present in the water. Students might also focus on how the lake is affected by local industry. A full understanding of the system
as a whole, however, means integrating all of these different perspectives or levels. For instance, a clear understanding of how industry affects the lake would include recognizing how chemicals in the lake influence the fish and plants, which then result in fish die-offs or reproductive increases, and in turn how wildlife survival transforms the vegetation contents of the lake.

Thinking in levels this way can be difficult, for both children and adults. People tend to think in terms of hierarchies and also assume that the causal relations within a system are one directional and easily predicted. The goal of systems curricula is thus to help learners recognize that there is value in exploring a new system from multiple perspectives, attempting to understand how each level within a system is both influenced by and in turn influences the other levels.

**Emergence**

Closely related to the notion of thinking in levels is the principle of emergence. Emergence is a concept used to identify those situations in which the properties or behavior that can be observed at one level of a system arise in an unintuitive way from the interactions at a lower level of a system. People find this particularly challenging because they often assume that a complex system is controlled by a single, centralized intelligence or intelligent plan in a highly predictable manner. The notion that simple behaviors can occur quite randomly and yet “add up” to something that appears intelligent is quite counterintuitive. Furthermore, it is common to assume that the actions in higher levels of a system cause the actions in the lower ones, but in complex systems research, we note that this is often the opposite of how things actually work.

For example, several species of fireflies are known to blink in unison when in close proximity, even in large numbers. This occurs not because there is a leader telling the other fireflies what to do but because each individual firefly can adjust its flash to match that of a nearby flash. It may seem odd that individuals responding only to their neighbors can lead to simultaneous patterns en masse, but this demonstration of local or agent-level occurrences giving rise to aggregate level patterns is a perfect example of emergence.

**Feedback**

One of the common systems concepts that helps explain how many systems operate, including how many emergent properties come to be, is the notion of feedback. Feedback is exactly what it sounds like; one component in a system affects another component so that it does more (or less) of something. For example, when children playing a game see that passing leads their team to get more points even if an individual child is less likely to score personally, they are likely to pass more often. However, the notion of feedback in complex systems is somewhat more nuanced than our intuitive definition; it involves seeing causality as something that occurs repeatedly and can “add up” over time. This shift involves viewing causality as a circular process that feeds into itself, rather than a single occurrence of a straight line.

A honeybee hive provides a good example: Honeybees in a hive will go out to look for nectar in flowers. If a bee finds a source of nectar, it will come back to the hive and communicate the location of the source to other bees. Those bees in turn will tell other bees where to find the nectar source, causing more bees to go to the flower, which causes more communication, and so on. Feedback can be positive, where the feedback leads to “more” of some behavior, such as increased population resulting in more people reproducing, which leads to a larger population, and so on. These loops can also be negative, where the feedback leads to a decrease. For example, the human body produces sweat in an effort to cool off. If the body begins to cool off, this lower temperature provides feedback, leading to less and less production of sweat as the body adapts to the new temperature and levels off. Unfortunately, youth often view feedback as something that is linear and simplistic. They identify the basic cause of a phenomenon without recognizing that it may require repetition. Or they may not recognize that the feedback within a system is happening at a different level than they recognize.

**Successful Approaches to Learning About Systems**

While an increasingly diverse set of research projects have explored how to help students learn about complex systems concepts, there are three
approaches that have consistently appeared across projects, which are briefly described in this section: (1) explicitly describing levels of a system, (2) agent-based modeling, and (3) participatory simulations. While these approaches have often been employed within classroom contexts, they also tend to involve simple, fun activities that have been employed to good effect in out-of-school settings.

Explicitly Describing Levels of a System

Many existing learning activities already involve explorations of what scientists think of as complex systems. However, because these activities explore these systems at only a single level or from a single perspective, students do not engage with system-level characteristics. For example, it is not uncommon for students to learn about honeybees in early elementary school by focusing on their anatomy or their role in pollination. However, the focus on a single aspect of the bees’ ecosystem means learners will not appreciate the rich sets of interactions that make up the system. One successful approach to overcoming this has been to explicitly teach students to look at a system from multiple levels, such as focusing on the superficial components, the mechanisms through which those components interact, and the overarching phenomena that occur.

When learners appreciate the need to look across perspectives and levels, they are more likely to approach new systems they encounter by asking how the components they see interact or how the phenomenon they are observing is driven by its underlying mechanisms. Some learning environments have explicitly taught learners to look across these levels, while others have been successful in incorporating an implicit awareness of these levels into their designs. An advantage of explicitly teaching learners to look for multiple perspectives on a system is that students may explore the different levels in new systems they encounter. In contrast, simply incorporating these different levels into a new design has the advantage that it may feel less instructionally burdensome to students, though it is unlikely that students will spontaneously recognize the need to look across levels in future contexts.

Agent-Based Modeling

Another successful approach to helping people of all ages learn about systems is the use of agent-based models. Agent-based models are environments where learners specify the behaviors of individual agents within a system, such as fish, bees, or cars, and then observe how those simple behaviors lead to system-level or aggregate behaviors. There are a number of agent-based modeling environments such as NetLogo and StarLogo, which are designed specifically to allow individuals to easily indicate the agent-level behaviors. Agent-based modeling environments can then be used to model a wide range of phenomena.

For example, a learner can specify the behavior of a single firefly in a simulation and then populate the simulation with 100 fireflies to see how they interact. As each firefly responds to its neighbors, the learner might appreciate the role of a feedback loop in this system, as well as the emergence of the flashing pattern in the entire population. In addition to helping learners explore individual systems, researchers have shown that once learners develop a facility with agent-based modeling, they can explore new and different systems with increasing ease. This leads to an improved appreciation of the relationships between how individual agents interact and how their behavior contributes to the whole system.

A particularly popular context in which learners can specify the behaviors of individual agents is game design. Scholars have noted that video games are, in many ways, complex systems made up of individual elements that have unique properties and behaviors but which add up to a robust environment and experience. Not all game programming environments explicitly highlight the properties of a complex system, but they have been shown to be powerful environments for motivating learners’ explorations of how the elements of a system can and do interact over time.

Participatory Simulations

While many games and agent-based models involve programming computer simulations, a number of designers have also shown how learners can explore a new system by pretending to be part
of the system itself. This can be done with or without supporting technology. For example, in a classic series of designs, youth explored how disease spreads by using simple electronic badges. The badges were capable of displaying whether or not the wearer was “infected” and would also communicate with other badges. The participants were then tasked with interacting and trying to visit with as many peers as possible. With each visit, however, there was a chance that the disease might be spread from person to person via their badges. As youth interact with their peers, they quickly come to recognize that they need to look at both their behaviors and their peers’ to make sense of disease spread. They also come to appreciate principles such as the latency of the disease, since they could catch the disease from someone who did not appear infected.

An important aspect of this kind of activity is that by being part of the simulation, youth become invested; they are clearly disappointed when things go awry but thrilled when they work. This excitement motivates the learners to engage deeply with the simulation and the ideas that emerge. Participatory simulations have been explored with physical devices such as badges, within virtual worlds, and without technology. In all of these cases, becoming involved has helped youth engage deeply. However, the experience is not enough on its own; discussion and reflection is an important part of the process as learners explore the relationships between their individual actions and the aggregate results. That is, when youth connect their own experience of catching a virtual disease to the pattern with which that disease spreads through their local simulated community, that is when they begin to truly appreciate the phenomena.

**Systems Thinking in Out-of-School Contexts**

The world is made up of interconnected complex systems. Understanding how systems work and interact is increasingly important, and this understanding cuts across content domains and disciplines as disparate as biology, physics, economics, and sociology. Learning about complex systems has proven challenging for learners of all ages and backgrounds. Fortunately, advances in theory and design have shown that youth as young as kindergarten can appreciate systems when they are supported in exploring them in productive ways. Making the levels of a system visible using agent-based tools and participatory simulations are two of the more popular and successful approaches.

At first glance, it might also appear that the inherent difficulty of systems thinking should relegate such learning to formal environments. However, this ignores how motivating and important these concepts can be. Successful implementation of agent-based approaches and participatory simulations have, fortunately, also shown how these approaches work well in out-of-school contexts, including in after-school clubs and virtual playgrounds. However, for these ideas to be successful, the designers and facilitators who support them need to be aware of systems thinking concepts and how to help learners explore systems-level properties.

As an example, game design has been a popular out-of-school activity for quite some time and helps learners engage with many important concepts. However, young game developers may not appreciate that they are developing a complex system if they are not encouraged to view their games as such. They may not come to appreciate that the interactions they are programming represent principles such as feedback, which can also help explain complex interactions in the world around them.

An important aspect of supporting systems thinking in youth is, therefore, helping teachers and facilitators also see the world through the lens of complex systems. This is challenging, because we naturally adopt more simplistic explanations for how things work. For example, it is quite common to take on a centralized mind-set, which assumes that seemingly complex behaviors can be explained by a simple external mechanism such as a knowledgeable individual who can coordinate across agents within a system. From this perspective, one might assume that fireflies flash in unison because a single firefly directs the flashing rather than recognizing how each firefly simply reacts to its neighbors. However, helping learners explicitly appreciate systems such as these from a complex systems perspective can support the development of more robust perspectives of the world around
us and help learners of all ages appreciate how to describe, explain, and transform these systems.

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See also Adults Learning Coding Out of School; Computational Thinking; Computer Programming; Game Design; Learning Sciences; Technology-Mediated Learning Environments; 21st-Century Skills

Further Readings


