INTERCONNECTIONS: *Understanding Systems through Digital Design*

GAMING THE SYSTEM

DESIGNING WITH GAMESTAR MECHANIC

Katie Salen Tekinbaș, Melissa Gresalfi, Kylie Peppler, and Rafi Santo

foreword by James Paul Gee

Gaming the System

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Gaming the System

Designing with Gamestar Mechanic

Katie Salen Tekinbaş, Melissa Gresalfi,
Kylie Peppler, and Rafi Santo

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SERIES FOREWORD

In recent years, digital media and networks have become embedded in our everyday lives and are part of broad-based changes to how we engage in knowledge production, communication, and creative expression. Unlike the early years in the development of computers and computer-based media, digital media are now *commonplace* and *pervasive*, having been taken up by a wide range of individuals and institutions in all walks of life. Digital media have escaped the boundaries of professional and formal practice, and of the academic, governmental, and industry homes that initially fostered their development. Now they have been taken up by diverse populations and noninstitutionalized practices, including the peer activities of youth. Although specific forms of technology uptake are highly diverse, a generation is growing up in an era when digital media are part of the taken-for-granted social and cultural fabric of learning, play, and social communication.

This book series is founded upon the working hypothesis that those immersed in new digital tools and networks are engaged in an unprecedented exploration of language, games, social interaction, problem solving, and self-directed activity that leads to diverse forms of learning. These diverse forms of learning are reflected in expressions of identity, in how individuals express independence and creativity, and in their ability to learn, exercise judgment, and think systematically.

The defining frame for this series is not a particular theoretical or disciplinary approach, nor is it a fixed set of topics. Rather, the series revolves around a constellation of topics investigated from multiple disciplinary and practical frames. The series as a whole looks at the relation between youth, learning, and digital media, but each contribution to the series might deal with only a subset of this constellation. Erecting strict topical boundaries would exclude some of the most important work in the field. For example, restricting the content of the series only to people of a certain age would mean artificially reifying an age boundary when the phenomenon demands otherwise. This would become particularly problematic with new forms of online participation where one important outcome is the mixing of participants of different ages. The same goes for digital media, which are increasingly inseparable from analog and earlier media forms.

The series responds to certain changes in our media ecology that have important implications for learning. Specifically, these changes involve new forms of media *literacy* and developments in the modes of media *participation*. Digital media are part of a convergence between interactive media (most notably gaming), online networks, and existing media forms. Navigating this media ecology involves a palette of literacies that are being defined through practice but require more scholarly scrutiny before they can be fully incorporated pervasively into educational initiatives. Media literacy involves not only ways of understanding, interpreting, and critiquing media, but also the means for creative and social expression, online search and navigation, and a host of new technical skills. The potential gap in literacies and participation skills creates new challenges for educators who struggle to bridge media engagement inside and outside the classroom.

The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning, published by the MIT Press, aims to close these gaps and provide innovative ways of thinking about and using new forms of knowledge production, communication, and creative expression.

FOREWORD

Today, we humans face massive problems because of complex systems. These are systems we have helped to create because of insufficient intelligence and care, systems like global warming, environmental degradation, broken governments, rapid technological change, national and global inequality, and global flows of immigrants fleeing war, poverty, and drought.

A *system* is any set of components or elements that are integrated, in the sense that to understand a system, we have to understand not just its elements (as a set), but also the ways in which they relate to each other to integrate into a whole that is more than the mere sum of its parts. A system can be simple, with only few elements and relations, or complex (complicated), with many elements and relationships. So, in one sense, a system can be said to be "complex" if it cannot be described easily because it has so many components and so many relationships and interactions among these components.

In mathematics and science, there is sometimes a more specific and technical meaning to the term *complex system.* In the technical sense, a system is complex if the inherent behavior of one or more components is nonlinear. Such systems are often said to be "sensitive to initial conditions" in the sense that very small changes in initial conditions will change the outcome of the system in such a way that we cannot predict the outcome of the system on any particular instance of it. Examples of such special complex systems include weather systems, global warming, the spread and evolution of viruses, markets, and the historical development of civilizations.

So what do video games have to do with complex systems? A *game* is a system of interacting rules that are normally invisible to the player. The player has to form hypotheses about these rules and how they interact in order to play the game strategically and well. This essentially means that strategic players form models of the rule system in their heads and test it in their play. This modeling can be tacit, or players can discuss it, debate it, and learn to articulate it in conversation with other players or on Internet game-based fan sites. This is model-based reasoning, the basis of science and the core way that we humans seek to understand and tame complexity.

Going further, players can "open the hood" of many games, looking at the program by which a game was designed. They are looking at the rules more directly now. If they want, they can "mod" them—that is, reprogram them and transform the game. When they do this, they are becoming designers, building and rebuilding systems as "tools for thought" and confronting the unintended consequences of their interventions. This is the basis of "design research" in terms of which scientists seek to design effective interventions into hard problems in the world.

Some systems in the world were not designed by humans (for example, weather). From time immemorial, storms were "acts of God," but now, thanks to human intervention, storms are increasingly the joint outcome of nature and humans. There are now fewer and fewer "natural systems" in which humans have not intervened. Other systems were designed explicitly by humans (for example, governments). More and more, it is important that we understand the interactions of humans as social beings with systems both designed and undesigned.

Games are important here, too, as they are inherently interactive systems between players and technology. Furthermore, the social aspect of games is taken further in modding and in interest-driven activities around games and gaming. Games as systems are more than software. They are linked software-social systems (what I have called "Big G Games").

Beyond the issue whether games—just as games—are good for developing systems thinking, games can have content that is about a system or systems thinking. This might be a game devoted to urban planning, complex machines, the spread of viruses, markets, the rise and fall of civilizations, or running an institution. Most games are not about systems; nonetheless, as systems that are "played," they invite systems thinking.

Gaming the System: Designing with Gamestar Mechanic is about a game that was explicitly designed to highlight the ability of games and game design to facilitate systems thinking. The game is a type of engaging Systems 101 course and is also meant to be good preparation for future learning in other areas of design and systems thinking. In that sense, it is a crucial intervention into our ongoing essential education for survival and human growth in the modern world.

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ACKNOWLEDGMENTS AND PROJECT HISTORY

ACKNOWLEDGMENTS

This book collection would not have been possible without the involvement of so many people, who were as inspired as we were by the idea of having youths develop powerful new ways for seeing and acting in the world. It's the result of years of collaboration with research and design partners across the United States, cycles of testing and feedback from teachers, and helpful insights from advisors and friends. In particular, we'd like to thank the following:

- Connie Yowell (Director of Education for U.S. Programs at the John D. and Catherine T. MacArthur Foundation), for the ongoing support provided to this project through the MacArthur Foundation's Digital Media and Learning (DML) initiative. The project would have been impossible without not only the funding provided, but also the incredible networks of colleagues within the DML field that she has done so much to foster.
- This material also is based in part upon work supported by the National Science Foundation under Grant No. 0855886, awarded to Kylie A. Peppler.
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- The hard-working team of graduate research assistants at Indiana University who have contributed to this project over the years, including Sinem Siyyahan, Diane

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HISTORY OF THE GRINDING NEW LENSES PROJECT

One of the important lessons to be learned from working on systems thinking is that nothing is created in a vacuum; the same is true of all the work shared in this book. In this section, we briefly share the background on the Grinding New Lenses (GNL) project, which has led to this book collection and shaped its focus.

Taking a systems perspective, it's somewhat challenging to tell a linear story about what led to this work. But a good place to start might be a school called Quest to Learn (Q2L; **q2l.org**), which was opened by Katie Salen and Institute of Play in New York City in 2009 (**www.instituteofplay.org**) with support from the MacArthur Foundation's Digital Media and Learning initiative (Salen et al., 2010). The school was designed as a proof of concept to answer a unique question: How can school-based learning be designed based on powerful learning principles found in the best games—ones that inspire engagement, collaboration, critical thinking, and, of course, systems thinking?

In answering this question, Q2L did a number of things differently from traditional schools. To begin with, it reorganized the curriculum so that disciplines with natural intersections that were usually kept separate were joined together. Mathematics and English language arts became "Codeworlds," a class that focused on symbolic and representational systems. Another class called "The Way Things Work," taught science and math combined, and still another class called "Being, Space, and Place" was put together to teach history and English literature. Assessment and testing also was done differently—instead of finals at the end of each semester, each class broke up into teams that needed to work collaboratively on a week-long "boss level," which challenged the youths to integrate insights from the rest of the course. More broadly, the school made the idea of youths as designers and makers of systems central to the overall setup of Q2L's learning environment an idea that was reflected in the after-school activities, the course design, the boss levels, and the school's integration of design thinking throughout the curriculum. All the different parts of the school aimed to have kids use what they were learning to make or design something concrete.

While the Q2L school represented great innovations in learning and was lucky to have the freedom to do a lot of things differently, it was just one school. How could what was being learned there be shared, tested, and added to by the wealth of innovative educators and schools in the world already doing great work? In many ways, the GNL project, titled from the idea that systems thinking offers a powerful new "lens" to see the world, came from a desire to do just this. In the initiative, Kylie Peppler and Melissa Gresalfi, researchers and educational designers from Indiana University's Learning Sciences program (**education.indiana.edu/learnsci**), began to work with Katie Salen from Institute of Play (**instituteofplay.org**), Nichole Pinkard of DePaul University, and the Digital Youth Network (DYN; **digitalyouthnetwork.org**) to develop a series of modular toolkits that used the design of digital media as a means to develop systems thinking skills, all based on the existing approaches taken in the Q2L school. With the financial support of the MacArthur Foundation and the help of additional partners like the NWP (**nwp.org**), (a network of educators and local writing project sites that serve up to 100,000 teachers annually), the initiative worked for three years to make this idea a reality.

The main goal of the initiative was twofold: to create a series of scalable modular toolkits that used the power of designing with new media to promote engagement in design and systems thinking dispositions in young people; and to conduct research on what kind of curricular supports lead to the development of systems thinking dispositions through design activities.

Ultimately, four sets of modular curricula were developed in close coordination with teachers in the NWP network at every step of the process. Each of these uses a different technology and provides unique ways to engage in design with various approaches to understanding systems. The *Gaming the System* curricula involves game design with the Gamestar Mechanic (G*M) platform (Salen, 2007) and focuses on understanding games as systems and young people as designers of those systems. A second and third set of curricula, *Short Circuits* and *Soft Circuits,* use physical computing technology like light emitting diodes (LEDs), sensors, and the wearable technology controlled by the LilyPad Arduino (Buechley, 2006) to show how youths can create electronics embedded in paper, clothing, and other everyday objects and understand how these creations operate as systems. Finally, *Script Changers* focuses on the idea of using narrative and stories to understand systems, and uses the Scratch programming environment (Resnick et al., 2009) as a way to tell digital stories about systems by way of a computational system.

A key part of the process of developing these curricula was ensuring that the activities that we developed would be able to work in a variety of contexts and populations, and, in particular, be modifiable in ways that would let educators meet the distinct needs of their educational settings and populations. Whether they worked in after-school programs in places like Boys and Girls Clubs or science classrooms in rural public schools, with youths from marginalized backgrounds or privileged ones, we wanted to create something that was adaptable while remaining powerful. Therefore, a big part of the initiative involved testing and refining the modules in many different contexts over the course of two years.

Using an approach called Design-Based Research (DBR) (Brown, 1992), which employs approaches found in the world of engineering to engage in an iterative and cyclical design process around learning activities in which each implementation yields lessons that are incorporated into final designs, we piloted and tested the modules in many contexts. A particularly positive benefit of DBR is that it acknowledges that you're not necessarily going to get things right the first time (we certainly didn't!) but trusts a process of embracing failures and missteps as learning opportunities that are really gifts in disguise. For us, the process of being active learners about what worked and where was a central part of the work that we did in developing the activities being shared here.

Many of the activities were, as mentioned, initially developed and tested in New York City at Q2L; others were developed and piloted at local schools like the Bloomington Project School in Indiana, as well as at a local Boys and Girls Club that serves a wide range of youths from varied ethnic and socioeconomic backgrounds. A significant amount of testing was done in close coordination with our NWP partners in sites across the United States and through extended, project-specific summer workshops hosted at DePaul University in Chicago and elsewhere. Testing and refinement also was done in Chicago in schools affiliated with partners at the DYN. Additionally, DYN's parent institution, DePaul University, hosted a summer camp that served as a major testing ground for the curricula. Over the course of four weeks in the summer of 2011, expert teachers from across the United States affiliated with the NWP worked with researchers from Indiana University and designers from Institute of Play to refine the modules based on lessons born of implementing them with almost 100 youths native to Chicago, again with a mix of kids from different backgrounds. These educators are too numerous to list here, but their voices and contributions to this volume are recognized both in our list of contributors and in the "Voices from the Field" sections that you will see throughout all four of these volumes. The exercises, ideas, and guiding pedagogical ideas throughout these books are infused with their perspectives.

In developing the volumes, we wanted to ensure that the work was grounded both in insights from the academic literature on systems thinking and the learning sciences, and also in the lived experiences of educators. The research team contained a number of members who had worked as educators for many years in both formal learning contexts like public schools and informal ones like after-school programs, libraries, and museums. Most importantly, though, the initiative's partnership with the NWP meant that the kind of educators interested in the sort of innovative approaches that we were developing were kept at the center of our designs. They played important roles in testing and refining the modules as previously described, as well as serving on an editorial advisory board (including, most prominently, the assistance of Christina Cantrill, Paul Oh, and Steve Moore) that offered insights, made substantial edits, gave productive feedback, and helped to create many of the activities and materials found in these volumes. They were indispensable to the core design team throughout the project. Through this partnership, we hope that the current volumes are useful to educators in a wide variety of settings to engage youths in design activities that will help them to become systems thinkers, with the ultimate goal of transforming the world that we live in today.

As you might have already noticed, this project brought together many different participants with divergent backgrounds, including game designers from Institute of Play; researchers with backgrounds in the arts, mathematics, and civic education at Indiana University; out-of-school educators at DYN; and professional teachers from the NWP. So, what common threads brought all of these partners together? While there was certainly a common interest in systems thinking as a critical skill for an increasingly complex world, the group also shared a common belief that kids in the twenty-first century had new opportunities for learning as a result of the changing technological landscape. Like many forward-thinking educators, we all saw that the ways that we've been educating young people as a society, through focusing on skill and drill rather than innovation and exploration, and through teaching to the test rather than teaching to youths' interests, were doing a major disservice to young people.

Each of these partners was involved in a broader movement started by the MacArthur Foundation in 2006 to investigate the ways that digital media was changing how kids learned and how these technologies might be leveraged to create new opportunities for learning that might have been previously unimaginable. The Digital Media and Learning (DML) initiative has supported over $80 million in grants to research and develop innovations in digital learning at the time of this writing. It has focused on youth-interest-driven activity in digital spaces as a source of inspiration for creating new learning environments that incorporated the kinds of engagement and higher-order skill development found in places like massively multiplayer online games or do-it-yourself online creative communities like those centered around fan fiction, video blogging, and many other forms of making, tinkering, and designing. The Q2L school and the G*M platform used in the game design module were two examples of learning environments that came out of the DML initiative. Both aimed to build off of interests that youths already brought to school with them, as well as focus on the kinds of twenty-first-century skills they'll need to thrive in the world.

We share this background to enable the reader to think about the activities and resources in this collection not as an isolated approach to teaching, but rather as part of a larger movement to rethink learning in a digital age. There is an incredible amount of innovation happening at the edges of education, and in places that people tend not to think of as learning spaces. We see youths learning in new ways connected to pursuing their interests, engaging deeply, and solving problems through engagement with technology. We want to bring that kind of learning into more formal learning spaces, and we know that we're not alone in this desire. If you're reading this, it's probably because you agree with us that education can be done differently, that youths can engage in problems that are meaningful for them, are connected to their lives, and prepare them for lifelong learning in a changing and complex world.

A TEACHER'S REFLECTION

In concluding this section on the history of the project, we wanted to share the voice and experience of one of the many talented educators that worked on this project. Laura Lee Stroud—a secondary teacher and English language arts instructional coach in the Round Rock Independent School District, as well as a member of the Central Texas Writing Project—reflected on her experience as a maker and learner while engaging with the GNL curriculum during the GNL summer camp in 2011. As part of a playtesting moment, Stroud joined a number of other teachers to construct her own understanding of tools like G*M, Scratch, and e-textiles, as well as facilitate understanding for youths at the camp:

> The Grinding New Lenses camp experience was unlike any experience I'd ever had the opportunity to engage in. NWP teachers from all over the nation gathered for one month in Chicago, away from our homes and families, hoping to learn about systems thinking concepts and internalize them into our existing teaching repertoires. The only thing that we all knew about each

> other and the work was that we believed in the lifelong learning process and that we had the NWP in common.

The group of educators, in partnership with researchers from Indiana University, Institute of Play, and the DYN, participated in conversations and activities that would evolve into the challenges described in these volumes. As the teachers explored platforms and tools in the service of systems thinking by doing what they soon would be asking youths to do, they also provided feedback, suggestions, and their own mods (modifications), contributing to the overall development of the modules as they exist today. As Stroud says, "As a professional, I was viewed as a professional and asked to help edit and revise the curriculum." This feedback and response process with the educators continued throughout the camp experience:

> After we were comfortable with the first layers of the curriculum we were to learn, we split into the modules we were to teach. We were partnered with another teacher and reviewed the materials, learned new vocabulary, and tried to familiarize ourselves with this newfound systems thinking perspective. Every day, in preparation for the summer camp youths, we processed the modules as learners and created the products—be it games, digital narratives with sprites as characters, or e-textile clothing and accessories.

Stroud was a facilitator of the *Soft Circuits* curriculum with youths, but also saw herself as a learner. By entering this brand new world of e-textiles (though it easily could have been a "brand new world of game development" or "brand new world of the programming of a digital story"), she discovered the gaps that existed in her own knowledge—about circuits and circuitry, for instance. This made her that much more sympathetic to the needs of her youths, which in turn allowed her to support them in relating the e-textiles work to their life experiences:

> As the youth entered the camps, for the most part not one teacher assumed the comfortable position of "expert" with our novice youths learning under us. Instead, we were positioned as learners alongside our campers. In some cases, our campers knew more about the content than did we the teachers. We had to remember our new value of supporter, encourager, observer, and researcher. We provided scaffolds for the new concepts, such as an immersion into the new vocabulary, and created a space in the modules for explicit vocabulary instruction. For example, the youths needed to know how to sew a "running stitch" before they could complete a circuit with conductive thread. In fact, in creating the e-cuff, we realized that many of the youths

> had never made a hem, which is created with a running stitch. As we tried to explain to them how we teachers learned to sew a running stitch, a previously disinterested camper had a light bulb moment as she realized she in fact knew how to sew. She'd worked with her mother in a beauty shop in which they sewed in extra hair for clients. She not only knew how to create a running stitch, she was able to teach the other children how to do it, too! This experience reinforced for me the iterative process of discovering the strengths available within our classrooms that in turn make our instructional systems most productive.

Stroud concluded by saying:

> When we teachers had group time to reflect on our experience, we found that we all struggled in one way or another and as a result we had a newfound level of respect for our youths' learning processes and struggles, as well as a wonderful glimpse into our own learning process.

LIST OF CONTRIBUTORS

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SYSTEMS THINKING CONCEPTS IN THIS BOOK COLLECTION

The goal of the *Interconnections: Understanding Systems through Digital Design* book collection is to make available an accessible set of activities that can help youths develop a "systems lens" for seeing the world—a lens they can use to make sense of problems around them. Our hope is that youths will be able to see, anticipate, and understand patterns in the systems that make up that world, and use those understandings to eventually design better systems.

In these modules, we share a range of practices and concepts related to systems thinking. These concepts by no means represent a comprehensive list of every major idea in systems thinking—instead, we have chosen to focus on a subset of key ideas that focus centrally on *understanding systems,* and, in some of the volumes, on more complex ideas related to *system dynamics.* Understanding systems involves recognizing the elements that structure a system, and, more important, the ways that those elements interconnect to impact each other and the overall function of a system. These understandings are mostly oriented toward analyzing a system at a particular point in time, which is a common focus in these modules. In contrast, the study of system dynamics is fundamentally concerned with understanding the behavior of systems *over time*. Examining how a system changes and the kinds of patterns that emerge over time is crucial to understanding how to intervene effectively in systems. As is detailed next, not all the modules deal with these ideas in the same way—the *Gaming the System* module focuses almost exclusively on supporting youths' understanding of systems, while the *Script Changers* module is more fundamentally concerned with understanding (and orchestrating) system changes over time.

The choices made about which concepts and practices to include were driven by the kinds of design activities that we envisioned for youths, and those ideas that are particularly easy to see via the tinkering and iteration processes associated with design. For example, all modules spend a significant amount of time helping youths to see the kinds of *interconnections* that take place among components of a system and the kinds of system dynamics that emerge through these interconnections. This focus is easily revealed through design work because youths can define interconnections, observe the functioning of the system, and then, through iterations on their designs, change the nature of these interconnections and immediately observe the resulting changes in system function. For example, when youths are designing a videogame (in *Gaming the System),* they can see immediately how changing the behavior of a single component (such as the health of an avatar, or the damage that an enemy can do) can immediately change how challenging the game is (the overall *function* of the game—the way it works). Likewise, in *Short Circuits* and *Soft Circuits,* youths can observe how changing the structure of light-emitting-diode (LED) connections (i.e., the ways that they're linked to each other) can immediately affect the number of LEDs that can light up.

Although there is a lot of overlap among the concepts covered in the four books, each one tackles these ideas uniquely, and there are some particular systems thinking concepts that are covered only in some modules. In the following sections, we describe and define the "big ideas" that are addressed in the modules. In the table that follows, the specifics of those big ideas and where they are addressed in each book and module are portrayed.

1. IDENTIFYING A SYSTEM.

Identifying a system and distinguishing it from other kinds of things that aren't systems. Specifically, a system is a collection of two or more components and processes that interconnect to function as a whole. Speed and comfort in a car for example are created by the interactions of the car's parts and thus are "greater than the sum" of all separate parts of the car. The way a system works is not the result of a single part but is produced by the *interaction* among the components and/or individual agents within it. A key way to differentiate things that are systems from things that aren't is to consider whether the overall way something works in the world will change if you remove one part of it.

2. USE LANGUAGE THAT REVEALS A SYSTEM'S CHARACTERISTICS AND FUNCTION.

A key indicator of youths' understanding of systems involves listening for the ways that they describe and make sense of a system. When using a systems thinking approach, youth will be able to identify a system's *components*, the *behaviors* of those components, how those behaviors are shaped by the *system's structure*, how these behaviors *interconnect* to form broader *system dynamics* which move the system towards a particular *function*. At times systems are designed to meet a particular *goal;* this goal can be (but is not always) aligned with the actual function of the system.

3. MAKE SYSTEMS VISIBLE.

When we learn to "make the system visible"—whether modeling a system on the back of a napkin, through a computer simulation, a game, a picture, a diagram, a set of mathematical computations, or a story—we can use these representations to communicate about how things work. At their best, good pictures of systems help both the creator and the "reader" or "audience" to understand not only the parts of the system (the components), but also, how those components work together to produce a whole.

4. SEEK OUT COMMON SYSTEM PATTERNS.

Beyond the core aspects of a system (i.e., components, behaviors, interconnections, dynamics, and functioning), there are a number of common patterns that are important for young people to look for when engaging with systems. Specifically, systems often have *reinforcing feedback loops* that cause growth or decline, as well as *balancing feedback loops* that create stability in a system. These loops are directly related to the *stocks and flows* of a system—what is coming into a system and what is going out. In particular, when more is flowing out of a system than is coming in, there begins to be a concern about *limited resources* within a system. Sometimes patterns in systems can be seen best by examining the ways that systems are *nested* within each other.

5. DESIGN AND INTERVENE IN SYSTEMS.

A key practice of a systems thinker involves both designing new systems and fixing systems that are out of balance. These interventions allow youths to go beyond simply interrogating existing systems in the world to use their understanding of how systems work to actually change the world around them, while doing so in a conscious way that respects the complexity of systems. The process of *designing* a system involves thinking deeply about the state of the system that you have envisioned, and how the particular components you have to work with might interconnect with other components for that state to be realized. This process of design involves more than understanding interconnections, however; it is also about considering what to do when things go wrong—the most productive *leverage point* to intervene or change a system, why a proposed solution might *fail*, and what *unintended consequences* might occur based on your design.

6. SHIFT PERSPECTIVES TO UNDERSTAND SYSTEMS.

Systems thinkers regularly shift perspectives as they look at systems to get the full picture of what's happening. They think about the actors in a system and what *mental models* they bring to the system that affect the way that they participate. They shift among different *levels of perspective*—from events, to patterns, to structures, and finally to the mental models that give rise to a system—to better understand that system. And finally, they change the *time horizon* associated with looking at a system in order to find *time delays* from prior actions in a system.

		Gaming the System: Designing with Gamestar Mechanic						Script Changers: Digital Storytelling with Scratch						Short Circuits: Crafting e-Puppets with DIY Electronics				Soft Circuits: Crafting e-Fashion with DIY Electronics			
		CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	CH 1	CH 2	CH 3	CH 4	CH 1	CH 2	CH 3	CH 4
1. Identify systems		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2. Use language that reveals a system's characteristics and function	Identifying the way that a system is functioning	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
	Distinguishing the goal of a system	x	x	x	x		x		x					x	x	x	x	x	x	x	
	Identifying components	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Identifying behaviors	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
	Identifying interconnections	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
	Perceiving dynamics									x	x	x		x	x			x			
	Considering the role of system structure			x						x						x	x		x	x	x
3. Make systems visible			x	x			x		x	x	x	x	x	x	x	x	x	x	x	x	x
4. Seek out common system patterns	Reinforcing feedback loops										x										
	Vicious cycles										x										
	Virtuous cycles										x										
	Balancing feedback loops						x					x		x	x			x			
	Stocks and flows																				x
	Limited resources in systems													x	x			x			x
	Nested systems								x											x	
	Dynamic equilibrium																				x
5. Design and intervene in systems	Designing a system		x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x
	Fixes that fail											x									
	Leverage points											x	x		x		x		x		
	Unintended consequences												x								
6. Shift perspectives to understand systems	Mental models									x											
	Levels of perspective									x											
	Time horizons and delays								x												

ALIGNMENT TO COMMON CORE STATE STANDARDS

The following tables represent an at-a-glance view of the alignment of Design Challenges from all four books in the *Interconnections: Understanding Systems through Digital Design* collection to relevant Common Core State Standards (CCSS) for English Language Arts and Literacy in History/Social Studies, Science and Technical Subjects. Only relevant standards are included in these tables. (For the complete list of standards, go to **www.corestandards.org/ELA-Literacy**.)

The Common Core State Standards for English Language Arts and Literacy in History/Social Studies, Science, and Technical Subjects are the result of an initiative to provide a shared national framework for literacy development to prepare youths for college and the workforce. The CCSS span kindergarten through twelfth grade, divided into three bands: K–5, 6–8, and 9–12. The CCSS may be thought of as a "staircase" of increasing complexity that details what youths should be expected to read and write, both in English and in targeted content areas. The CCSS are built upon a set of guiding "anchor standards" that evolve through grade-level progression and emphasize informational text and argumentative writing, particularly at the middle and high school levels. In addition, the CCSS include a strand that emphasizes literacy skills associated with production and distribution via technology.

For newcomers, a useful way to enter into the English Language Arts standards is to read the online About the Standards page at the CCSS website (**www.corestandards.org/about-the-standards**), and then read the anchor standards for each grade band, as well as for the content areas.

Through the Design Challenges, youths are introduced to a range of core skills and information that stretch their learning potential and build on prior knowledge. Expect them to encounter material described in the English Language Arts standards for reading informational text for key ideas and detail, as well as the integration of knowledge and ideas; for producing and distributing writing with technology; and for speaking and listening tasks that prepare youths for college and careers through comprehension and collaboration, as well as the presentation of knowledge and ideas.

Because the *Interconnections* collection presents curricula that engage youths in literacy practices that fall in the English Language Arts domain, as well as the domains of History/Social Studies and Science and Technical Subjects, the letter-number designation that accompanies each standard in the table aligns with the CCSS letter-number designation as follows:

- R—Reading Literature
- RI—Reading Informational Text
- W—Writing
- SL—Speaking & Listening
- RST—Reading in Science and Technical Subjects
- WHST—Writing in History/Social Studies, Science and Technical Subjects

The standards included in these tables serve as a guide through which the Design Challenges can be understood in conjunction with the CCSS. They do not represent an exhaustive list of all possible alignments, but rather those most prevalent and immediate to the central tasks.

Common Core English Language Arts Standards	Gaming the System: Designing with Gamestar Mechanic					
	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6
R.6-12.7 (anchor standard) Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.	x					x
RI.7.3 Analyze the interactions between individuals, events, and ideas in a text (e.g., how ideas influence individuals or events, or how individuals influence ideas or events).						x
RI.7.7 Compare and contrast a text to an audio, video, or multimedia version of the text, analyzing each medium's portrayal of the subject (e.g. how the delivery of a speech affects the impact of the words).						x
RI.7.9 Analyze how two or more authors writing about the same topic shape their presentations of key information by emphasizing different evidence or advancing different interpretations of facts.	x		x	x	x	
W.6-8.3 Write narratives to develop real or imagined experiences or events using effective technique, relevant descriptive details, and well-structured event sequences.	x	x	x	x	x	
W.7.6 Use technology, including the Internet, to produce and publish writing and link to and cite sources as well as to interact and collaborate with others, including linking to and citing sources.						x
RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	x	x	x	x	x	
RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.						
RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph or table).	x	x	x	x	x	x
RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.	x	x	x	x	x	x
RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.						x
SL.6-12.4 (anchor standard) Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.	x	x	x	x	x	x
SL.7.5 Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.	x	x	x	x	x	

Common Core English Language Arts Standards	Script Changers: Digital Storytelling with Scratch					
	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6
R.6-12.3 (anchor standard) Analyze how and why individuals, events and ideas develop and interact over the course of a text.			x	x	x	x
R.6-12.7 (anchor standard) Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.	x	x	x	x	x	x
RI.7.3 Analyze the interactions between individuals, events, and ideas in a text (e.g., how ideas influence individuals or events, or how individuals influence ideas or events).		x	x	x	x	x
W.6-12.2 (anchor standard) Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.		x	x	x	x	x
W.6-8.3 Write narratives to develop real or imagined experiences or events using effective technique, relevant descriptive details, and well-structured event sequences.	x					
W.8.6 Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas efficiently as well as to interact and collaborate with others.	x	x	x	x		x
W.8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.						x
W.6-12.7 (anchor standard) Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.		x	x	x	x	x
W.6-12.9 (anchor standard) Draw evidence from literary or informational texts to support analysis, reflection and research.			x	x	x	x
RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	x	x	x	x	x	x
RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.						
RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph or table).		x	x	x		x

Common Core English Language Arts Standards	Script Changers: Digital Storytelling with Scratch					
	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6
RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.						x
SL.7.2 Analyze the main ideas and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text or issue under study.		x	x	x	x	x
SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.						
SL.6-12.4 (anchor standard) Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.		x	x	x	x	x
SL.7.5 Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.			x	x		x
WHST.6-8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.						x
WHST.6-8.5 With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.						x
WHST.6-8.6 Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently.						x
WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.			x			x

Common Core English Language Arts Standards	Short Circuits: Crafting e-Puppets with DIY Electronics				Soft Circuits: Crafting e-Fashion with DIY Electronics			
	CH 1	CH 2	CH 3	CH 4	CH 1	CH 2	CH 3	CH 4
R.6-12.7 (anchor standard) Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.								x
RI.7.3 Analyze the interactions between individuals, events, and ideas in a text (e.g., how ideas influence individuals or events, or how individuals influence ideas or events).			x	x		x		
RI.7.4 Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze the impact of a specific word choice on meaning and tone.						x		x
RI.7.5 Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.			x	x			x	
RI.8.5 Analyze in detail the structure of a specific paragraph in a text, including the role of particular sentences in developing and refining a key concept							x	
RI.8.7 Evaluate the advantages and disadvantages of using different mediums (e.g., print or digital text, video, multimedia) to present a particular topic or idea							x	
W.6-12.2 (anchor standard) Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.	x				x			x
W.6-8.3 Write narratives to develop real or imagined experiences or events using effective technique, relevant descriptive details, and well-structured event sequences.	x	x			x			
W.7.6 Use technology, including the Internet, to produce and publish writing and link to and cite sources as well as to interact and collaborate with others, including linking to and citing sources.								x
W.8.6 Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas efficiently as well as to interact and collaborate with others.			x					x
w.8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.							x	
rST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.		x		x		x	x	x
rST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.	x	x			x			x
RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph or table).	x				x			x

Common Core English Language Arts Standards	Short Circuits: Crafting e-Puppets with DIY Electronics				Soft Circuits: Crafting e-Fashion with DIY Electronics			
	CH 1	CH 2	CH 3	CH 4	CH 1	CH 2	CH 3	CH 4
RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.						x		x
RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.	x		x		x			
SL.6-12.4 (anchor standard) Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.	x		x		x		x	
SL.7.2 Analyze the main ideas and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text, or issue under study.						x		
SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.				x				
SL.7.5 Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.			x			x		
WHST.6-8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.			x					x
WHST.6-8.6 Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently.							x	

NEXT GENERATION SCIENCE STANDARDS

Because the Interconnections book collection presents curricula that engage youths in design-oriented activities that embrace the sciences, the standards included in this table serve as a guide through which the challenges can be understood in conjunction with the Next Generation Science Standards (NGSS; found at **www.nextgenscience.org/next-generation-science-standards**). They do not represent an exhaustive list of all possible alignments, but rather those most prevalent and immediate to the central tasks.

As the NGSS are explicit in assigning specific scientific topics and learning to specific grade levels, the correlations in these tables range from third grade to high school. The following tables were created to help identify which national science standards align to our Design Challenges, to what grade, and in which challenge each is addressed. Please note, however, that all the Design Challenges have been tested in a wide range of ability, grade, and age groups.

NGSS CODE DESIGNATIONS

- 3–5: Upper elementary grades
- MS: Middle school grades 6–8
- HS: High school grades 9–12
- ESS: Earth and Space Science
- ETS: Engineering, Technology, and Applications of Science
- PS: Physical Sciences

Next Generation Science Standards	Gaming the System: Designing with Gamestar Mechanic					
	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6
ETS1 Engineering Design						
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.	x	x	x	x	x	x
3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	x	x	x	x	x	x
3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	x	x	x	x	x	x
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.			x	x	x	x
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	x	x	x	x	x	x
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.				x	x	x
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	x	x	x	x	x	x

Next Generation Science Standards	Script Changers: Digital Storytelling with Scratch					
	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6
ETS1 Engineering Design						
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.	x	x	x	x	x	x
3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.			x	x	x	x
3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.				x	x	x
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	x	x	x	x	x	x
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.			x	x	x	x
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.					x	x
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.		x	x	x	x	x
ESS3 Human Impacts						
MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.			x	x	x	x

Next Generation Science Standards	Short Circuits: Crafting e-Puppets with DIY Electronics				Soft Circuits: Crafting e-Fashion with DIY Electronics			
	CH 1	CH 2	CH 3	CH 4	CH 1	CH 2	CH 3	CH 4
PS2 Motion and Stability: Forces and Interactions								
3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.	x	x	x	x	x	x	x	x
MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.	x	x		x	x	x	x	x
PS3 Energy								
4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.	x	x	x	x	x	x	x	x
4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.		x		x		x	x	x
MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.		x				x	x	x
HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.								x
ETS1 Engineering Design								
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.	x	x	x	x	x	x	x	x
3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	x	x	x	x	x	x	x	x
3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.		x	x	x		x	x	x
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.								x
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	x	x		x	x		x	x
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.		x		x		x	x	x

INTRODUCTION

You think that because you understand "one" that you must therefore understand "two" because one and one make two. But you forget that you must also understand "and."

—Sufi teaching

Few would argue with the idea that the world is growing more complex as the twenty-first century unfolds. We live in a time that not only requires us to work across disciplines to solve problems, but also one in which these problems are of unprecedented scale, coming from a world that is more interconnected than ever. In such a context, power rests in the hands of those who understand the nature of the interdependent systems that organize the world, and, more important, can identify where to act or how to intervene in order to change those systems. Effective intervention requires considering not just simple causal relations, but also the complex interconnections that work together in often-unexpected ways to produce an outcome. Taking action in our complex world requires a set of twenty-first century skills and competencies called "systems thinking."

Systems thinking is best characterized by the old dictum that the whole is always greater than the sum of its parts. It's an approach that involves considering not just the behavior of individual components of a system, but also the complex interconnections between multiple parts that work together to form a whole. Systems are ubiquitous in our world—which includes natural systems that deal with climate and biodiversity, economic systems that drive production and labor trends, and political systems that enact governance of communities and nations. And, of course, these systems are themselves connected to one another in important ways, so understanding the nature of these interconnections, not just within but also across systems, is becoming ever more vital. The promise of learning to reason about how systems work is that of creating a new and effective lens for seeing, engaging with, and changing the world.

Systems thinking allows one not just to understand better how systems function, but also to decide the best way to intervene to *change* systems. Systems thinkers have the potential to have a significant impact on the world around them—an impact that is often denied to those who think in simple cause-and-effect terms. As a consequence, we believe that to effectively and ethically educate children to thrive in the twenty-first century, we must create contexts in which young people are supported in learning to be creative and courageous about making changes to systems in the world and to understand that those changes will always have an impact on other parts of the system—everything is interconnected. It's not enough to instill this competency in current leaders—we must prepare the next generation to be effective and thoughtful stewards of the world that they will inherit soon. Helping young people to understand how systems work, how they are represented, and how they change—via direct or indirect means—is critically important to this larger project. Furthermore, it's important that young people learn about systems not in a distant and unfamiliar context, but in contexts that have meaning to today's youth—those rooted in popular culture, design, and new technologies. This approach is the basis of this collection.

Digital media are central in almost every aspect of daily life, most notably in how we communicate, understand political issues, reflect, (co-)produce, consume, and share knowledge. We are living in an era in which digital media is rapidly becoming a driving force in globalization, scientific advances, and the intersection of cultures. The growing accessibility of digital tools and networks, the prevalence of many-to-many distribution models, and the large-scale online aggregation of information and culture are leading to profound changes in how we create and access knowledge. Perhaps nowhere is this digital influence contested more than in education, where questions arise about the ability of traditional systems to prepare young people for the social, economic, and political demands of a complex and connected new century.

This collection, Interconnections: Understanding Systems through Digital Design, builds on the existing work of educators, management theorists, designers, and learning scientists who are aiming to promote systems thinking in young people. The project uses a design-based approach to learning and offers a toolkit for supporting systems thinking in ways that are aligned to current Common Core State Standards (CCSS) and relevant to youth interests in digital culture. Through a collaborative effort across a leading group of designers and educators from Institute of Play, Indiana University's Creativity Labs, the Digital Youth Network (DYN), and the National Writing Project (NWP), we've developed an innovative approach to supporting the development of systems thinking in young people; one that allows them to see how systems are at play in the digital contexts that they regularly engage with and one that puts them in the position of designers of those systems. Most prior work on teaching systems thinking has focused on the biological, physical, and social sciences. By contrast, this collection aligns itself with a growing body of work emerging from the fields of game design, digital storytelling, and do-it-yourself (DIY) electronics as contexts for engaging in systems thinking. Creating animated digital stories about aspects of their community they would like to see changed, for example, provides young people with rich opportunities for observation, analysis, and problem solving.

Each of the four books in the collection is rooted in *constructionist* learning theory, which positions young people as active creators of their own understanding by engaging in the design, iteration, and sharing of media artifacts within communities of interest (Papert, 1980; Kafai, 2006). Each book teaches systems thinking concepts and skills in the context of a specific digital media platform and includes an average of six design "challenges" totaling between 25 and 40+ hours of project time.

The first book in the collection, *Gaming the System: Designing with Gamestar Mechanic*, orients readers to the nature of games as systems, how game designers need to think in terms of complex interactions between game elements and rules, and how to involve systems concepts in the design process. The core curriculum uses Gamestar Mechanic (G*M), an online game design environment with a strong systems thinking focus. *Script Changers: Digital Storytelling with Scratch*, focuses on how stories offer an important lens for seeing the world as a series of systems and provides opportunities for young people to create interactive and animated stories about the systems around them. The projects in this book use the Scratch visual programming environment as a means to tell stories about how to affect change in youths' local communities. The two final books, *Short Circuits: Crafting e-Puppets with DIY Electronics* and *Soft Circuits: Crafting e-Fashion with DIY Electronics,* both explore the field of electronics and "e-textiles," which involves physical computing projects using fabrics and other everyday materials, including incorporating microprocessors into these materials and programming them with an accessible tool called Modkit.

WHAT IS SYSTEMS THINKING?

It has become increasingly clear that youths' experiences in school do not match the kinds of experiences that they are likely to have once they have completed school. The push to support "twenty-first-century" skills stems from this mismatch, and many have advocated for ensuring that young people learn to think about the world not as a simple set of cause-and-effect experiences, but rather as a set of complex systems. *Systems thinking* generally refers to a way of understanding the world as a set of systems that are made up of many components, each of which has distinct behaviors that change and interact, giving rise to emergent behavior. There are many advantages to understanding the world as a set of systems, but a chief one is that systems thinking allows youths to understand and interpret the world across content areas (Goldstone & Wilensky, 2008). Unfortunately, supporting youths to develop systems thinking has proven to be a significant challenge. First, systems thinking ideas are difficult (Hmelo-Silver & Pfeffer, 2004) and also can be counterintuitive (Wilensky & Resnick, 1999). Systems thinking requires youths to look for myriad contributions to system behaviors as opposed to simple cause-and-effect. Indeed, a key concept of systems thinking involves understanding that a small change can lead to a significant outcome—an idea that flies in the face of many core assumptions that we have about the world. Linda Booth Sweeney (2001) points out that most of our experiences in the world, particularly those we have as children, are explained in terms of linear causality. As a consequence, we have limited opportunities to practice talking about or interpreting our experience of the world as a set of systems.

Despite these challenges, the advantages to supporting youths to understand something about systems are clear. The open question is the best way to go about doing it. The *Gaming the System* module is designed based on findings that youths can learn about systems when they engage in tasks that require systems thinking to support their successful completion. Specifically, this module seeks to support development of youths' nascent understandings of systems thinking by building and experiencing systems for themselves. Our goal is to give youths opportunities to both create and be a part of systems through the design of computer games. We believe that this immersive involvement will help to ground their understanding of the world in experiences of complexity, rather than in the simple causal experiences that they generally have had.

While linking systems thinking to digital media and learning may seem novel, an integration of systems thinking in K–12 education began in the late 1980s and continues today through the efforts of many organizations and individuals, including the Waters Foundation, the Creative Learning Exchange, the Society for Organizational Learning Education Partnership, and various research groups at institutions like the Massachusetts Institute of Technology (MIT), Northwestern University, Rutgers, and Indiana University. There are also many passionate educators across the United States who have been informed by these initiatives, as well as by leaders in the field of systems dynamics, including Jay Forrester, Linda Booth Sweeney, Peter Senge, and George Richardson. According to Debra Lyneis of the Creative Learning Exchange, the field first began to take root in classrooms when Gordon Brown, a retired MIT dean of engineering, introduced a piece of modeling software called STELLA to a middle school teacher at Orange Grove Junior High School in Tucson, Arizona. That teacher, Frank Draper, and his principal, Mary Scheetz, worked for years to integrate systems thinking across grades in their school. The work was transformative, as Draper writes of his classroom experience:

> Since October 1988 our classrooms have undergone an amazing transformation. Not only are we covering more material than just the required curriculum, but we are covering it faster (we will be through with the year's curriculum this week and will have to add more material to our curriculum for the remaining five weeks) and the students are learning more useful material than ever before. "Facts" are now anchored to meaning through the dynamic relationships they have with each other. In our classroom, students shift from being passive receptacles to active learners. They are not taught about science per se, but learn how to acquire and use knowledge (scientific and otherwise). Our jobs have shifted from dispensers of information to producers of environments that allow students to learn as much as possible.
>
> We now see students come early to class (even early to school), stay after the bell rings, work through lunch, and work at home voluntarily (with no assignment given). When we work on a systems project—even when the students are working on the book research leading up to system work—there are essentially no motivation/discipline problems in our classrooms. (Draper, 1989)

At the same time, other initiatives rooted in digital media have used computer-based modeling and simulations as a powerful approach to teaching about systems. Leading designers have produced other kid-friendly modeling software packages such as StarLogo, NetLogo, and other tools to study the ways that these sorts of technologies can be used in the context of small and large groups in classrooms (Colella, Klopfer, & Resnick, 2001; Wilensky, 1999; Goldstone & Wilensky, 2008). The field also has extended its use of simulations to include participatory simulations (Colella, 2000) that use technology to allow youths to act as agents in simulations of complex systems. In addition, it has found ways to use simulation software to teach even children in early elementary classrooms the properties of complex systems (Danish et al., 2011).

Systems education now can be found in such diverse places as an elementary school in the Netherlands, public middle and high schools in New York City and Chicago, a private elementary day school in Toledo, a charter school in Chelmsford, Massachusetts, rural schools in northern Vermont and Georgia, suburban schools in Carlisle and Harvard, Massachusetts, and an entire school district in Tucson, Arizona. Some people believe that the middle school level is a good place to begin because of the developmental level of the youths and the flexibility of the middle school structure, but many (including Sweeney, 2001) advocate that both stories and simulations can be used to bring systems thinking to elementary schools, and others (including Lyneis, 2000) have developed robust systems thinking programs in high schools as well.

Throughout the process of coming to know something about their own capacity as systems thinkers, this book collection encourages educators and youths alike to manage and reflect on their evolving identities as learners, producers, peers, researchers, and citizens. The resulting focus is on learning how to *produce meaning*—both for themselves and for external audiences—within complex, multimodal, and systems-rich contexts. Creativity, expression, and innovation underlie this learning as learners practice and apply systems thinking concepts through the coding and decoding of linguistic, computational, social, and cultural systems. This approach challenges traditional barriers between consumer and producer/viewer and designer, allowing youths to gain the skills to act as full citizens within a connected, participatory landscape (Salen et al., 2010).

WHAT IDEAS ABOUT SYSTEMS WILL YOUTHS LEARN IN *GAMING THE SYSTEM*?

Although typically systems thinking curricula are concerned with encouraging youths to describe the behavior of systems, the goal of the *Gaming the System* module is for them to experience the internal structure and interconnections within systems. This is accomplished by creating design experiences that allow youths to tweak components of systems and examine the impact of those tweaks on other components of the system and on the overall function of the system as a whole. Specifically, our goal is that, by the end of the module, youths will have had opportunities to deeply engage with the following practices:

- **Identifying a system:** Understanding that a system is a collection of parts, or components, which interconnect to function as a whole.
- **Identifying how a system is functioning:** Understanding what a system is actually doing—the "state" that it is moving toward.
- **Distinguishing the goal of a system:** Identifying the ideal state or function of a system from the particular perspective of the designer.
- **Identifying components:** Considering what a system is composed of—what are the parts that work together to make a system function as it does?
- **Identifying behaviors:** Identifying the different ways that each component can act.
- **Identifying interconnections:** Identifying the different ways that a system's parts, or components, interact with each other through their behaviors and, through those interactions, change the behaviors of other elements.

- **Considering the role of system structure:** Understanding that the way the system works (i.e., what it actually does) is the product of a set of complex interconnections between components that cannot simply be reduced to an account of the components themselves—these sorts of system dynamics emerge from the way the components interconnect, and these interconnections largely are determined by the way that the system's structure sets them up in relation to one another.
- **Designing systems:** Students are participating in an iterative design process that involves designing systems, tweaking elements of those designs, creating new iterations, and then reflecting on how changes they made fundamentally shape the ways that those systems function and whether they satisfy their own goals for the system.
- **Modeling systems:** Students create versions of existing systems as designed games; that creation involves the act of translating what they understand about the target system to a new domain with new representations.

These are just a subset of the ideas relevant to systems thinking that are covered in the *Gaming the System* module. Each challenge details the ideas about systems thinking that are specifically covered. In addition, these ideas are explored in more depth in the "Delving Deeper into Systems Thinking" chapter that appears at the end of the Design Challenges.

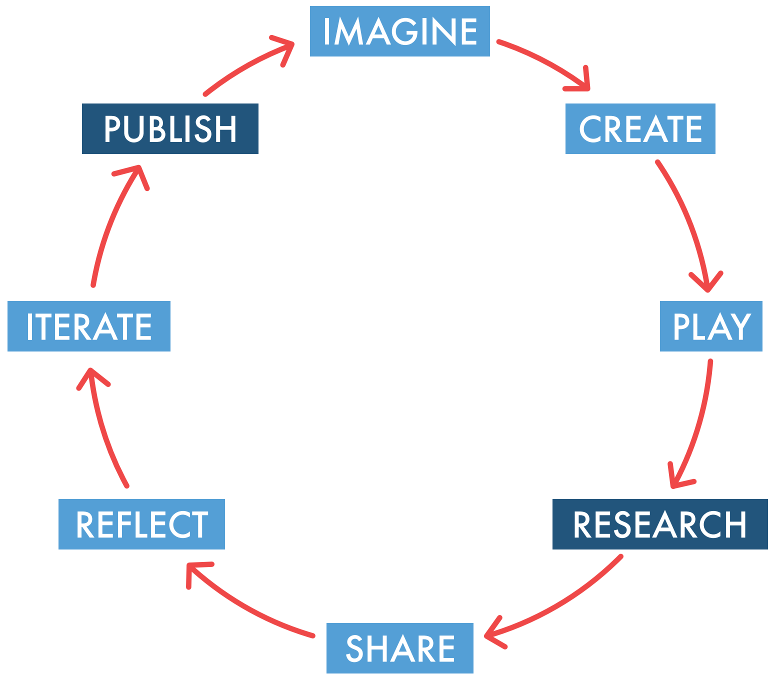
WHAT IS DESIGN THINKING?

To know the world, one must construct it.
—Cesare Pavese

When a young person creates a video, a poster, an animation, a customized T-shirt, or a digital app, she is operating within the space of design. Design is a particularly important activity for learning because it positions the learner as an active agent in the creation process. As learners construct a public artifact, they externalize their mental models and iterate on them throughout the design process (Papert, 1980; Kafai, 2006). In contrast to prescriptive approaches to design, where youths all construct the same artifact in parallel or arrive at an idealized solution through design, the challenges in this book strike a balance between structure and free exploration (Colella, Klopfer, & Resnick, 2001). The activities presented here engage youths in design activities to encourage them to learn key systems thinking concepts. We also acknowledge that learning happens best when it's done in a collaborative setting and there are purposeful moments for reflection.

As such, the challenges in each volume share a common structure of activities, based on the creative design spiral proposed by Rusk, Resnick, and Cooke (2009).

Resnick describes the creative process of design as an idea that is realized by iteratively imagining, creating, playing, sharing, and reflecting on the work. *Imagining* begins with youths' open exploration of the materials to ignite their creativity and imagination to take the work in unexpected and personally meaningful directions. *Creating* places an emphasis on building, designing, and making artifacts that can be shared with a broader community. The act of construction not only provides opportunities to develop and enrich creative thinking, but also presents youths with the chance to experience disciplinary content through hands-on reconstruction of their prior knowledge. *Play*, the next step in the design cycle, is where playful experimentation with ideas is done in a low-risk environment to explore and test the boundaries of the materials. The public presentation or *sharing* of work in progress or completed work is also critical to the learning and motivation in the design process, where youths become more engaged and find new inspiration and an audience for their ideas. Resnick also argues for systematic *reflection* on both the design and learning process, where youths discuss and reflect on their thinking. Making



Design-based approach to learning

the thinking process visible through easy access to the design artifacts from various parts of the creative process is crucial to learning. Finally, Resnick describes this pathway through the design process as a spiral that is then iteratively repeated.

To this work, we add two more steps to the design cycle: Research and Publish. *Research* encapsulates the information gathering that is critical to high-quality teaching and learning. This includes the introduction and definition of key terms and vocabulary, the introduction of key concepts that are important to systems thinking and disciplinary content, and the activities used to gather this information (including the use of videos, diagrams, and other information sources). We also disentangle the sharing of the final product, which we call *Publish*, from more informal moments where sharing is done within the local community to assist in iteration. Current research has demonstrated that this is an important moment for learning and community building, and that there are some crucial differences in who is likely to post in the informal, interest-driven hours (Lenhart & Madden, 2007).

As a methodology for learning about systems, design is all about providing constructive contexts in which to explore ideas, interactions, and expressions. Linking design to digital media tools expands this context further: digital tools often make it easier, faster, and less risky to test ideas. There is no need to worry about wasting expensive materials, and erasing a mistake is as easy as clicking a mouse. The act of designing incorporates complex technical, linguistic, and symbolic elements from a variety of domains, at a variety of different levels, and for a variety of different purposes. Designers explicate and defend design ideas, describe design issues and user interactions at a meta-level, imagine new possibilities, create and test hypotheses, and reflect on the impact of each of their creations as a distinctive medium in relation to other media. And each of these involves a melding of technological, social, communicational, and artistic concerns in the framework of a form of scientific thinking in the broad sense of the term. Designers make and think about complex interactive systems, a characteristic activity today, both in the media and in science.

The challenges included within this book emphasize a process of prototyping and iteration based on a design methodology: youths envision new solutions to open-ended problems, work through multiple versions of any idea, integrate ongoing feedback into the learning process, and identify the strengths and weaknesses of both their processes and solutions. In some cases, youths may choose to build on previous solutions or approaches of their peers, seeing themselves as contributors to a larger body of collaboratively generated knowledge.

DESIGNING A SUPPORTIVE LEARNING ENVIRONMENT

Before sharing the Design Challenges that we've developed, it's important to provide a set of guiding design principles for creating a supportive learning environment that are never stated explicitly, but form the base assumptions about what kind of pedagogy they're aiming to promote. As you adapt (and appropriate, of course), the activities in this book, we hope that the principles here might help guide you.

A design-oriented experience, particularly one created to support systems understandings has to be … well, designed. The curriculum modules shared in this book focus on activity structures and learning outcomes—what learners might be doing, with what tools, and in what kinds of configurations. Young people must experience the activities robustly when they take into account a set of larger principles defining the qualities of the learning context itself. The principles outlined next help to structure a learning setting that is itself understood as a dynamic system—one where the interactions among learners and mentors, peers, resources, and social contexts has been considered and where specific attention has been paid to the ways in which these different relationships reinforce or amplify each other.

The principles are intended to offer suggestions for how the experience of learning might be designed to support the learning resources offered later in the book. Please note that the principles should be understood as working together within a system—that is, no single principle does much on its own. It is in the relationships between principles that the robustness of the system resides. For example, creating learning experiences where a challenge is ongoing likely will fail miserably if it doesn't also include feedback that is immediate and ongoing. Organizing a classroom environment where authority is shared, expertise is distributed, and a broad range of ways to participate is allowed matters only if there are also visible ways for learners to share and exchange expertise and discover resources. The whole is far greater than the sum of its parts. The fact that the principles are listed separately should be understood as a limitation of the page, not as a feature of the principles.

1. Everyone is a participant.

Create a shared culture and practice where everyone contributes. Design learning experiences that invite participation and provide many different ways for individuals and groups to contribute. Build in roles and supports for teachers, mentors, and instructors to act as translators and bridge-builders for learners across domains and contexts. Make sure that there are opportunities for participants (especially new participants) to lurk and leech (i.e., observe and borrow), and that peer-based exchange, like communication and sharing, is easy and reciprocal. Provide a diverse set of resources to support teaching and peer-to-peer mentorship activities, allowing youths with various forms of expertise to take on leadership roles.

2. Feedback is everywhere; iteration is assumed.

Encourage youths to assume that their first draft is never the final version—they should make something and then gather feedback, rather than waiting to share their creation until they "get it right." Feedback should include structures for guidance and mentorship, which may take place via the online communities associated with the modules, or in classroom, after-school, or home settings. Make sure that there are plenty of ways for participants to share their work in progress with their peers, solicit feedback, teach others how to do things, and reflect on their own learning. Provide opportunities for participants to incorporate feedback in iterative design cycles. One key aspect of this latter element is allowing every participant's contribution to be visible to everyone else in the group through frequent posting, sharing, group discussion, or a combination of the three. Utilize the tools associated with the module platform to enable communication and exchange between peers who may or may not be part of the same program or setting to broaden the kind of feedback that youths receive.

3. Create a need to know.

One of the more powerful features of challenge-based experiences is that they create a *need to know* by challenging youths to solve a problem whose resources are accessible but require work to find. They must develop expertise in order to access the resources, and they are motivated to do so either because they find the problem context itself engaging or because it connects to an existing interest or passion. Make sure that challenges are implemented within learning environments that support situated inquiry and discovery so that youths have rich contexts within which they can practice using concepts and content. As participants advance through a challenge, provide a diverse array of opportunities for them to build social and cultural capital around their progress. Allow youths to collaborate in many different ways as they explore different roles or identities related to the design project at hand.

4. Learning happens by doing.

Modules emphasize performance-based activities that give rise to authentic learning tasks. These experiences provide opportunities for participants to develop knowledge and understanding through direct discovery and engagement with a complex but well-ordered problem space. These spaces often require participants to figure out the nature of the problem space itself, rather than proposing a specific problem to be solved.

Make sure that learners have access to robust mechanisms for discoverability; a number of resources to support this type of inquiry are included in this volume (on Systems Thinking Concept cards and Gaming the System Challenge cards), while additional resources—peer-produced tutorials and other materials—should be easy to find, use, and share. Think of ways to situate challenges within a context that has meaning or relevance for participants, whether in peer, interest-driven, or academic contexts. Provide participants with multiple, overlapping opportunities to interact with experts and mentors who model expert identities associated with the problem space. Explore teaming and competing structures like competitions and collaborations that mix collaborative and competitive elements in the service of problem discovery and solving.

5. Create meaningful public contexts for sharing.

In addition to sharing and receiving feedback during the design and iteration cycles, encourage the sharing of final products and projects with both local and global audiences. Knowing that there will be an audience, especially one that youths care about, is motivating, but also promotes a sense of creating something with a particular audience in mind. This contrasts with creating things in a vacuum, which is too often the case in educational contexts.

Create infrastructures for youths to share their work, skills, and knowledge with others across networks. These channels might take the form of online public portfolios, streamed video or podcasts, student-led parent conferences, or public events where work is critiqued and displayed, to name only a few options. Allow participants to develop identities in contexts of their own choosing; create opportunities for the acquisition of status via achievements that are visible in a range of home, school, workplace, and peer group settings. Provide diverse forms of recognition and assessment, which might take varied forms, including prizes, badges, ranking, ratings, and reviews.

6. Encourage play and tinkering.

Youths often learn best by experimentation, tinkering, and doing things that might look like they're "wasting time." As much as possible, build in open-ended spaces for playing and tinkering with the tools, materials, and platforms in addition to more structured challenges. Invite interaction and inquiry into the limits and possibilities of the platform, media, or form in which youths are working. Support learners in defining goals that structure the nature of their interaction and inquiry from moment to moment, as well as over a longer term.

7. Position youths as change agents.

The whole process of design implies agency—that people are able to create innovative solutions in the face of problems, be they large or small. And a big idea behind a pedagogy of systems thinking is that young people who bring this lens to complex problems can envision better solutions than those who don't. Help youths reflect on the choices that they are making in the design or transformation of a system—empower them to see themselves as agents of change.

WHO IS THIS BOOK COLLECTION FOR?

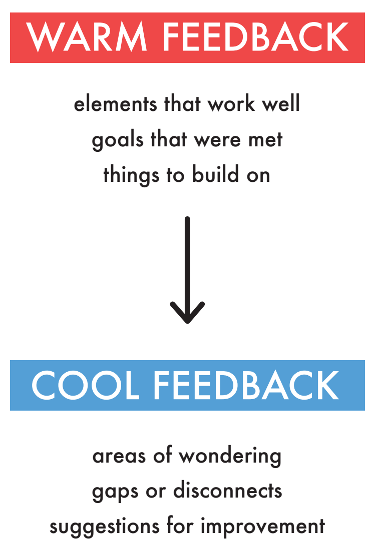
These materials were designed for both in- and out-of-school spaces. Educators and mentors using the materials and tools in this book, such as G*M, do not need to be experts in game design. The activities in this book are designed to spur a range of interactions between young people and the digital platform or tool, as well as between peers. Educators should serve as facilitators for youth discussion, reflection, and ideation. The principles of systems thinking encourage young people to figure things out, put puzzle pieces together, look for similar patterns, and work together to ask questions and find answers across disciplines. The activities have been designed to invite young people to teach one another, because the act of playing and making products for each other (be they games, stories, or physical objects) places learning in a collaborative context. Youths can show others what they've discovered as they work on their projects, which provides an opportunity for them to act as experts. We recommend that educators try and support youths taking on these roles in the classroom, serving as teachers and mentors to their peers. (A handy summary sheet for site administrators can be found at the very end of the book.)

APPROACH TO CONVERSATION AND CRITIQUE IN THIS VOLUME

With the aim of creating a participatory environment where feedback is welcomed and iteration is assumed, several processes and protocols have been included that support productive conversation and critique within groups. For example, there are many points where youths share their work with each other, with the goal of getting feedback to refine and improve their designs. This can be a tricky endeavor, as they might be reluctant to let others see their work, and not all youths are practiced at offering feedback that goes beyond being simply laudatory or critical, to hit a point of being *constructively critical.* Although there are many ways to help them learn to find this “sweet spot” of feedback, in these Design Challenges, we encourage them to give a balance of “warm” and “cool” feedback to each other, taking turns as presenter and responder. In any community that does not have much experience providing constructive feedback and critique, the warm and cool feedback protocol can be a really effective tool. Next, we give details about this process, as well as a few related suggestions. All of these could be modeled and discussed beforehand with youths to support familiarity and ease of use.

Warm/cool feedback: This type of feedback begins with a few minutes of warm feedback from the responder, which should include comments about how the work presented seems to meet the desired goals. Next, the responder provides a few minutes of cool feedback, sometimes phrased in the form of reflective questions. Cool feedback may include perceived disconnects, gaps, or problems in attaining the goal. This is an opportunity to include suggestions for making changes as well. You might note that people feel encouraged to improve something that they have worked on when they feel *good* about it. A young designer, especially, can become discouraged without some positive feelings and compliments about the design.

Consider role-playing this, with you—the teacher or mentor—taking on the part of the partner receiving feedback. Ask for a volunteer to give you examples of feedback, starting with warm feedback and then moving to cool. When processing the results



afterward, focus first on what felt like helpful feedback. Then explore with the group what types of feedback seemed unhelpful. Provide examples of several feedback sentence starters that might lead to more constructive conversation. (e.g., "Have you thought about ...?" "What were you thinking when you ...?" "I was confused when ... Can you help me understand?")

"Yes, and ..." feedback: Another way to support youths in developing ideas together is to have them generate "Yes, and ..." feedback as opposed to "Yes, but ..." or negative feedback. This type of feedback reserves judgment, challenge, or dismissal, and instead focuses on refining the original idea that the youths generated. It is a technique often used in supporting iteration in a design process.

One way to demonstrate the difference between these two types of feedback is to create a silly or neutral situation in which one person presents an idea (such as "I think we should get rid of all money. We don't need it."), and then a larger group answers only with "Yes, but ..." feedback (e.g., "Yes, but how can we buy things online without money?"). Then ask the presenter to present the same idea again and have the larger group answer only with "Yes, and ..." feedback (e.g., "Yes, and then maybe we could then use [suggestion] when we want to buy something online."). Ask the presenter, and then the group, to describe the differences between the two experiences.

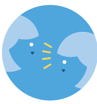
Response starters: At any given moment, not everyone in any community will agree completely about what's working or not working in a creative project. Sometimes this means that debate is necessary to clarify ideas, and healthy debate can support the development of critical thinking skills around systems at play in their communities. To help youths respond to each other civilly while still disagreeing—during both formal response times and informal collaborative work periods—you may want to post in the room a range of possible response starters that introduce disagreement respectfully, such as the following:

- "I see your point, and ..."
- "I am wondering about ..."
- "I understand that you see this as a way to ..., and from my perspective ..."
- "What if ...?"
- "Yes, and ..."

APPROACH TO ASSESSMENT IN THIS VOLUME

Assessment is designed to happen in three ways in these modules: informally, through *embedded discussions* within challenges; and formally, as *structured reflections* and design feedback in the challenges, and as *written assessments,* which can be administered as pre- and post-tests. Of course, all assessments can and should be used at the discretion of the educator. All of the assessment opportunities that we included here were designed to be formative, serving not just as an important opportunity for the educator to get information on how youths are learning, but for the youths themselves to gain insight into their own understanding of the key ideas being explored and the areas that they might want to work to improve.

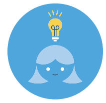
With the goal of helping to prepare you to listen for and evaluate youths' understanding, we also include rubrics that offer an overview of what "novice" versus "expert" understanding of the concepts in each section would look like. These rubrics are intended to be used for instructional decision making, so that the educator can determine whether students are ready to move on, must talk more about a particular idea, or need more chances to show what they know.



Informal assessments are marked with this "Let's talk" icon. These assessments are designed to be formative and informal, in that they take place within the context of the Design Challenge as small-group or whole-group conversations. These conversations should serve both to help youths formalize some of the ideas that they've been working on and to create an opportunity for the educator to gauge what they understand about a particular idea.

Structured assessments, indicated by the "Hands on" icon, are times when youths write down and document what they understand about a particular idea. Structured assessments come in a variety of forms, such as a piece of peer feedback about another person's design, a sketch or diagram about a youth's own design, or perhaps a paragraph in which the youth reflects on a particular idea. These assessments are intended to help youths formalize their understanding of a particular idea and are designed to provide educators with a formal representation (i.e., a hard copy!) of what they understand about a particular idea at a particular time. If desired, these assessments can be graded and returned to youths as a means of tracking performance toward a grade in the context of classroom use.

Written assessments are given at the end of the module (and perhaps at the beginning, if the educator is interested in pre- and post-change information). The written assessment is designed to measure what youths have learned across the entire module, and it targets both youths' understanding of key systems thinking content and what they've learned about a particular technology platform.



Information about ways that students might reason about the content can be found in the *What to Expect* sections of each Design Challenge. We share the end points of student reasoning (novice and expert) but, of course, youths may be novices in one area while expert at others—or transitioning between. Thus, the goal of these rubrics is not to merely categorize youths' thinking, but rather to determine how they are thinking about the content to inform decisions about how to proceed, review, or intervene.

COMMON CORE STATE STANDARDS AND TIPS FOR INTEGRATION

You might be asking yourself: Why focus on the Common Core State Standards (CCSS) for English Language Arts in a book designed to support understanding of systems thinking concepts through the use of a computer program like G*M? What do computer programming and literacy have in common? You will find that the art of game design in these challenges involves a number of key literacy arenas.

The CCSS for English Language Arts and Literacy in History/Social Studies, Science, and Technical Subjects are the result of an initiative to provide a shared national framework for literacy development. The CCSS span kindergarten through twelfth grade and may be thought of as a "staircase" of increasing complexity for what youths should be expected to read and write, both in English and in targeted content areas. The CCSS are built upon a set of guiding "anchor standards" that evolve through grade-level progression and emphasize (particularly at the middle and high school levels) informational text and argumentative writing. The CCSS also include a strand that emphasizes literacy skills associated with production and distribution via technology.

The challenges in this book rely on youths' ability to *prototype*—that is, draft and revise in an iterative manner until they come up with a final product (a key skill in game design). During the prototyping process, youths chart ideas, devise plans, and then communicate those plans to their peers in small and large groups to receive and incorporate feedback. In addition, youths are asked to analyze "texts," such as explanatory videos, as they relate to particular systems thinking concepts that are manifested in real-world contexts, and then apply what they've understood to their own game design process. Youths are asked to write as part of the reflective process and as a way to demonstrate understanding. As mentioned previously, in these Design Challenges, youths will be involved in a number of key literacy arenas, such as speaking and listening, analyzing texts, and visual literacy, as outlined in the CCSS through anchor standards such as the following:

> *Speaking and Listening (Presentation of Knowledge and Ideas)*
>
> 4. Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.
>
> 5. Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.
>
> *Reading (Integration of Knowledge and Ideas)*
>
> 9. Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take.

In addition, technology is woven throughout the standards as a way to gain knowledge, as something to be understood through critical media analysis, and as a means to produce and disseminate work. These standards are featured in a variety of ways within the challenges of the *Gaming the System* module. Youths employ technology tools to gain meaning—from online videos to the instructions needed to progress through G*M. But perhaps most important, youths use technology tools to *produce*, to create artifacts that demonstrate their knowledge. Knowledge of G*M coding practices—its own literacy, one might argue—as well as knowledge of a complex systems example like predator-prey relationships. As your youths engage in the task of understanding how to develop digital games that make manifest systems thinking concepts, they will be doing so via challenges in this book that offer a rich toolset of language arts literacy practices infused with digital media.

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