Teaching Systems Thinking Through Game Design Curricula

The Case of Hexacago Health Academy

Madeline Quasebarth, Jessica Wilks, Yul Ailea Stites, Sophie Knifton, Vanya Manthena, Robin Michelle Cogdell, Mason Arrington, and Patrick Jagoda

The authors describe Hexacago Health Academy (HHA) 2.0, a five-year summer intervention designed to increase interest in science, technology, engineering, and mathematics (STEM) among mostly Black high school students in Chicago. The program features public health fundamentals and game design using principles of systems thinking, social-cognitive career theory, experiential learning, playing and making, and storytelling. They conclude that game play and game making can facilitate community collaborations and encourage marginalized youth to engage in complex systems thinking. **Key words:** education; experiential learning; game design; public health curriculum; pedagogy of the oppressed; STEM; systems thinking

Introduction

Conceptual Framing of Hexacago Health Academy 2022

Hexacago Health Academy (HHA) is a game-based public health curriculum that uses systems thinking and the theoretical tenents of Paulo Freire's *Pedagogy of the Oppressed* (1996) to engage with historically marginalized young learners. This approach employs asset-based strategies and positive youth development (PYD) to enhance science, technology, engineering, and math (STEM) participation among underrepresented individuals (Gilliam, Bouris et al. 2016; Gilliam, Hill et al. 2016; Macklin et al. 2018). HHA is the product of a decade of game-based learning research focused on decreasing disparities of access to science, technology, engineering, mathematics (STEM) and health education for young Black, Indigenous, and people of color (BIPOC) populations. The 2022 version of the multiyear HHA program focused on topics that included the systems level implications of food insecurity and community violence with a

American Journal of Play, volume 17, number 2
Contact Madeline Quasebarth at mquasebarth@bsd.uchicago.edu

group of nineteen students who participated in a fifteen-day curriculum. Using semistructured interviews with those who participated in the program and an analysis of their workbooks, we explore the educational achievements that can occur through game design and game play.

Employing game play and game design, HHA uses epistemic tools to facilitate learning and collaborative meaning making. These tools, defined by Ke and associastes (Ke et al. 2020), encompass conceptual frameworks, classroom routines, and tangible artifacts that foster students' participation in educational activities. According to them, epistemic tools facilitate knowledge building and can range from objects that allow students to use practice based learning to routines that help build community. They suggest supplementing lessons with tools that support systems thinking, or the kind of thinking that considers the complexity of the world by looking at it in its wholeness and its relationships rather than by breaking it down into individual parts. Applying systems thinking to a chemistry course, Blatti and her colleagues (Blatti et al. 2019) coupled traditional educational techniques with community-based and service learning, which demonstrated to students that the application of scientific principles can affect broad, complex systems and can make a positive impact on the world. Like Blatti and her associates, who combined traditional education with community-based learning, HHA uses games to merge systems thinking with practical applications, demonstrating the influence of STEM education on the main curricular components—community violence and food insecurity.

HHA's application of epistemic tools aligns the theories of Freire (1985, 1996) about disrupting traditional educational hierarchy by replacing it with knowledge that emerges from collective invention. He learned that doing so taught people to "read the world" through critical consciousness. This, coupled with game-based design theories, reinforces Freire's key form of knowledge—critical consciousness—by using systems thinking (Schrier 2021; Dishon and Kafie 2019; Bogost 2007; Meija, 2004). Further, critical systems thinking enables learners to be agents in the education process by creating space to question and identify the types of knowledge and their validity (Schrier 2021; Jackson 2001; Meija 2004).

Systems thinking can be challenging to apply to classrooms and has been shown to be confusing to learners (Ke et al. 2020; Orgill et al. 2019; York et al. 2019). York and her associates (York et al. 2019) highlight the issues related to the existing assessment tools for STEM learners when using systems thinking.

Our work employs game design pedagogy as a way to approach what design thinking characterizes as "wicked problems" (Buchanan 1992). Wicked problems are complex challenges that lack evident solutions but have an urgency given their structural dimension. Such problems include food insecurity, community violence, climate change, and pandemics. Many of the issues highlighted during the years of the HHA curriculum fall into this category because they are inherently rooted in structural inequalities. HHA uses both the systems thinking of serious games and the design thinking that is an integral part of game making to tackle the wicked problems associated with systemic inequities. We argue that games enable an accessible modeling of complex and sometimes abstract systems, including wicked problems, for students who are learning about them for the first time.

Further, although some scholars acknowledge the many beneficial effects of systems thinking in STEM education, they also recognize that there are issues with streamlining this approach in traditional classroom settings (Portnoy and Schrier 2019; Ke et al. 2020; Pazicini and Flynn 2019). For example, Pazicini and Flynn note in their study of systems thinking in chemistry education that attention may be diverted to unintended areas of the system such as components that are more meaningful to an individual's lived experience. These challenges are likely to occur because systems thinking complicates simple causality.

Addressing the challenges young learners face in grasping systems thinking in the cases of wicked problems such as food insecurity and community violence, HHA employs hands-on game play and foundational principles of public health. HHA uses these tools to help conceptualize systems thinking and disrupt the hierarchy of a traditional classroom, because young learners often fail to understand the complexities of systems thinking in the cases of food insecurity and community violence (Ke et al. 2020). This approach aligns with the recommendation of Verhoeff and his colleagues (Verhoeff et al. 2018) to introduce theoretical bases and key concepts to foster systems thinking. Game play offers an opportunity to use epistemic tools and bridge principles such as emotion, affect, and improvisation to better develop students' systems of thinking. HHA serves as a case study, showcasing that game play can effectively communicate systems thinking to young learners in an accessible manner. By leveraging emotional elements of game play and pedagogy of the oppressed, HHA provides a tangible and concrete framework for comprehending a systems thinking approach that might otherwise seem abstract.

Gaming and Pedagogy of the Oppressed

In traditional educational settings, students often find themselves in passive roles, recipients of knowledge rather than active participants capable of critically engaging with their own lived experiences. Freire and practitioners of critical pedagogy also add an understanding of power asymmetries and the role of gender, race, class, and age in classroom environments.

Freire's ideas in *Pedagogy of the Oppressed* (1996) challenge traditional power dynamics and established norms in education. This approach seeks to empower learners by challenging hierarchal educational and social structures and establishing an inclusive and equitable learning environment instead. Gaming, which does not figure into Freire's text, is a medium that enables students to take on active roles in their own learning, inspiring critical thinking and civic change (Schrier 2021). By playing particular games, students become active participants, rather than passive recipients of information, thus taking part in a more immersive and engaging educational experience. Games, as formal systems composed of interconnected elements, frequently invite thoughtful consideration of how these components interact to shape tactics and strategy in the course of play.

Although many aspects of contemporary competitive gaming do not align with the core tenants of Freire's theories, cooperative game play does so by pushing against traditional hierarchical structures through interdependent roles (Seif El-Nasr et al. 2010; Jagoda 2020). Board games such as Pandemic and video games such as the Left 4 Dead series require inherent horizontal collaboration in which power is distributed and changing rather than static (Valiaho 2014). These games contrast with more competitive games that focus on hierarchy, antagonism, and a winner-takes-all dynamic. Such games are antithetical to Freire's principles and achieve the opposite of a pedagogy of the oppressed by training learners to practice and adopt competition in their everyday lives. Competitive game play, whether in sports or video games, often relies on techniques of biopower (wielding life and death decisions over a population) to exert control (Foucault 1978; Väliaho 2014; Jagoda 2020). In an extreme example, Makarychev and colleagues (Makarychev et al. 2019) explain how the Russian government adopted biopower through doping and competitive game play at the 2014 Sochi Winter Olympics. In contrast, co-operative games help to heighten critical consciousness and encourage social interactions among players (Flanagan 2009; Frasca 2010; Gee 2003).

Further collaborative game play is congruent with the political framing

of Freire's *Pedagogy of the Oppressed*. The field of game studies has shown that games embed beliefs and world views within their structures and mechanics (Tekinbas et al. 2003; Flanagan 2009; Jagoda 2020; Trammell 2023). The expression of belief through creative techniques demonstrates how game design has the potential to increase critical consciousness and critical reflection among learners. In introducing Brian Sutton-Smith's framework of play as power, Mary Flanagan (2009) demonstrates that games enable learners both to inhabit and to challenge hierarchy. Games that encourage critical play—creating and playing as a way of questioning aspects of lived experience—can open up critical consciousness and even pathways to agential behavioral changes (Flanagan 2009). This thought process is exemplified by the work of serious game designers like Paolo Pedericini, who has developed such critically oriented video games as *Democratic Socialism Simulator*, *Casual Games for Protesters*, and *Welcome to the Desert of the Real*.

Beyond cooperative, collaborative, and serious games, value exists in moving students from game play to game design. Although much can be learned from playing a game that includes either content- or medium-specific interactions and introduces a learner to, for example, a new area of public health, the creation of a game requires a different pathway to systems thinking (Young et al. 2012; Miftachul Arif et al. 2024; Seelow 2022; Jagoda et al. 2022). A game designer must research a content area (such as food insecurity); build game mechanics, rules, and objectives specific to that area; identify an audience and outcome; prototype, play test, and iterate on a build; and often collaborate with a team of peers to complete the project. This level of involvement reinforces the topical focus and requires the designers to think about it systematically as they convey it, via a game system, to a group of players. Beyond playing an already constructed game as a consumer, the process of designing a game requires individuals to navigate and understand these intricate systems in even greater detail. Young learners who take part in designing their own games—as opposed to solely consuming commercially available games—acquire not only valuable research and technical skills but also interpersonal abilities that contribute to their holistic development (Kafai and Burke 2016).

Previous Research on Systems Thinking and Game Play

The HHA program sought to introduce and apply systems thinking through a game-based curriculum. Systems thinking involves explaining, comprehending, and interpreting complex and dynamic systems, varying from race-based

systemic inequity to STEM and business (Bashan and Kordova 2021; Lynch et al. 2021; Watson and Collins 2023; Wongprapinkul and Vassanadumrongdee 2022). In science, systems thinking holds the potential to deepen a student's grasp of fundamental scientific ideas and to foster the development of a coherent and scientifically grounded perspective. Verhoeff and his associates (Verhoeff et al. 2018) emphasizes three primary aspects for cultivating students' systems thinking. First, they encourage focus on systems concepts to explore and analyze intricate biological systems. Second, they prioritize the conceptual core of systems theory by considering the entire system or network rather than a collection of disparate interacting components. Third and finally, they argue that integrating systems thinking into scientific education can foster creative thinking as a component of the scientific method, nurture collaborative aptitudes, and accentuate interdisciplinary problem-solving abilities.

Importantly, systems thinking is a tool not only for education but for sustainable equity initiatives (Hernández et al. 2017; Omukuti et al. 2021; Watson and Collins 2023). A recent study by Omukuti and her colleagues (Omukuti et al. 2021) encourages the usage of systems thinking to reduce newly increased gender-based inequalities due to the fallout from COVID-19 restrictions, resource depletion, and novel policies. Hernández and her associates (Hernández et al. 2017), similarly, argue for the real-world application of systems thinking in their study of reduced health inequity for Indigenous peoples by recognizing the complexity of the systems affecting health outcomes.

Systems thinking entails viewing complex systems holistically by engaging a set of advanced cognitive skills acquired through the application of multiple parts of a system. Game design depends on the same four elements that all systems share—objects, attributes, internal relationships, and environments (Tekinbaş and Zimmerman 2003). By framing game design as the creation of a dynamic formal system, educators can map, simulate, and teach systems. For example, a prominent concept in games studies called "procedural rhetoric" describes the process used iteratively to persuade and articulate an argument about another process (Bogost 2007). Built upon the software term "procedural system," procedural rhetoric shows that mechanical and rule-based models can change how players think. When applied to education, Anderson and his colleagues (Anderson et al. 2019), found that procedural rhetoric techniques had a positive impact on learning objectives. Game play for systems learning uses a strategy of procedural rhetoric to animate the intricacies of system models. The resonances between these two theories demonstrate that elements are connected

to each other not just in a static manner, because systems can change over time through procedures.

Various studies have illustrated that not only game play, but game design programs can impact young learners' grasp of systems thinking (Akcaoglu and Green 2019; Nordby et al. 2016; Culyba 2018; Fullerton 2014). Akcaoglu and Green discovered that students who participated in a game design course exhibited notable enhancements in their system analysis and design competencies compared to their counterparts in the control group. Nordby and associates (Nordby et al. 2016) explored the efficacy of a game that taught sustainability through systems thinking to elementary school students. Their findings provided compelling evidence that games serve as means for supporting systems thinking skills. Furthermore, Akcaoglu and Green found that young individuals could transfer the knowledge acquired from designing and constructing intricate systems to real-world systems. This process not only enabled youth to identify issues and devise solutions but also nurtured higher-order cognitive skills.

In Akcaoglu and Koehler's (2014) study, as students participated in a game design after-school program, their problem-solving skills, including system analysis and design, underwent significant enhancement. The introduction of progressively complex systems into the curriculum resulted in increasingly intricate games created by the students. Moreover, the application of causal mapping facilitated students' comprehension of system relationships. These studies underscore the potential for integrating game design and systems thinking to cultivate students' analytical skills and deepen their understanding of complex systems.

Materials and Methods

Theoretical Framing of Main Curricular Components

The fourth workshop of HHA took place in July of 2022 in the Media Arts, Data, and Design (MADD) center at the University of Chicago. The MADD center is a collaborative space for experimentation where students, faculty, and staff create pioneering technologies that drive arts, culture, and science. Students participating in HHA rarely experience the learning opportunities that take place within such locations, and in past programs students have reported that they enjoyed being at the MADD center. Many students lived on the south side of Chicago, and HHA provided funding for bus passes to students who lived outside the immediate area of the center to mitigate any barriers to access.

In general, as young people progress from kindergarten to high school, the classroom transforms from a place of flexible, experiential learning to one of rigid and prescribed engagement. However, young adults benefit equally from interactive spaces that foster social behavior, empathy, and subjective well-being (Chan et al. 2021). Playful experimentation also engages higher-order cogni-

Week	*Day*	*Curriculum Type*	*Learning Objective*	*Participant Perspective Quote*
Week 1	Day 1	Public health research/scientific inquiry on food justice & community violence prevention	Reflecting on Jesmyns' Experience	"The understanding of the past gives you knowledge what to do in the present thus affecting the future"
Week 1	Day 2	Public health research/scientific inquiry on food justice & community violence prevention	Modeling Human Health	"After completing the model I felt like my mind was really opened up to the possibility that may have not been connected and actually can be"
Week 1	Day 3	Public health research/scientific inquiry on food justice & community violence prevention	Defining Food Insecurity and Violence	"The definition gave words to all the specific forms that occur. It can help us understand all the pieces that promote violence."
Week 1	Day 4	Public health research/scientific inquiry on food justice & community violence prevention	Illuminating the Great Darkness	"She (Jesmyn Ward) brings in ideas of the systems failing. The systems are things we put our faith in, however, they are not really as perfect as we would think."
Week 1	Day 5	Public health research/scientific inquiry on food justice & community violence prevention	Developing Interventions	"I learned more about building upon ideas that were recently given and it is important to realize there are more things that are connected than you think"
Week 2	Day 6	Analyzing Games	Game Design through 3 Lenses	"The simulation aspect of the game design connected me to the system models by showing in real time"
Week 2	Day 7	Playing Games	Social Deduction	
Week 2	Day 8	Playing Games	Drafting	
Week 2	Day 9	Playing Games	Resource Management	"Informational games are hard to make fun as it seems like a learning lesson"
Week 2	Day 10	Playing Games	Serious Games	
Week 3	Day 11	Designing Games	Six Steps	"I learned collaboration skills and the importance that games could have."
Week 3	Day 12	Designing Games	Studio Time	
Week 3	Day 13	Designing Games	Studio Time	
Week 3	Day 14	Designing Games	Playtesting	
Week 3	Day 15	Presenting Games	Expo Presentation	"This program was really enjoyable and very informational and really opened my eyes to so many things and I feel I will definitely be using the things I learned in the future"

Figure 1. Hexacago Health Academy Curriculum

tive skills, such as hypothesizing, designing, and constructing (Anderson and Krathwohl 2001; Gopnik 2016; Kolodner et al. 2003).

The program adhered to the idea that a well-designed classroom positively influences learning (Barrett et al. 2015). Throughout the program, the participants worked in a bright, open, and communal space filled with portable white boards, chairs, and tables—an environment that encouraged collaboration and deemphasized the hierarchical structure of many classrooms. The curriculum lasted fifteen days and was administered in two phases.

The design of our project blended areas like games and learning, serious game design, game studies, and public health outreach to foreground these ranges of literature. After we introduced the concept of a paper prototype educational board game as the eventual output of the program, we had the students begin with an experiential learning curriculum that used public health methodologies to engage in systems thinking (Zakrajsek and Nilson 2023). We broke the public health investigation into five modules (see figure 1).

For the remaining ten days, students applied systems thinking by designing games about current public health crises (see figure 1). Our curriculum was strongly influenced by Freire's (1996) definition of praxis: "To surmount the situation of oppression, people must first critically recognize its causes, so that through transforming action they can create a new situation, one which makes possible the pursuit of a fuller humanity" (29).

Our participants used this pattern of reflection and action to educate themselves about two significant public health issues affecting their community—food insecurity and community violence. These topics are deeply personal, so we took care to cultivate a learning experience that allowed the students to explore them from a safe distance. To achieve this, we used the following four approaches in both our content learning and game-based curriculum.

First, the bulk of the activities took place within small student groups (from four to six students) called "learning communities," led by undergraduate-aged, near-peer mentors (Kolodner et al. 1998; Kolodner et al. 2003). The instructor facilitated classroom-wide conversation and activities, but most of the teaching and learning took place among the students themselves with near-peer mentors guiding the process. This arrangement allowed the students to control the pace, depth, and direction of the discussions.

Second, we used "think-pair-share" throughout the curriculum. Students were given time to write in their workbooks before sharing their ideas with their learning community. When the students voiced their thoughts, the comments

were written on the learning community whiteboard. Then, after discussing the topic with each other, the learning communities would share their ideas with the whole class. This procedure gave the participants time to process the emotionally and cognitively demanding material.

Third, through "scientific inquiry" the students addressed the content as public health researchers. Using scientific inquiry methods distanced the students from these topics, which encouraged a thorough examination without causing deep distress.

And fourth, as part of an "emotional nonpersonal engagement," the curriculum begins with the observation from Jesmyn Ward's memoir *Men We Reaped* (2013). Ward is a National Book Award–winning author who grew up in a small town in Mississippi. During her early twenties, many of the young men she loved died by violence. She ends her memoir questioning why so many died so young. Our students' task was to uncover the root cause using public health and sociological research methods. Ward's story provided students the space to engage with these issues emotionally without focusing exclusively on their own experiences.

Week 1 Curriculum Activities: Content and Theory Introduction

Day 1. Prior to the more novel game-based curriculum, Week 1 established key theories in systems thinking and public health. On the first day, students reflected on Ward's *Men We Reaped* (2013). Because the young people were from historically marginalized communities, the curriculum had to foster a feeling of belonging within academic fields such as public health and sociology (Farrington et al. 2012). HHA selected an interview of Ward with Jelani Cobb (dean of the journalism school at Columbia University), and Khalil Gibran Muhammed (professor of history, race, and public policy at Harvard University's Harvard Kennedy School). Both interviewers are acclaimed academics who discuss their experience as Black men in America during the conversation. The dynamic between Ward, Cobb, and Muhammed modeled thoughtful dialogue about race among people who shared the students' experiences. After exploring six "food for thought" questions, the students were left with Ward's painful observation that "something vast and large took [her brother]" and "there is a great darkness bearing down on our lives and no one acknowledges it" (250). The students spent the next four days revealing the true nature of these forces. These discussions also established our eventual approach to game design by way of serious topics and critical thinking.

Figure 2. The Story of Urie Brofenbrenner

Day 2. To become public health researchers, the students first had to learn about the sociological framework they would use during the investigation. In 1977 the psychologist Urie Bronfenbrenner (1977) published a paper entitled "Toward an Experimental Ecology of Human Development" in which he detailed

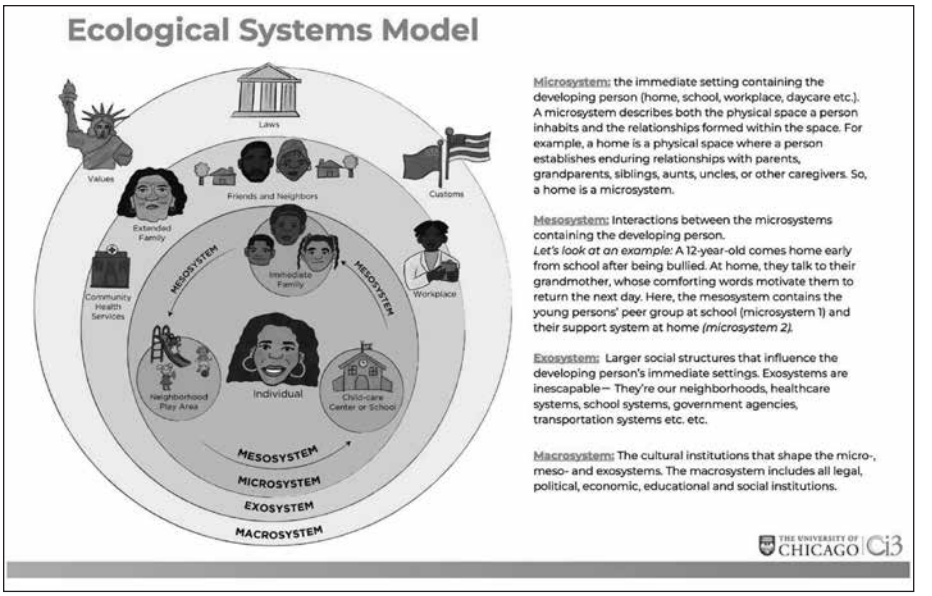


Figure 3.. Ecological Systems Model

the new (at the time) socio-ecological systems model. The systems model has been used in early education for decades but has only recently been adopted by the public health field (Golden and Wendall 2020). To help the students understand the origin of this theory, our curriculum team collaborated with a graphic designer to create a short comic book about the life and work of Urie Bronfenbrenner (see figure 2). The comic used the narrative of Bronfenbrenner's life to explain the model's meaning and significance. After reading and discussing the comic, students used Bronfenbrenner's model as a template to develop a socio-ecological model of human health.

Figure 3 displays the socio-ecological model our students engaged with for this project. At the center lies Jesmyn Ward (Individual). Then, surrounding Ward are four concentric circles: mesosystem, microsystem, exosystem, and macrosystem. We gave the students a word bank containing different aspects of a individual's ecology. They had to assign these words to different parts of the model (e.g. health care system would be assigned to macrosystem). There were no right or wrong answers as long as the students could support their ideas with reasonable claims and evidence during their group's discussion (McNeill and Markin 2011). In the end, each learning community generated a unique model.

The instructor facilitated a classroom-wide discussion generating a final consensus model. To highlight the interconnectivity among different dimensions of their model, students built a life size version of it. The students formed four concentric circles, each one representing a different level of the socio-ecological model, connected by a piece of string. When the students on the outer edge of the model (largest system, such as law and government) tugged on the string, the students on the inner circle (individuals) were pulled apart from each other. This activity showed the students how seemingly amorphous systems affect the health and well-being of individuals. This approach to systems thinking established a foundation for their eventual play with and creation of games that modeled public health systems.

Day 3. On the third day, we introduced food insecurity and community violence to the participants. Since systems thinking can be abstract, these topics made the approach more concrete. Because both food insecurity and community violence have complex definitions, before we began the discussion we facilitated a session to define our terms. Students needed a shared definition of these concepts to proceed with their investigation. Food insecurity and violence are two major public health issues appearing throughout Ward's memoir. The students became public health researchers who aimed to uncover the root causes of food insecurity and violence and explore if and how they are connected. First, we gave the students two definitions of food insecurity, one from the United Nations and the other from the United States Department of Agriculture (USDA) (Chilton et al. 2009). They compared and contrasted these definitions within their learning communities. This analysis led to a broader classroom discussion during which they reached a consensus definition. Then, the students repeated this activity with the definition of violence by the World Health Organization (WHO) (Rutherford et al. 2007). These topics became the basis of the games they designed later in the program.

Day 4. The students performed qualitative research using their socio-ecological models to code excerpts from *Men We Reaped*. Each learning community received a different passage, allowing them to share their novel findings with the whole group. We then set up the classroom as a scientific conference, so each learning community traveled from excerpt to excerpt asking questions and finding commonality among the passages. In the end, they discover that larger systems—such as economic, housing, and educational institutions—made it dif-

ficult for people in Ward's community to escape cycles of poverty and violence.

Day 5. The students then analyzed a primary research article by Aurora P. Jackson and her colleagues (Jackson et al. 2009). The article, "Single Mothers in Low-Wage Jobs: Financial Strain, Parenting, and Preschoolers' Outcomes," discusses in detail the U.S. government's Welfare Reform Act of 1996 and its detrimental effect on single mothers supporting their young children, which, in turn, negatively affected the children's behavior. Through path analysis (a means of determining relationships between variables in a hypothesized model), Jackson revealed that the stress of poverty led to a deterioration in a mother's mental health. The resulting anxiety and depression hindered a mother's ability to support her children emotionally, after they exhibited problematic behavior at home and at school. Jackson's findings tied together detrimental systemic practices (welfare reform policies) with food insecurity (discontinuation of welfare funds) and violence (negative behavioral impacts). We knew that none of the participants had encountered path analysis before, so we provided a scaffolded diagram in their student workbooks. Researchers use path analysis to verify their models, which they represent as path diagrams. These diagrams depict causal relationships between variables using straight arrows that link the variables into an interconnected system. The strength of these relationships is quantified using correlation coefficients. Here, we explained the method at a ninth-grade level and used a set of questions to guide the participants through the analysis. Our goal was to create moments of "productive struggle" within the learning communities (Hammond 2014). Notably, the students developed their own conclusions for their papers. Neither the instructor nor the peer mentors did the work for them. This type of reflective practice was meant to mirror Freire's pedagogical approaches, in which insight is generated within the individual, not deposited by the educator.

After discussing the data, the students brainstormed interventions that would support these families. At the end of the activity, they connected Jackson's research with Jesmyn Ward's observations.

Week 2 Curricular Activities: Game Design Principles

With the foundations of systems thinking established, week 2 focused on game play and introduced the idea of games as interactive system models. One of collaborative game design's limitations, particularly with young people, involves the lack of a common vocabulary. During the preintervention survey, 37 percent

indicated that they play games on a cellphone or mobile device a few times a week, 42.1 percent mentioned that they never play games on a computer, 56 percent indicated that they play games on a console a few times a month, and 68.4 percent said that they prefer to play card games or board games in person a few times a month. To alleviate this tension, we devoted week 2 to giving students an opportunity to play as many games as possible while thinking of them as interactive systems. At the start of the week, we provided a framework for critical game analysis, and at the end of each day, we asked students to reflect on the game mechanics and the system modeled and connect it explicitly to the public health lessons from week 1.

Day 6. We introduced three important concepts of game design: simulation, abstraction, and affect. To illustrate these concepts, students played one of two exemplary games in learning communities then analyzed the games through our key concepts in small and large group discussions. The shared games that we provided were Babytown and Smokestacks, two board games initially prototyped by young people and produced by Ci3 game designers and researchers.

In game design, the first concept, simulation, creates simplified models of real-world systems. In our case, Babytown is a simulation of unplanned parenting by high school students, and Smokestacks is a simulation of tobacco industry advertising practices. After two rounds of game play, students were asked to map these games onto real-world systems using the ecological-systems model and path analysis introduced in week 1. At the end of the discussion, we set aside time for game design in learning communities in which each group brainstormed about the systems from week 1 they might simulate in their own game.

For games, the second concept of abstraction allows the mapping real-world actions onto simulations through metaphor (Olsson et al. 2014). In Babytown, the act of having a baby is abstracted by picking up a "baby" card. In Smokestacks, gaining new tobacco customers is abstracted by picking up person-shaped game pieces ("meeples"). In their discussion of abstraction, students used pathway analysis to break down the parts of the simulated systems abstracted by the game they played and each action that connected to move play forward. After the discussion of abstraction, there was another round of design time during which learning communities thought about the elements of the systems they had chosen to simulate that would go into their own game.

For our third game design concept, we focused on affect. In game studies, affect designates a specific emotion induced by a game-based action or event

(Mekler et al. 2016). In the dexterity game Operation, a moment of affect may happen when the player's tweezers touch the game board, resulting in a buzz to signify failure. The affect here may be disappointment or frustration. In Monopoly, there may be a moment of relief when a player draws a get-out-of-jail-free card. In Babytown, an affective encounter may happen when players achieve one of their goals and increase their points. In Smokestacks, say, a positive moment may happen when a player earns a large profit. The emotions here may be happiness, excitement, or triumph. In their analysis of affect in learning communities, students broke down each positive moment they felt during game play and what happened in the game to induce that emotion. In learning communities, they mapped this onto the systems model and pathway diagram they had built in previous discussions, identifying the actions and elements of game play that came together to make it happen. Finally, in learning communities they discussed the emotions associated with the systems modeled in their own game, using excerpts from Ward's memoir as well as their own lives.

Our large group discussion was delivered in the style of a scientific poster presentation. Each learning community created a poster summarizing its game analysis and the game design concepts that connected with the public health systems in week 1. Each group designated one group member to be the presenter. The learning communities rotated through discussions of each poster in five-minute rounds and engaged in discussion with the presenting group member.

Days 7 to 10. For the remainder of the week, we followed a similar structure—game play in learning communities, followed by small group discussion and poster presentations—and design time in learning communities at the end of the day for their own game prototype. Each learning community chose from a daily selection of several contemporary commercial board games centered on a key game mechanic—social deduction on day 7, drafting on day 8, and resource management on day 9. Day 10 centered on serious or educational games. Students selected from a suite of Ci3 games codesigned with young people in previous Hexacago iterations, including Babytown, Smokestacks, and others. The purpose of such varied game play during week 2 was to develop a shared gaming vocabulary among participants and to foster a sense of community in small groups. Each discussion included an analysis of the commercial game's simulated system, abstracted elements, key mechanics, and moments of affect.

Though we focused on game play during week 2, the end of each day also

included designated design time in learning communities centered on participants' game prototype. These ongoing discussions eventually transitioned into the week 3 activities.

Week 3 Curricular Activities: Prototyping and Design

On the first day of week 3 (day 11), we presented a series of six steps to help design serious games—choose an important topic; identify a system to simulate and the player perspective from which to do so; select an existing core mechanic; begin the process of reskinning; play test; and iterate.

Reskinning is a technique that allows for game prototyping without the intimidation of starting from a blank page. This approach proved particularly welcome given the limited three-week timeframe of this workshop. Reskinning entails taking the core mechanics from an existing game and transforming them in some way—mapping them on to new content, or adding or removing complexity, and so on. In week 3, each learning community began with the systems model, pathway diagram, and notes on the desired affect for their eventual game prototype from weeks 1 and 2. They discussed which of the concepts or key takeaways from week 1 they would incorporate into their game. Based on the discussion, they then selected one or more game mechanics from the example games they had played in the previous week. Then, they began the process of reskinning by mapping these game mechanics onto the pathway diagram they had built during week 2 for the system they had chosen to model in their game prototype. This collaborative, nonhierarchical process not only reinforced the lessons from week 1, but recontextualized them in game design for a specific purpose. Such recontextualization is a unique affordance of game design concepts that allows students to engage with the material in an empowering way (Olsson et al. 2014).

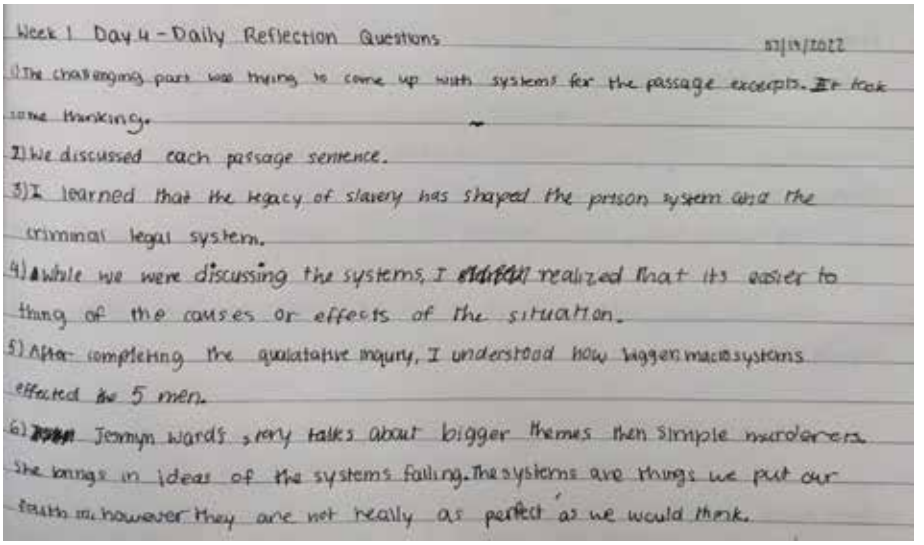
Through most of week 3, students divided into learning communities for independent design time. By day 13, each learning community had built a working paper prototype game based in game mechanics from week 2 and the public health systems modeled in week 1. On day 14, each learning community play tested another learning community's game and provided feedback. The students presented the progress they had made to each other at the end of each day, culminating in an exposition on day 15 in which University of Chicago faculty, staff, and other MADD center summer program participants played the game prototypes and listened to participants discuss the process of designing their games.

Methods

This article concerns the multimodal qualitative data collected in July 2022 in Chicago. The research project is part of a larger National Institutes of Health program, Hexacago Health Academy, funded from 2017 to 2024. Although we are reporting only on data from the summer 2022 initiative, the authors have published on other HHA projects (Gilliam et al. 2016; Jagoda et al. 2022; Macklin et al. 2018). We recruited nineteen teenagers to participate in HHA 2.0 Summer 2022 program via email listserv, snowball sampling, paid Instagram advertisements, flyers shared with public school teachers, and emails sent through professional networks. Eligible participants were entering either eleventh or twelfth grade, lived in Chicago, and belonged to communities typically underrepresented in STEM-related and health care careers. Interested candidates filled out a REDCap screener after clicking on the Instagram advertisement. After checking for eligibility, the research team set up a time to obtain consent from parents and assent from participants younger than eighteen. All those who met eligibility and provided parental consent were invited to participate in the program. The program was held for three weeks Monday through Friday from 1:00 p.m. to 4:00 p.m.. Along with participants, we recruited six peer mentors and one instructor. Participants, mentors, and teachers were compensated for their time.

Participants also completed surveys on REDCap before and after attending HHA 2022. We administered these surveys on the first and last day of the summer program respectively. Along with the postintervention survey, participants also engaged in individual, semistructured interviews on the last day of the program. Study team members conducted interviews, which lasted no longer than thirty minutes. Participants received a daily incentive of forty-five dollars for each day they were in attendance. This research project obtained ethical consent from the Institutional Review Board.

Qualitative data collection explored the participants' feedback on the HHA curriculum and their daily reflections. We collected the participants' daily workbooks for data analysis at the end of the program. Before the program started, we informed participants that workbooks would be collected. We added the workbook to an Excel sheet, which we deductively coded until reaching saturation (see figure 4). We had participant interviews transcribed using a secure, third-party transcription service. After transcription, we verified all transcripts and removed any identifiable data. Two researchers on the study team—Madeline Quasebarth and Vanya Manthena—created a codebook based on the interview guide and insights from interviews. First, they coded the same transcript, then modified the


Week 1 Day 4 - Daily Reflection Questions 2/14/2022

1) The challenging part was trying to come up with systems for the passage excerpts. It took some thinking.

2) We discussed each passage sentence.

3) I learned that the legacy of slavery has shaped the prison system and the criminal legal system.

4) While we were discussing the systems, I realized that its easier to think of the causes or effects of the situation.

5) After completing the qualitative inquiry, I understood how bigger macrosystems effected the 5 men.

6) Jesmyn Ward's story talks about bigger themes then simple murderers. She brings in ideas of the systems failing. The systems are things we put our faith in, however they are not really as perfect as we would think.

Figure 4. Student Notebook Page

codebook based on emergent themes such as STEM and health careers, college readiness, and social justice and science. Once the team established consensus on coding, study team members coded the remaining transcripts individually using Dedoose software. To facilitate in-depth analysis, Quasebarth and Sophie Knifton later created a theme matrix and code summaries from emergent themes.

Data was organized and coded through deductive thematic coding. Workbook entries were added into an Excel sheet, which researchers deductively coded until reaching saturation (see figure 4). Researchers also conducted fifteen- to twenty-minute exit interviews with each participant. We coded data using a deductive thematic code book. Quasebarth and Manthena coded interviews together until reaching consensus, and after reaching consensus on code usage and the codebook, we coded interviews separately. Knifton and Quasebarth wrote summaries for each code based on emergent themes.

Results

Sample Characteristics

Figure 5 shows participant demographics. Eleven individuals, or 57.9 percent of the participants, identified as female, and eight, or 42.1 percent, identified

n=19	N (%)
Age	
15	1 (5.2)
16	8 (43.0)
17	10 (52.6)
Mean	16.5
Sex	
Female	11 (57.9)
Male	8 (42.1)
Declined	(5.3)
Grade	
11th Grade	10 (52.6)
12th Grade	9 (47.4)
Sexuality	
Queer	2 (10.5)
Straight	16 (84.2)
Gay or Lesbian	1 (5.2)
Race	
Black	12 (63.1)
White	1 (5.2)
Asian	7 (36.8)

Figure 5. Participant Demographics

as male. Participants represented a mean age of 16.5. One individual, or 5.3 percent of participants, declined to report their gender identity. The majority of participants identified as straight (84.2 percent) and Black (63.1 percent). Participants split evenly between grade 11 (52.5 percent) and grade 12 (47.4 percent). On average each day seventeen participants were in attendance for the program. Prior to the intervention, 68.4 percent of participants reported that they would like to play board games at least a few times a month. Further,

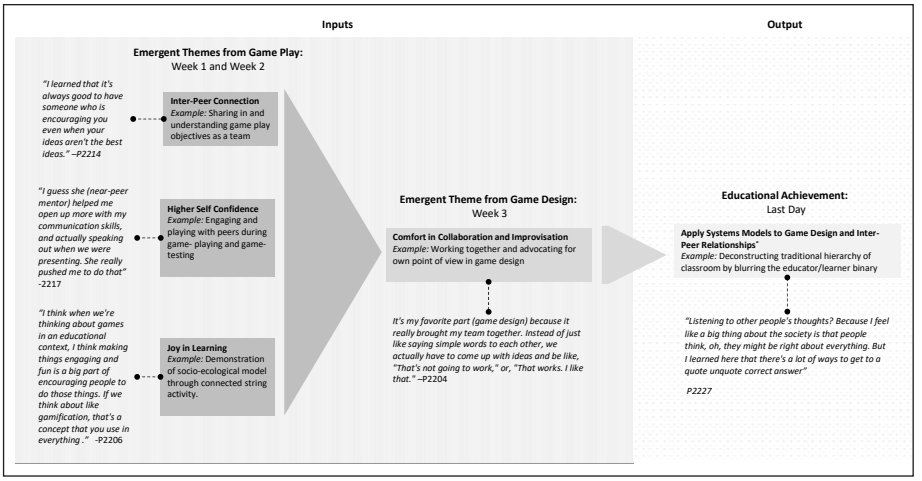


Figure 6. Relationship Of Emergent Themes Throughout HHA 2022 Curriculum

when asked at the end of the intervention, all participants indicated that they would recommend this program to their peers.

Overall, as we will elaborate, participants discussed a distinction between game play and game design in their learning outcomes (see figure 6). Participants found that game play better helped them connect emotional reactions to learning objectives and outcomes, while game design helped better facilitate community collaboration and improvisation. Further, participants demonstrated that content learning and successful game design prepared them for purposeful game design (see figure 6).

Emotional Responses and Understanding Complex Systems Through Game Play

In learning about systems models through game play, many participants reported an emotional response to the curriculum's learning objectives. Emotions ranged from feeling a higher sense of self-confidence, finding joy in education, and feeling better understood and connected to their peers.

Two participants mentioned that the program positively affected their self-confidence and helped them overcome obstacles that prevented them from communicating their thoughts and opinions. One of these participants, a seventeen-year-old Black male participant, simply stated, "I'm shy sometimes—but I overcame that," during the program. Further, several participants explained that through the game play aspect of the curriculum—which presented issues

like food insecurity—they felt more connected and comfortable in talking about their own experiences. A seventeen-year-old Black female participant wrote in her workbook, "I felt that some of the way I get food, such as food stamps, were okay," while another sixteen-year-old Black male participant wrote, "I am really not alone, and there are people who can relate to me in the same way." These reflections demonstrate how the curriculum cultivated emotional responses such as belonging and confidence in some participants.

Overall, participants enjoyed the teaching about the socio-ecological model and found the teaching methods to be successful in breaking down complex themes. Many participants said the unique gamification of the socio-ecological model helped them understand and integrate lessons into their daily lives. Participants called the immersive nature of the curriculum, particularly the string activity, helpful in conceptualizing the complexities of the socio-ecological model. For example, a seventeen-year-old Black female participant explained that the hands-on activities "helped to deepen my understanding of what I'm seeing."

Some participants mentioned that the socio-ecological model allowed them to better understand how social issues such as community violence and food insecurity are interconnected and related to systemic issues. For example, a seventeen-year-old Black male participant stated: "We also played a game where each person was a different thing. I think I was groceries in the stores. And then other people were the government, the Supreme Court. And then we all tied a string to each other if we thought that this was connected to that. . . . And then we pulled, we tugged it, and we saw what affected. Who got tugged. So it was very interesting to see how every person felt a tug once."

Similarly, others found that the socio-ecological model allowed them to deconstruct larger issues and provided them with a framing to pinpoint issues and put a name to them. One participant felt that learning about the socio-ecological model brought not only a personal awareness to understanding systemic issues but also inspired them to share this knowledge as an act of bringing about positive social change. "If I can help," explained a seventeen-year-old Black female participant, "do something to bring awareness to other people understand (socio-ecological model), that's something that I would want to do. And I feel like it's also important to enlighten other people about this." Some participants also found that, even though they were familiar with complex topics like food insecurity, the interactive aspects of the curriculum allowed for these problems to "become more real."

Many participants found that there was a connection between having fun in

the curriculum and the level of their understanding of and integration with the educational material. This emotional relationship assisted them both in understanding how systems relate to one another and how students may be connected to others. One seventeen-year-old Asian male participant explained: "I think when we're thinking about games in an educational context, I think making things engaging and fun is a big part of encouraging people to do those things. If we think about like gamification, that's a concept that you use in everything."

Most of the participants noted that game playing was a fun way to understand and remember information from the curriculum. A seventeen-year-old Black male participant said, "So really thinking about ways to make games fun, or connect to the real world, was very interesting and fun. . . . I like how they introduce the world problems at first."

In another example of game play as a fun method for understanding the systems model, a seventeen-year-old Asian male participant wrote in his notebook that "the simulation aspect of the game design connected me to the system models by showing [them] in real time." A sixteen-year-old Black female participant echoed this statement, writing, "When we [were] playing the game, that's when I experienced an A-HA! moment. Because I finally got the point of it."

Overall, many participants felt that the emotion created in game play allowed them to understand better the intricacies of curricular material such as the socio-ecological model. As a sixteen-year-old Asian male participant summarized, "When it comes to games, I think having successful game play and engaging game play does definitely contribute to successfully disseminating learning objectives and information like that."

Improvisation and Collaboration Through Game Design

Improvisation proved essential to understanding both how to play within the system and how to critique it. Participants created and learned organically to collaborate with their peers within top-down and nonhierarchal learning systems. Many participants felt that improvising and designing games to model systems helped them understand—and connect with—the larger implications. Improvisation generally emerged implicitly as participants had to act out and adapt to challenges extemporaneously in their own game design.

Several participants mentioned that the collaborative nature of game design meant they learned something either from one of their peers or their mentor. Collaboration is essential to improvisation, because participants have to work with one another to take account of the others in the room amid changing pro-

cedures, and this informs the game play and game design. Several participants felt that the program's mentorship helped them learn how to collaborate. A seventeen-year-old Asian male participant proclaimed his mentor essential to understanding curriculum objectives and game play: "He taught us a lot about game mechanics but also how the math works when it comes to point values in games. So our game had a customizable part, and each part had pros and cons. And so we kind of went into the math of those pros and cons and looked comparatively how they kind of stacked up against each other. And that was like a cool way of looking at it mathematically."

Another participant, a sixteen-year-old Black female, mentioned that her mentor "helped me open up more with my communication skills, and actually [speak] out when we were presenting. She really pushed me to do that." Further, several participants found their mentors essential to understanding how to collaborate when designing games. Many participants found it difficult to design a game using complex systems thinking. However, mentors facilitated collaboration in game design. As one sixteen-year-old Asian male participant noted, "We tried to really agree with each other a lot, so it wasn't nothing really negative. Only other comments I have about is when you're trying to come up with one answer and you all have different answers or different viewpoints, you have to agree on something. So you may not get your exact point across how you want to, but it's going to be a combination."

Among the participants who mentioned learning from their peers, one described the program as helping take on others' perspectives, which also helped in learning the different aspects of the curriculum more effectively. In addition, some participants mentioned that the small group nature of the program helped them form better and stronger connections with their group mates. For example, a seventeen-year-old Black female participant explained the importance of collaboration in game design: "I really found what I like to do because I'm very indecisive. Working with this team and developing a game, it made me think, 'Oh this is something I really like doing. Maybe I should pursue it in my future.' That's something that I learned for myself and something that I just learned in general was that it doesn't have to be serious to be a class or to be taught to you."

Overall, most participants found game design helpful in connecting with peers and improvising new ideas or making suggestions. In reflecting on game design, a seventeen-year-old male participant who identified as Black noted: "There are a lot of possibilities. Someone said it in a way that I didn't say it. They

got to the answer in a way that I didn't get to it. So, it was just interesting seeing another person's perspective."

Discussion

The HHA 2022 curriculum represents an innovative approach to engaging learners in the complex challenges of systems thinking through game-based learning. This study's findings shed light on the utility of using systems thinking principles to engage students in understanding issues such as food insecurity and community violence. The study's results reinforce the notion that integrating systems thinking into education through game-based approaches can curate an engaging learning environment (Gray and Leonard 2018; Arif et al. 2024; Young et al. 2012). The curriculum's focus on games, both in playing and designing interactive systems, facilitated emotional connections to the learning material, and subsequently promoted a deeper understanding and integration. Emotional engagement in educational contexts has long been recognized as a powerful tool for fostering learning retention and comprehension (Pekrun and Linnenbrink-Garcia 2012). Participants' statements about increased self-confidence and the breaking down of barriers to communication underline how emotional responses can lead to a sense of belonging and empowerment.

By allowing students to manipulate and engage with the rules of the system, games enable learners to construct their own understanding of complex issues and values (Flanagan and Nissenbaum 2016). The procedural rhetoric deployed in HHA helped to make learning about key concepts both accessible and fun, ensuring we do not subvert the joy possible within learning (Doucet and Srinivasan 2010). The study's findings resonate with this principle, showing that participants were able to grasp the socio-ecological model more effectively through game play and suggesting that procedural rhetoric was crucial for encouraging systems thinking comprehension (Bronfenbrenner 1979; Bogost 2007; Doucet and Srinivasan 2010). Further, the games introduced in HHA made systems thinking palpable and concrete. In doing so, the HHA curriculum took the principle that it is hard to move from theory to curricular practice and made it emotionally accessible to students.

The collaborative and improvisational nature of game design contributed significantly to the participants' learning experiences. Collaborative game design fostered interpersonal skills, and participants noted that working together not

only improved their understanding of the subject matter but also nurtured a sense of community. This aligns with Freire's (1996) ideas of dialogic education, where learners engage in cocreation of knowledge through respectful dialogue. Cooperative game design exemplified the horizontal collaboration that subverts the hierarchy within traditional educational environments.

Finally, the study also suggests that critical play can encourage critical consciousness (Flanagan 2009; Freire 1996). By designing games that explore complex social issues, students were pushed to consider the underlying structures and relationships, fostering critical thinking skills and an awareness of social inequities. The recognition of these issues demonstrates a level of critical consciousness akin to Freire's (1985) notion of "reading the world." Just as Freire focused on literacy as a way to read the world, game play offers a way for students to conceptualize systems thinking through their everyday experiences. By creating an accessible mechanism—game play—to teach systems thinking, students were comfortable in engaging and understanding the complexity of such inequities as food insecurity and community violence.

Limitations

Although our study had many strengths, it also included several limitations. First, we used a small sample size restricted to the Chicago area. Second, the study team lost eleven participants after they had consented to the study. The population mostly skewed suburban. Our recruitment methods may have further skewed it so, because participants needed to use social media (Instagram) to access recruitment materials. Finally, we held the workshops on campus in Hyde Park in the afternoons. This limited some participants because they needed to have transportation for the afternoon sessions. Although the team attempted to mitigate these barriers by paying for time and providing bus passes and snacks, some potential participants remained unable to overcome logistical obstacles.

Conclusion

Our findings offer significant implications for educational practices and the integration of systems thinking within marginalized communities. The success of this curriculum suggests that game-based approaches can effectively bridge the gap between complex systems concepts and the lived experiences of young learners. By combining systems thinking with emotional engagement, collaborative learning, and improvisation, educators can create a more holistic and empowering educational environment. Future research could delve deeper into

the nuanced connections between game design and the effective integration of systems thinking, epistemic tools, and game-based education for fostering critical thinking, active learning, and understanding of complex systems among historically marginalized young learners.

Our work employs game-design pedagogy to address what design thinking identifies as "wicked problems." These are intricate challenges without clear solutions or boundaries, but they carry a sense of urgency due to their structural nature. Many of our focus areas fall into this category because we aim to address structural inequality. Additionally, games promote connected learning. Through connected learning, we illustrate how participatory design by, for, and with stakeholders can challenge traditional hierarchies. By embracing a pedagogical framework that combines theoretical concepts with practical application, HHA stands as a testament to the potential of game-based learning in nurturing analytical skills and promoting equitable education.

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