Applying Systems Thinking to Learner-Centered User Design for Game and Cyber School Learning Contexts

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Abstract

A lot of research currently addresses *change thinking in educational systems*, particularly *change issues centered on learner cultures* and systemic disruption. As a part of a major reference work on systems thinking and change, this chapter focuses on user design as an imperative instructional theory allowing designers,

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demonstrating how two research studies were conceptualized and interpreted using systems thinking. For designers, user design theory helps us to utilize learning ecosystems to map the meaning-making journeys and then to distinctions, systems, relationships, and perspectives (DSRP) in complex learning environs so that we can refine and design environments for the relationships between complex experiences of knowledge sharing and interactions. As we explore critical literature in this chapter, we offer two examples as the basic material for prioritizing indigenous domains within user-centered design, demonstrating how we overcame common systemic boundaries and obstacles that typically plague student-centered learning models. One study addresses boys and gaming as indigenous ecosystems of an ecology of play within a student user design, and the second study investigates cyber charter schools' science labs as ways to empower traditionally disengaged learners.

Keywords
User design · Qualitative research · Learning ecosystems · Digital media · Online learning · Learner-centered approaches

Applying Systems Thinking to Learner-Centered Design

Introduction

Within the United States and in many K-12 educational systems, student engagement rates incrementally decrease as learners climb through sequenced grade levels (Busteed, 2013). Disengaged learners are all around us – especially boys who are failing at record rates (Jackson & Hilliard, 2013) while students and parents exercise school choice, drawing education-funding dollars from public schools in many instances. School choice has led to students moving to cyber charter schools since the mid-1990s (Barbour & Reeves, 2009). Keeping pace, an organization for digital learning reports that 4.5 million supplemental online course enrollments and around 275,000 students were enrolled in a fully online charter school (Evergreen Education Group, 2015). The potential benefits of personalized learning and flexibility are a major attractor for families supporting cyber charter schools (Klein, 2006; Waters, Barbour, & Menchaca, 2014). A steady increase in student migration from public schools to alternative systems, specifically to cyber charter schools, is another example of a long-term deficiency unaddressed by education leaders and designers today (Kowch, 2009). With the promises of more personalized learning environments, charter schools have become more appealing locations for parents to send young students.

Our contemporary educational change efforts emphasize a power structure or system perpetuated by a top-down or vertical power in today's highly interconnected school systems (Sarason, 1996). From a broader systemic change perspective, students are often coerced into accepting or rejecting instructional interventions that are required by political exigencies (Carr-Chellman & Savoy, 2004).

Among other paradigm changes necessary to conceptualize and to realize a dire need for education system change, Reigeluth and Karnopp (2013) argue from a lifetime of research that systemic thinking, in particular, is necessary for effective civic education because system thinking helps us to unpack the many interrelationships within complex systems. Too often we design learning or learning environment change at the micro (classroom) level without enough consideration of the education ecosystem. In addition, these authors advocate for learning customization, learner and teacher diversity, and empowerment for everyone in educational systemic change (Reigeluth & Karnopp, 2013). At the conclusion of this chapter, the reader should be able to:

- Unpack experiences from the examples of boys and videogames and cyber charter science labs, with a focus on the student culture to better understand and mitigate learner disengagement.
- Discuss the evidence of disengaged learners as an argument for the design of disruptive systemic change through learning ecosystems and systems thinking.
- Actualize the position of learner-centered user design as a potential systemic theory-based approach to reducing these high levels of learner disengagement.

Literature Review and Theoretical Frame

The literature review is framed to make sense of *user design instructional design theory* as an imperative construct of instructional design systems. We begin with user design because research shows that instructional designers often take on a top-down approach from expert to novice in learning environment design, too often neglecting authentic learner centers (Carr, 1997). However, when user design is used by instructional designers, we see a dramatic shift in power that centers on the *learners as designers* and on user design as the design itself (Reigeluth, 1996). Therefore, user design of instructional systems advantages a more "blank slate" in which end users (learners, instructors) are engaged in the creation of their own systems (Carr-Chellman & Savoy, 2004). So, "to pursue user-design research is to begin to deny the power and expertise of the instructional design field" (Carr-Chellman & Savoy, 2004, p. 702).

Given these frames and the priority of user design, this chapter examines and reports two research studies that explored agency and ownership from the learners' perspectives. They are included to shed light on the impact of user design effects. We see learner engagement as essential to effective teaching and learning as a critical component in successful learner outcomes. This engagement informs our systemic perspective on teaching and learning in this chapter through learner engagement and user design principles. For systems thinking to be a successful foundation for change efforts, multiple perspectives must be considered (Cabrera, 2006). Our contribution to systemic change here advocates for *authentic ecosystemic approaches* to increase learner engagement by engaging learners in defining and planning their own educational paths. Implicitly and explicitly, **we embrace the culture of students** in this chapter as a priority, rather than accepting the culture of traditional schools that tends to alienate learners from their own school. Here we lay out a theoretical framework by exploring *engagement* and the *culture of indigenous knowledge*. We then examine research on *user design* literature to conclude with an exploration of *learner ecosystems* and conclude by examining a deeper understanding of the theoretical underpinnings of *systems thinking*, including Cabrera's (2006) DSRP Model.

Learner Engagement. Fundamentally, the two studies presented here are centered on different parameters of learner engagement.

Project 1 is a *gaming study* of individual learner engagement through their basic experience in the decidedly non-learning *intended* activity of social gaming. Ultimately, our findings from this study are grounded and similar to theoretical and practical understandings of learner engagement and increased learner engagement in the online learning practices of virtual communities (Engerman, 2016; Mincemoyer & Raish, 2015; Raish, Teng, & Carr-Chellman, 1995).

Project 2 is a study of cyber charter science labs. We focused on the extent to which cyber charters can engage learners, particularly in a learning discipline (science) that is often heavily hands-on and learner engagement oriented. In Project 2, we are particularly concerned with presenting and exploring the extent to which designers are able to make learning experiences authentic. Secondarily, we examine some of the negative impacts when user design is not used in in virtual (cyber) learning.

Learner Culture and Indigenous Knowledge. While the colloquial use of *indigenous knowledge* typically implies an orientation to particular culturally sensitive curriculum making, here we are using the notion in an expansive fashion looking at learner culture (Anthony-Stevens, 2017; Anthony-Stevens, Stevens, & Nicholas, 2017) and the *ways in which learner culture can be reflected as an indigenous source of knowledge* in a learning environment. Both Projects 1 and 2 demonstrate the power gained from indigenous understandings of the digitally supported learner experiences, specifically by exploring findings from the understanding the power of indigenous overlays of learning experiences in video gaming and cyber charter science learning experiences. In both cases, you will see that both indigenous knowledge and learner culture are honored and interpreted to better inform future instruction designers. We emphasize and narrate the shift in power dynamics we found by focusing on learner voices as experts within their indigenous knowledge domains to arrive at the user design construct.

User Design. Readers are aware that we believe that authentic, learner-centered approaches seeking learner engagement should incorporate *learner-centered user design* (Carr-Chellman & Savoy, 2004). This design consideration transfers the power of learning and change in learning to the learner. Instead of imposing change efforts "upon" learners in a coercive fashion, "User-design … empowers the users to engage authentically in the decision-making process that *is* design. In this case, the end users are empowered to play a central role in the creation of their own systems" (Carr-Chellman & Savoy, 2004, p. 709). Unlike learner-centered *user-centered design,* which considers the learner as a factor, but not as a designer, user design differentiates learner engagement because the shift to engage is offered to learners not created as cause-effect systems in the learning environment. When taking a learning environment design approach, user designers seek social and cultural change for end users by investing in their (learner) interests and by advocating for decision-making power. Therefore, our chapter encourages *systems thinking* approaches in education by deeply investigating *cultural* and *social* influences on meaning-making processes of adolescent learners.

Systems thinking is a construct for ways or means to approach complex interrelated problems by *thinking* and not just by *applying* system theory models (Cabrera, 2006). We know that to create a change in status quo learning systems, we need to understand that systems are constantly changing and that we can create, as complexity theorists say, a perturbance to help people consider new ways and means for doing things (learning, in our case) (Kowch, 2013). The authors wonder: *"How can we introduce systemic disruption to make sweeping changes to current educational practices"?* System dynamics theory provides a model for enacting change through systems thinking (Forrester, 1994). While a focus on quantitative measures for system dynamics (as it is in that subfield) is not taken here, the goal of improving a process by designing alternative structures (of user design, in our context) is also the goal of this chapter (Forester, 1993). User design requires an authentic respect for learner interests and indigenous knowledge (Carr-Chellman, 2007; Carr-Chellman & Savoy, 2004). As mentioned above, by indigenous knowledge, we refer to the localized and shared knowledge structures that are native to a particular culture of people groups (Carr-Chellman & Savoy, 2004; Yapa, 1996). So we believe that it is imperative for designers to examine the indigenous knowledge spaces of our learners by investing in and by considering student voice.

User design theory posits that along a continuum of empowerment in research approaches, action research (AR) and participatory action research (PAR) most align with the user design agenda (Carr-Chellman & Savoy, 2004). However, Carr-Chellman and Savoy (2004) admit that because user design has very little research on process or product, we cannot say with certainty that PAR is the best match to measure the results or processes of user design. Therefore, we posit that a user design agenda can be further developed by utilizing a wider, ecological *approach* for investigating the sociocultural habitats of end users (learners, instructors) within our qualitative learning environment designs. This type of investigation bolsters the empirical findings of user design, investigating the design process and suggesting where user design may align as a systemic change approach.

Learning Ecosystem. An ecological construction can be beneficial in bringing light to the influential components of adolescent meaning-making (learning). So a *learning ecosystem* is helpful here as a design concept and in learning systems because the term formalizes a specific system thinking frame and a widening perspective of learners-in-systems for our investigation. Several scholars would agree that ecological approaches satisfy our desire to investigate the intersection of learners and context that produce developmental changes (Barron, 2006; Bronfenbrenner, 1979; Lerner, 1995; Lewin, 1951; Guitierrez & Rogoff, 2003). Borrowing from Barron's (2006) articulation of learning ecosystems, the authors operate ecosystems under the following three conjectures:

- Conjecture 1: Within any life space, a variety of ideational resources (e.g., ongoing activities of other people, conversations, books, computer programs, projects, or assignments) can spark and sustain interest in learning.
- Conjecture 2: People not only choose but also develop and create learning opportunities for themselves once they are interested, assuming they have time, freedom, and resources to learn – the crux of user design culture.
- Conjecture 3: Interest-driven learning activities are boundary crossing (across contexts, relationships, and geography) and self-sustaining (Barron, 2006, p. 200).

Furthermore, Barron suggests that this learning ecology frame unpacks development from sociocultural and activity theory (Barron, 2006). These approaches both capitalize on informal and formal environments for best practices. After this identification of the basic components and reasons for a more meaningful learning system, we also need to examine a framework that helps us understand the connections between the interrelated elements within system. We need a way to explain and enact thinking about systems or systems thinking itself (For more detail, see other chapters in this volume by Cabrera).

Thinking About Systems: Cabrera's Model

DSRP Model. The distinctions, systems, relationships, and perspectives (DSRP) model for systemic thinking (Cabrera, Cabrera, & Powers, 2015) has been a guide for our ongoing work because it is as a way think about systems, and it is also a way to understand the complex and interrelated elements of a learning system, aligning with the "openness" of our *user design* concept.

Distinctions. *Distinctions* mean differentiating between what a concept's identity is (or is not), shedding light on specific internal and external boundaries of a system (Cabrera, 2006; Cabrera et al., 2015). Distinctions can lead to an us-vs-them dichotomy or the development of the "other" as well. To make distinctions, we must also have a perspective or impulse in defining identity (Cabrera, 2006). You will see that through learner-centered approaches, our two project investigations distinguished between learners' awareness of their *own* experience, self-*awareness*, the self in different *roles*, embodied *action, purpose* or intention in action, *awareness* of other persons, *linguistic* activity, *social* interaction, and everyday activity in a surrounding life world (Engerman, 2016; Mincemoyer & Raish, 2015; Raish et al., 2012).

Systems. Organizing *systems* require distinguishing parts to wholes and between internal and externals to the whole. Even further, according to Cabrera (2006), systems organize between parts and their wholes and then relate *this* whole within parts of larger *other* wholes. *Systemically*, in our work and projects, we highlight an interest in sociocultural impacts on educational systems as potentially nested but definable systems. Systems theories (Hutchins, 1995) help us to form the foundation of deeper understandings of the culture of schools and societal impacts on learning gains.

Relationships. ***R****elationships* refer to actions (cause) and reactions (effect) among people or "actors." Relations are the connections through which actors can better appreciate the consequences of their actions as well. Relationships help people (learners) to guard against limited thinking, for example, thinking in terms of direct causality without investigating context and nuances. As an inevitable part of systems, our understanding of relationships can make us less likely to harm one another as a deeper appreciation of the complexity of being part of a larger whole (Cabrera et al., 2015). Relationships are constructed by the analysis of mediating artifacts and their impact on primary subjects to their motive objects (Engerman, 2016; Engeström, 1987). In Project 1 (later in the chapter), for example, *relationships* are mapped through systems of activity (Engeström, 1987; Foot, 2014). Therefore, the network can be articulated as an ecosystem that maintains a more holistic structure of influences (Engerman, 2016).

Perspectives. Taking *perspective* is integral to our thinking within the DSRP frame, because perspectives increase our awareness of the assumptions we do and do not make in our systems thinking (Cabrera et al., 2015). To increase our metacognition, for example, we must be aware our perspectives in this way. Therefore, perspective taking is a distinction between the view of the object and the object's view. Taking perspectives implicitly and consciously also affects our ability to recognize our development of the other. Within qualitative studies, it is important to practice reflexivity in perspective taking (Rossman & Rallis, 2011). Reflexivity is the researchers' acknowledgement of his/her own bias and position within the report of the study and must rely on deep analysis of the participants' "emic" perspectives of their experiences (Rossman & Rallis, 2011). So by knowing our perspective, as we know our epistemology and ontology, we know how we approach systems thinking.

Summary of Literature and Conceptual Framework

From this literature, we prioritize user design as a pivotal approach to instructional design systems from the learner's perspective in alignment with *change thinking in educational systems,* particularly *change issues centered on learner cultures* toward systemic disruption. By using a learning ecology concept (Barron, 2006) to situate the learning experiences and then by taking a systems thinking approach of distinctions, systems, relationships, and perspectives (DSRP) (Cabrera, 2006; Cabrera et al., 2015), we then ***unpack a new mechanism to engage in learner-centered approache***s for a new digital generation of virtual communities.

Table 1 outlines our demonstrative Project 1 (Boys and Gaming) and Project 2 (Virtual Science Lab learning) research questions, user design principles, learning ecosystem conjectures, and systems thinking (DSRP) work in this chapter. The table conceptualizes the relationships between the design, ecosystem and systems thinking frames within, and the research questions of our example empirical studies.

Table 1 is an organizer for our descriptions and analysis of Projects 1 and 2 as follows. These research projects sought to deepen our understanding of indigenous learning environments with student voice as we seek to develop newer learning models. Ultimately the DSRP systems thinking model helped us to interpret findings

Table 1 Major theoretical frames and research questions table

Project questions	User design	Learning ecosystems	DSRP
Project 1: Boys and gaming			
How do boys perceive their gaming experiences within the online game space of "*Call of Duty*?"	User design in instructional systems is a blank slate seeking student voice and student design. We sought to empower students within their indigenous knowledge systems to identify critical components of instructional design for boys. In our findings, we found themes of socializing with peers, competing, identity formation, and highlighting expertise through Flow states	Conjecture 3: Interest-driven learning activities are boundary crossing (across contexts, relationships, and geography) and self-sustaining	Boys used **perspective** taking to shift their choices by taking on their own views of a concept or object and from taking the object's point of view. In addition, the boys constantly *explored* the perspectives they were taking and how they are related to others in the social group These **perspectives** are taken within the context and understanding of parts to wholes. Organizing (learning) systems required perspectives of the gaming culture to ones on identity as player as well as the identity of players to subsections of the gaming community
How are social and material practices developed by playing Call of Duty?	Students self-organize and self-select the places in which they feel most connected. Through authentic respect and student voice, the boys were empowered to develop social practices and to leverage shared knowledge practices Taking a learning environment design approach, our observation revealed socially agreed language and value development among	Conjecture 1: Within any life space, a variety of ideational resources (e.g., ongoing activities of other people, conversations, books, computer programs, projects, or assignments) can spark and sustain interest in learning Conjecture 2: People not only choose but also develop and create learning opportunities for themselves once they are interested, assuming they have	Social practices are created by developing clear distinctions of acceptability. Player consistently explored their **identity** and other The social practices emerge out of interrelated **relationships** that satisfied feelings of belonging and also increases awareness of their effects on other people. Cause and effect are iteratively evaluated to determine value

(*continued*)

Table 1 (continued)

Project questions	User design	Learning ecosystems	DSRP
	boys with a competitive drive, teamwork, strategic organization, communication through telecommunication tools of the CoD ecosystem	time, freedom, and resources to learn – the crux of user design culture	add and achieve in community goals
Project 2: Virtual science Labs			
What is the state of virtual science labs in cyber charter schools from the student and teacher perspectives?	Virtual science labs used in hybrid or cyber charter schools allow very little room for interpretation or ownership of the content. Often assigned terms like hands-on or interactive without asking the students and instructor how they perceive the virtual labs. From the learning design perspective, some virtual labs (PheT) were better than others at giving over ownership of the content and empowering teachers to create their own lesson plans. Others required more of a standard template for all use cases	Conjecture 1: Within any life space, a variety of ideational resources (e.g., ongoing activities of other people, conversations, books, computer programs, projects, or assignments) can spark and sustain interest in learning	The distinctions in the virtual science labs were between learners that were completed entirely online and those that used at-home kits or readily available materials Organizing systems of virtual labs for online learning required supplementation of virtual labs where content was lacking, and alignment with the overall curriculum (did not always happen). The **relationships** occurred between the virtual labs and the participants completing the labs, often in isolation of any broader social learning environment **Perspectives** taken from students who viewed the labs as not interactive to teachers frustrated with the lack of autonomy of content

(*continued*)

Table 1 (continued)

Project questions	User design	Learning ecosystems	DSRP
Why do students choose to attend cyber charter schools?	Openly listening to the needs and preferences of students to know why they decided to attend a cyber charter school. School choice theoretically empowers students and their parents/ guardians more flexibility with school completion. Sought to understand from the student perspective why they made the choice they made	Conjecture 2: People not only choose but also develop and create learning opportunities for themselves once they are interested, assuming they have time, freedom, and resources to learn – the crux of user design culture	Cyber charter school enrollment is a choice made in a **complex system choice** that involves multiple identities including not only identity as student but also as citizen, child, and many others. There are no geographic boundaries, and thus schooling choices are much broader. The relationship between cyber charter school enrollment and student preference and choice did not always align. For example, some students did not feel much empowerment to make their schooling decision

from both studies through Barron's (2006) learning ecosystems frame, leading us toward ***a better understanding how users design their native learning environments***, hence empowering the agency of self-developed learning pathways. That native learning environments took place in complex and interdependent environments within sociocultural and historical habitats such as video game spaces and cyber charter schools. With an emphasis on learner experiences, we adhered to Barron's (2006) call for an ecological approach to educational change. So, Cabrera, Cabrera, and Powers (2015) DSRP model helped to clarify how the researchers thought about the complex systems and the relationships between the evolving elements.

> Next, by way of demonstrating systems thinking with a change mindset, we present Project 1 and Project 2 research designs and findings. In the following sections, we explain, in general our different study (Project), methods, findings, and themes while making clear our systems thinking (elements, processes) during the study design, data gathering, and analysis. This work is

(continued)

demonstrative of systems thinking applied by researchers. (More detail on the study conceptual frames, methods, findings, and conclusions will be available in other publications.)

Methods

Boys and Gaming Playcology Research Methods

Our first investigation utilized an integrated methodological approach combining ethnographic and phenomenological research design to draw upon the essence of the human experience, while an ethnographic design helped the participant observer collect data (Engerman, 2016; Van Manen, 1990). Specifically, a hermeneutic phenomenological design was implemented (Van Manen, 1990). Seidman's (2006) semi-structured interview process allowed us to explore historical roots and present relevance and reflective meaning-making of the phenomena including 16 purposive sampled participants, their family members, coaches, and teachers, as the researcher also captured in game play, for historical meaning, think alouds for in game processing, and reflective interviews (Seidman's (2006) for 9 months. During this investigation, data was analyzed and reported through developed themes (Braun & Clark, 2006) and an expansive learning matrix (Engeström, 2001) and drew out sociocultural and historical meanings.

The investigator was continually aware of his position as researcher, coach, and teacher as potential influential factors on the study (Rossman & Rallis, 2011). These concepts on researcher identity are fundamental, not only to the type of interpretive qualitative work under way but also to contributed to the notion of perspective taking within the DSRP framework (Cabrera et al., 2015).

Cyber Charter School Research Methods

The primary researcher in these studies previously taught in a cyber charter school and had become frustrated with the lack of innovative and student-centered teaching practices. As a result, Projects 1 and 2 were explored with the end user as a point of emphasis. The cyber charter school study explored below followed two different research approaches. The first study exploring the state of virtual science labs from the student and instructor perspective utilized phenomenography. This was supplemented by an ethnographic content analysis. The question about why students choose cyber charter schools was addressed via survey research. Purposive samples were used with all questions based on specific criteria associated with those studies. These samples were different between each study.

The design methods for the two studies in this project aligned nicely with Barron's (2004) emphasis that studying the learning ecology of students gets at the "details of learning in context" (p. 8). Many students in cyber charter schools are learning independently regardless of whether the content is designed for individual learning.

To analyze the data, the qualitative interviews employed phenomenography, the examination of virtual labs used ethnographic content analysis, and the survey research took a descriptive approach. Regardless of the research study, the end focus was always on the student experience and their perception of their experiences. The following sections will discuss the two research projects that further examine learners' indigenous habitats through learning ecosystems.

Project 1. Engage Me: Boys and Games, an Ecological Approach

Introduction

The Organization for Economic Co-operation and Development (OECD) reports international data on school performance and gender differences in academic achievement (2015), finding that adolescent boys continue to underperform academically in schools. Several scholars believe that this disengagement is due to the culture of schools negating the culture of boys and disallowing opportunities for them to engage in activities that they do best (Carr-Chellman, 2011; Lopez & Calderon, 2013; Steinkuehler, 2005). Re-engaging this lost generation of adolescent boys requires new approaches that investigate their peer cultures and new ways to approach design of learning environments.

Video games (VG) have been a staple within boy social spaces, past and present (Kafai et al, 2008). While not all boys love video gaming, for most, video game culture is a pervasive influence in their learning ecosystems, which include home, peer communities, fluency development, and distributed resources (Barron, 2004, 2006; Engerman, Mun, Yan, Carr-Chellman, 2015).

For 5 years, we investigated the interactions between adolescent boys and the commercial gaming environments to which they gravitate. Our data gathering in these studies has primarily utilized four phases of Seidman's (2006) three interview series process including focused life history, the details of the experience, and reflection on meaning (Engerman 2016; Engerman, MacAllan, & Carr-Chellman, 2014; Engerman et al., 2015; Engerman, MacAllan, & Carr-Chellman 2019). Project 1: Boys and Gaming, represents the **fourth** study of the series that represents a culmination of the previous works. The "Boys and Gaming" study was designed to investigate the lived experiences of gameplay for adolescent boys toward unpacking knowledge sharing practices in indigenous virtual communities. Ultimately, **this study discovered an ecology of play or play ecology** that illuminated the meanings and values we found from learners participating at the intersection of a boy culture and Call of Duty (CoD) virtual community. Project 1 serves as an important frame for understanding native learner-centered ecosystems of meaning-making.

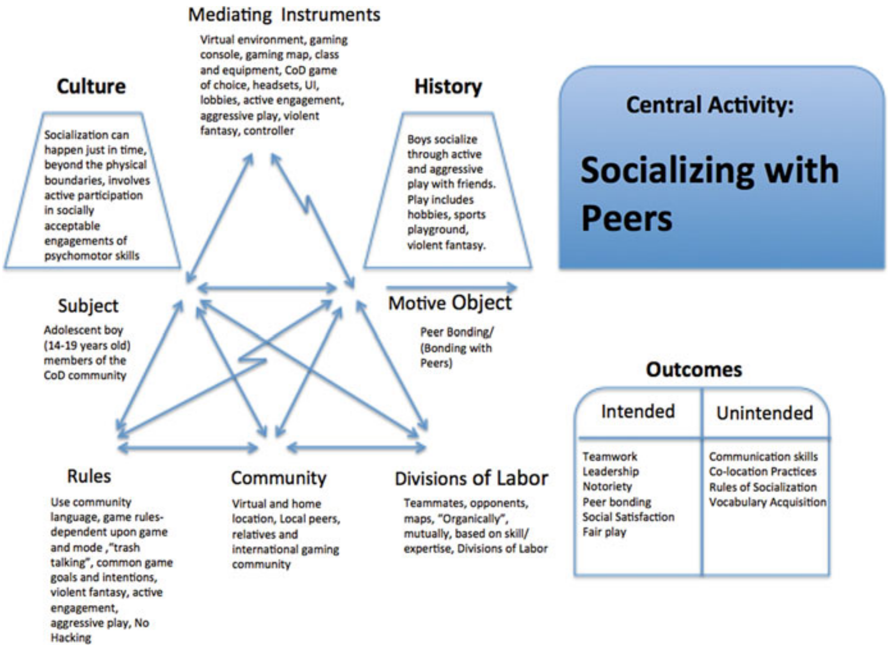

Fig. 1 Socializing with peers activity system

Findings for Project 1: The Network and Themes of a *Playcology* *(Ecosystem) Using Call of Duty (CoD)*

The main findings in terms of themes found for Project 1 were (1) adolescent boys were driven by their desire to bond with peers, (2) competitive drives were encouraged by the boys' desires to exercise power and display expertise, (3) identity formation was developed by a passion to gain agency in their self-awareness, and (4) the participants advanced leadership skills when they sought to sync with their play environments.

Through systems thinking, we realized that this network of system interactions shed light on a new concept for us – we were in fact describing an *ecology of play* (we term "**playcology**") forming about the four main themes. The playcology not only demonstrated learner meaning and values but also how social and material practices are developed within the primary permeable boundary of CoD. These researchers use DSRP (Cabrera et al., 2015) to interpret and explain the benefits of using learning ecosystem conjectures (Barrons, 2006).

Theme 1: Socializing with Peers

The first major theme that emerged from study findings is that the primary purpose for boys engaging in CoD gameplay was to build peer bonds through socializing with peers activity (see Fig. 1). As illustrated by Fig. 1, the play systems represent interrelated and dynamic living systems at snapshots in time and space. Figure 1 demonstrates Conjecture 1 that interest-driven learning activities are boundary crossing (learners form relationships across contexts, relationships, and geography) and that they are self-sustaining (Barron, 2006). During a play session with friend, for example, participant Blake learned about relationships and experienced nuanced communication styles important in his social learning system. We noticed this while Kevin was trash talking with a lobby teammate named WadeFaze. As Kevin soon found out, Kevin's language use was not a successful form of communication:

Kevin: (on the mic) I am, I was watchin the bomb dude. You know what I mean?!
Blake: the point of the game?!
Kevin: But I mean I was still watching just in case he did, so
Blake: Dude I don't know how he going to use kimbo, . . .
Kevin: (on the mic) So I mean I was still watchin the bomb though. Cuz I'm playing the mode. That's why I was watchin' the bomb. (To Blake) I hate people! (on the mic) Ima mute you. (To Blake) How do you mute somebody? (Both laugh)
Blake: This is the exact opposite of communicating. Coach Engerman is like, "what are these guys doing"….. (Blake & Kevin, Video Recorded Conversation)

Distinction determines who or what is included and who or what is not and its profound impacted at various levels in a system. Distinctions made by the participant (boy game player) in the dynamic nature of systems (Cabrera et al., 2015) contributed to the expansion of language use toward enhancing communication skills. Kevin and Wadefaze did not communicate using the same language norms, which is noticeable when Kevin acknowledged, "This is the exact opposite of communicating." Kevin recognized his defunct attempt to bond with his own teammate further by stating, "Coach Engerman is like, '*What are these guys doin*g?'" In effect, Kevin was distinguishing boundaries by characterizing ideas and things from one another within his own internal system, which was enforced by the discomfort of the external experience (Cabrera et al. 2015). The backlash Kevin received began to alter his communication style and tone later in the conversation.

Kevin: (sarcastically) Why don't you go and defuse a bomb dude instead of making fun of me dude. God you're mean.
(Blake and Kevin start laughing)
Kevin: (To Blake) Where those tags at? He's too busy making fun of me. He needs to be playing the game. (Blake & Kevin, Video Recorded Conversation)

Kevin discovered that the language used by his local peer group was not universal to the broader CoD community and needed to be modified for certain teams that are randomly chosen online. Like Kevin, all participants adapted their communications skills by exploring colocation dialogues between and among international CoD community members. As rules of communication were negotiated, the relationship between part and whole was illuminated more explicitly (Cabrera et al., 2015) as participants built closer relationships among peers.

Theme 2: Competing in Call of Duty

The participants engaged in socially acceptable forms of competition in *CoD* driven by their deep desire to exercise themes of power and dominance. Socially acceptable forms of activity were found rooted in psychomotor activity, fantasy, violence, and aggressive competition. In order to win, players used environmental factors, team dynamics, and individual skill across the various mediating artifacts such as user interfaces, headsets, specific game language, team compositions, and rules and tools of in-game and equipment. Particularly, CoD players frequently change classes or perks, choose different maps to play, and even change lobbies to gain a competitive advantage to optimize their team play. These player strategies of self-motivated learning were found to be appropriated as cultural practices and adapted autonomously by the study participants. Within a learning ecosystem, Conjecture 1 (stated earlier) suggests that within any life space, a variety of ideational resources, such as ongoing digital gaming activities with peers, can spark and sustain interest in learning (Barron, 2004, 2006). Christopher said it this way, “Once you played with the same people you kind of have a barrier. . . .If you play with them the whole entire time and you can’t really learn any more tactics, which there’s more than thousands out there” (Christopher, Interview #3). In a previous interview, a year prior, Austin elaborated Christopher’s point by saying, “I like to challenge myself because it gives me a feeling that I’ve accomplished something great on my own” (Austin, Phase II). In alignment with Barron’s (2006) Conjecture 2, players regularly sought out more information or found new learning companions through competition in the CoD lobbies.

Christopher was interested in serving in the armed forces after high school and had an intense interest in serving his country in combat. He utilized CoD as a resource to learn about weapons and strategic tactics to improve his understanding of the situations he might face in an infantry unit. He also paired up with a close friend who shared his vision of serving his country in the same way. Ideational resources found in use include digital media platforms as well as YouTube videos, magazines, and deep conversations about strategy within the various versions of CoD. Figure 2 is a screen capture of the video of Christopher’s third interview.

Illustrated in Fig. 2, Christopher went on for about 40 min speaking to the very nature of gameplay within CoD being facilitated through interest-driven learning activities. He spoke to boundary crossing through competition and self-sustaining acquired knowledge and immediate use (Barron, 2006). The boys in this study set new goals, challenged, and sought out learning companions. This aligns with Conjecture 3 while supporting Barron’s work on gendered gaming (Barron, 2004, 2006). Over his 4-year participation, Christopher, along with other participants, not only reported learning activities through in-game adaptation but also often read sources outside the game space, such as gaming books, YouTube, and discussions

Fig. 2 Christopher’s reflective interview

with friends (Observations, 2012–2016). This historical perspective revealed that the boys were self-motivated to learn and accessed a variety of resources, including online environments, gamestop, school, and supportive peer groups (Barron, 2006).

Theme 3: Identity Formation Through Playographies
The activity of *identity formation c*entered around a player’s ability to enact role-playing opportunities. However, data showed that the boys required role-playing activities within these peer groups to solidify identity forms (Erikson, 1954). Playographies help to articulate the play biographies of the adolescent participants. Playographies address a historical representation of the relationship between players and their gaming habits through self-identified meaning-making and historical relevance through player voice (Mitgutsch, 2011; Rice, 2011). Conjecture 1 (Barron, 2006) of learning ecosystems was met through the notion of playographies as the history of digital gameplay revealed that the boys repeatedly chose life spaces that contained a variety of ideational resources based on their sustained learning interests.

Blake mentioned that game players have an opportunity to be good at a skill and take pride in it, where he wouldn’t have opportunities elsewhere (Interview #3). Brad’s interview supported Blake’s statements and brought clarity to relationships by reporting:

> I feel like most people when they’re good, when they become good at something, they do not just want to stop and be good at that one thing. Most people want to be good in other things, and I feel like *Call of Duty* could be one of these things that could, like, start you in that direction; and once you are good at that, you are, like, “Oh, well if I can be good at *Call of Duty* I could be good at this other game. If I could be good at all these other games, I can

> be good at other stuff like playing a musical instrument or like math, or chemistry". I do not know, or anything. It just becomes a motivator if you use it the right way. (Brad, Interview #3)

This quote also shows direct alignment with Barrons' Conjecture 2 (2006), and given the time, the data showed that with freedom and resources within gaming spaces, the boys sought out information resources, peer learning companions, and opportunities to grow in knowledge and understanding about themselves and who they were becoming.

Theme 4: Showcasing Expertise Through the Flow State

The boys in this study constantly referred to "being in it" or, more directly, "being in *the zone*." These expressions signified the ultimate achievement of existing within the game space, especially because it led to the most success in competition. Being in the zone is more formally known as "Flow," which is described as a player's ability to be at harmony with their play environment to such an extent that their actions become instinctive (Csikszentmihalyi, 2013). According to the current study, Flow was achieved when the aforementioned activities, which represented the collective conditions, were satisfied. Flow required social connectivity through camaraderie, expertise built through aggressive competitive play, and self-awareness through autonomous role-play. Ultimately the boys needed to feel that they were recognized and praised for the skill development within their social circle of CoD players and being successful through their unique Flow state. Therefore, as a culminating event, the experience of Flow bound up all Conjectures 1–3 (Barron, 2004, 2006) within itself and allowed the players to navigate through their library of resources, at will, without barriers and based on their collection of culturally acceptable resources.

In his living room, Ben played with his father and brothers (Brad and Bryan) and gave us a verbal description of his Flow experience (see Fig. 3). Each number represents the number of kills Ben had, and the badged accolades the game communicated to him during his Flow experience.

Ben: Oh my God! That guy scared me (1)
(Brad: There's another guy over there)

Ben: Done! (2) That guy's dead too (3) [jumps away] Oh God! Grenade! (4-Avenger) [switches to scope. Scopes- switch back to assault rifle]
Grenade! Grenade right there! (5) (Ben Dies) Oh there's two guys in that, yeah, that room!
(6) Huh that guy was jumping up in the air
(Bryan: Oh man on that side. We're dead, dead, dead, dead. Oh no we're not)
[Ben throws grenade] Someone just (Ben Dies)
(Bryan: Oh man I just got filled with bullets)[Ben cloaks himself]
(7-Payback/Avenger) (8-Avenger) I see you invisible man! (9-Savior) (10-Avenger)
(Ben Dies) Wow! I just went on a crazy killing spree right there.
(11-Kingslayer/Payback)[exo jump]

Fig. 3 Ben playing with family

Ben's kill-to-death ratio (KDR) is 11:3, representing 11 kills to 3 deaths or a KD of 3.67. Considering KD of 2.0 is considered very good in the community, Ben's example shows us the quick pace, enchantment, and alluring nature of Flow can have extraordinary effects. He clearly acknowledged that something special had happened, as he said, "Wow! I just went on a crazy killing spree right there." In a conversation afterward, Ben admitted that he was "feeling it" and described Flow as the ultimate motivation of playing CoD because he felt invincible (Ben, Interview #3). In this space, we can say that the conjectures of sustained interest, developed learning opportunities, and boundary-crossing activities (Barron, 2004) were under the control of the player.

Implications of a Play Ecosystem

The results of this study highlight the sociocultural and historical meaning-making practices of gameplay experiences for both the learning designer and the learners themselves through a meaning-making ecology of play. The physical locations included the school, the home, and the football field among other sports. The boy learners were at the center of learning hubs in their system (see Fig. 4).

Barron describes learning ecologies as the sets of contexts, activities, distributed material resources, relationships, and co-located physical or even virtual spaces that provide learning opportunities (2004). Likewise, the meaning-making playcology (play ecology) found within this study represents an interrelated set of activities within the boy-centered communities both physical and virtual but particularly around the primary permeable boundary of CoD video game play. Based on a player's sociocultural learning ecosystem, Engerman (2016) defines a playcology as an ecology of play, that is, (a) driven by the players' desire to control their Flow states (Csikszentmihalyi, 2013), (b) socioculturally and historically bound by human

Fig. 4 Boy learning ecosystem

activity, (c) pervasive with overlapping and complex systems but clearly defined primary permeable boundaries, and (d) promotes metacognitive processes directed at developing self-awareness. Based on a player group's playography, and their learning ecosystem, a playcology is a source of illumination for the learner as well as the learning designer (Engerman, 2016). The playcology represents the spaces and places in a learning ecosystem that demonstrates the deepest footprint. A visual representation of a playcology can be seen below (see Fig. 5).

The boy participants were free to play (Huizinga, 1949) and explore their own identities in peer-supported communities at the edge of the boundaries of friendship/bonding/game experiences, expanding opportunities and boundaries for learning (Barron, 2006). For designers that seek a user design approach, we see potential for meaningful learner-centered environments that seek social and cultural change for end users by investing in playcologies that reflect indigenous learning ecosystems. Next we will explore the perceptions of educators and students about virtual science labs within cyber charter schools.

Project 2. Virtual Science Labs in Cyber Charter Schools: An Engaging Inquiry

Introduction

Cyber charter schools represent one option for parents in the school choice movement away from traditional public education. In the United States, a cyber charter school is a public charter school that can enroll students across a state regardless of geographic location. The predominant curricular delivery model in these schools is via asynchronous or synchronous online instruction. In 2015, there were estimated to be 275,000 full-time cyber charter school students across the United States taking 3,300,000 courses (Inacol, 2015).

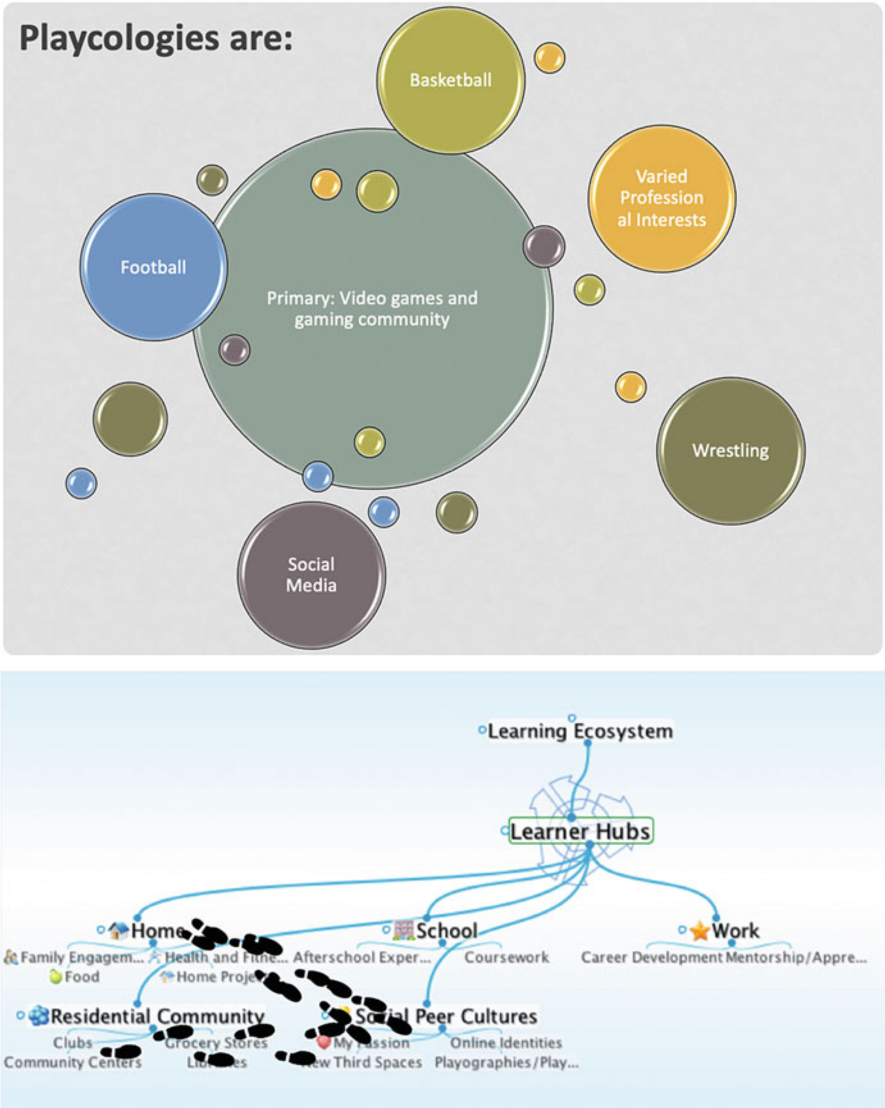

Fig. 5 CoD playcology

Barron (2004) states that "internet technologies offer students new possibilities for expression of creative agency and the ability to form new communicative and learning contexts" (p. 5). The promise of cyber charter schools is that students have more ownership and can personalize their learning pathway. This, theoretically, engages students in their education and promotes *Conjecture 2: People not only choose, but also develop and create, learning opportunities for themselves once they are interested,* assuming they have time, freedom, and resources to learn. Students in cyber charter schools have internet resources at their fingertips and a flexible schedule for completing their schoolwork. The potential for user design engagement is significant at cyber charter schools. However, as will be demonstrated throughout this research, the learning environment was not structured to support learner empowerment as user design suggests.

Included here is research on why students choose cyber charter schools, potential engagement from the virtual science labs, and teachers' experiences delivering the labs. From a systems approach, these experiences matter, but they are outside of the plane of analysis for this study. The learning ecology, as defined by Barron (2006), for students in cyber charter schools consists of their virtual school and their experience with it. When analyzing student choice and empowerment, the constraints a system places on student choice and indigenous knowledge are highlighted as findings throughout these studies in stark contrast to user design and its impact on student engagement.

Findings for **Project 2**. The thematic findings **for Project 2** were (1) student preference for physical over virtual labs, (2) boundaries defined between physical and virtual labs, (3) learning advantages of virtual labs, and (4) artificial constraints on the students' learning environment. These findings originated in the phenomenographic research with students (Study 2) and were confirmed by the ethnographic content analysis of the virtual science labs (Study 2).

Theme 1: Student Preference for Physical Over Virtual Labs

Students preferred physical labs over virtual labs in general, but one student was able to pick up on an advantage of the virtual labs as it provided multiple opportunities to complete the lab. Cyber charter school students are in a unique learning environment that is not the typical environment used in research studies around virtual science labs and learner selection.

Barron's (2004) learning ecosystem affords a connection between a systemic perspective and the learner's ecosystem. The learning ecosystem defined the boundaries and relationships within their meaning-making environment. The boundaries included the laboratory assignment and the student. Parents might have been home while the students were completing the labs and could have served as a valuable discussion partner, but the learning ecosystem defined the communication practices of the virtual labs as not involving parents. Barron's (2004) second learning conjecture, pointed to the freedom and resources to learn, was connected to the students' perspective that the lab restricts their available resources.

All four of the students had a general preference for physical labs over virtual labs. Samantha and Cole found that the interactions they completed in the virtual lab were not synonymous with the way they felt while interacting with a physical lab;

Researcher: So how are these labs similar to the hands-on labs you have done and how would you say they are different?

Samantha: One is real-life stuff and one is on the computer.

Researcher: Why would you say the one on the computer is not real-life stuff and Cole, how would you say these virtual labs are similar to the hands-on labs you did before?

Samantha:	Cuz its all like non touchable.
Researcher:	Okay, so do you think it loses some of the meaning because it is all virtual?
Samantha:	Yes
Cole:	You can interact with the labs, but you can't with the vitual labs.
Researcher:	So why would you say you can't interact with the virtual labs?
Samantha:	Cuz u cant get hands on with the stuff on the computer (AdobeConnect Room, 2013-04-16).

The students did not prefer completing virtual labs because they did not consider these labs to be hands-on, and the data showed that labs did not foster understanding or make a strong cognitive presence for the students, yet that students were in an environment that was rife with possibility for creating with technology and using imaging tools (Barron, 2004). However, students were left disengaged due to their experience with the virtual labs that lacked end user design. This contradicts earlier findings that the medium of instruction does not impact learning of the content (Pyatt & Sims, 2011). If the student voice was considered from the beginning of the curriculum design or virtual lab selection, then these findings of disengagement might have been lessened.

We found that students did not have a choice in their curriculum and learning pathway, as user design would denote. Barron (2004) notes in the first conjecture that ideational resources can spark learning. Students were being told what to do and did not have an option to choose different learning pathways or take ownership of their learning. The lab culture did not align with a culture of student-driven learning. Limitations of the virtual lab software to empower students were observed in the ethnographic content analysis. It is acknowledged that many user design efforts have failed in the past because it is complex to engage users in all aspects of the design (Carr, 1997).

However, this limitation affected more than the learners in the learning system – teachers were impacted too. In the following quote from data offered by a teacher from cyber charter School A, it was evident that teachers did not feel empowered either. This quote was telling because it demonstrated the complexity of the constraints placed on students in their learning environment. The curriculum was not user-driven for any of the stakeholders within the school.

Cyber Charter School A Teacher:	I cannot change the actual document the way that they have to do it... I can’t change things in the software program that is the way it is. That is something that we want to have more autonomy with because we are not fans with a lot of these things as teachers because we don’t have a say in it.

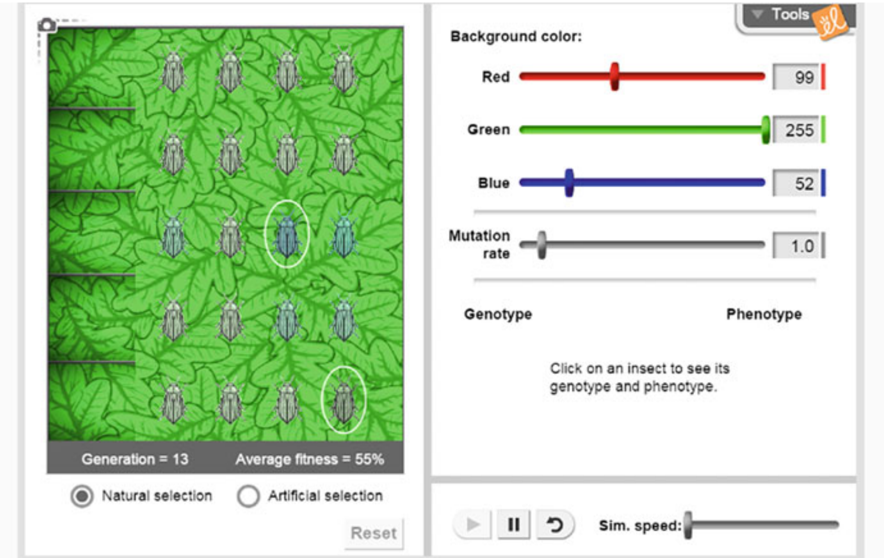

Fig. 6 Virtual lab simulation on evolution

Of the 20 labs studied, only 1 allowed students to form their own research questions, 17 controlled the confounding variables for the students, and 10 gave students a level of control. The labs that gave students a sense of control had a range of scaffolded presence. Some labs gave students feedback on their responses, while others simply had a box for students to mark as complete to move onto the next section of the lab. These design features reduced choice for students and gave them little control over what was going to happen in the experiment.

Figure 6 is an example of a lab that did give students choice and empowered them to make their own decisions regarding variables. The students were exploring mutation rates in this lab. They had the option to change the type of selection and what the background color was. Their relationship with the lab was constrained by the capabilities of the software.

Theme 2: Boundaries Defined Between Physical and Virtual Labs

Our findings strongly indicate that the system in which these students were placed seemed to limit their learning potential. So thinking about system boundaries in learning design matters. As can be seen in the following conversation with Emily, she felt as if she did not understand the material as well in a virtual lab as she would in a physical lab. The students didn't believe that the labs fostered their understanding of the science concepts.

Researcher: So that is the one you did not like?
Emily: Yes.

Researcher: Why not?
Emily: I hated them because they are so hard to learn and just do in a lab on the computer.
Researcher: Okay, do you think doing the lab virtually lost some of the understanding?
Emily: Yes, because I am actually a hands-on person.

Students made a *distinction* (Cabrera, 2006) between virtual labs and hands-on or interactive labs. If a lab was completed virtually, it was not interactive or hands on. The other parts of DSRP needed to be addressed at the same time that boundary making was occurring to consider the entire system of students completing virtual labs. Anna made the following statement to reaffirm this distinction boundary between virtual labs and hands-on labs.

Anna: Probably the one with the bacteria slides because I've done a hands-on lab which I felt was more exciting to see the real images under a real microscope.

Students felt most connected to the labs when they activated prior knowledge and connected relevance to the lab tasks. There were five labs that asked about prior knowledge and nine labs with authentic activities throughout. A prior knowledge prompt was observed in the genetics lab pictured above in Fig. 6. After students completed the lab simulation, they were prompted to apply artificial selection to dog breeds they are familiar with.

Theme 3: Learning Advantages of Virtual Lab
Some of the students in the study were more able to discern the learning advantages from having access to a virtual lab than compared to a physical lab.

Students learn better when they have multiple opportunities to engage with material (NRC, 2000). In this case, the virtual labs were available to students at any point in the curriculum. Therefore, unlike a physical lab, they could refresh their understanding by going back to the lab and practicing with the content. This is a perspective that emerged from the findings and so could be utilized in a user design approach where this student's approach to reviewing the labs could be scaffolded and prompted for in the design of the labs. Soloway et al. (1994) make astute observations even back then about the necessity for software to support individual learner needs. This includes needs like their diversity of background and experiences as well as motivation.

Theme 4: Artificial Constraints on the Students' Learning Environment
In face-to-face sessions, the communication among peers and between teacher and peers is an integral part of the system (Raish, 2016). Encouraging communications supports students' articulation of their experience and fosters a sense of community

among the students. In a manner consistent with DSRP (Cabrera et al., 2015), this communication is connected by the *relationships* that are built while students work on a virtual lab and the perspectives that will be taken by students while they are engaged in the class. When students in cyber charter schools complete virtual labs in the context studied, their spontaneous scaffolded communication simply could not occur. There were physical and electronic boundaries that prevented this communication, creating boundaries within the learning ecosystem. We found that the students were completing the virtual labs in isolation form their peers and that they had asynchronous, delayed communication as their primary interaction method. Teachers could not see or know when students needed assistance.

For example, data throughout the study describes students that completed the virtual labs by themselves and without the assistance of expert guides. In this system, students' entire communication occurred with a predesigned virtual lab. Where and when students in a face-to-face class can have teachers interject and build understanding around an aspect of the lab, it was found that the same learning ecosystem does not exist for students in cyber charter schools. Therefore, a huge part of charter school participants system of learning was shaped by the engagements they had with the virtual lab. Three of the labs provided scaffolds for students communicating their findings and understandings in the virtual labs. One of the cyber charter schools had a teacher who facilitated discussions. However, w**e found that the relations between peers, instructors, and learning objects were defined by the structure and sequence of virtual labs within the overall curriculum**. Of the 20 labs studied, five had metacognitive scaffolds built-in for students to respond and six had reflection scaffolds.

The following quotes from Cole and Samantha show how they communicated and searched for information when completing the virtual labs:

Researcher:	How would you say you communicate while doing the labs?
Cole:	We just do them, that's it.
Researcher:	What do you consider Googling for answers?
Samantha:	That depends on the question.
Researcher:	So if you have a question, how do you get it answered?
Samantha:	Google.
Cole:	Figured it out on your own or Googled it.

The above quotes provide a lot of insight into the engagement potential this learning design afforded from empowering students. Learners' relationships with the lab included all of the information at their fingertips, yet the student default was to use search queries that were comfortable in other settings. This was because the curriculum and virtual labs were not designed in a way to either scaffold students to a new search strategy or to bring in natural search queries that students would use as they worked by themselves on their curriculum.

Cyber charter schools expect parents or guardians to be active partners in the student's education (Huerta & Gonzalez, 2005). This unexplored assumption proved a barrier in the completion of the virtual labs. From the perspective of the teacher this was problematic, because teachers felt that they could not ask parents to help with a lab. A difference was unearthed between the *relationships* presumed to occur between a top-down policy and what happened in reality. Policy assumes that parents or guardians would be present to help the students with their work (Huerta & d'Entremont, & Gonazalez, 2006). Reality showed that parents were rarely involved in the child's work. There is a disconnect between expected culture and actual culture that affects the social, cognitive, and scaffolded presence for students.

Cyber Charter School E Teacher:	I think a lot of the courses that we deal with are almost afraid to ask that to happen, because very often there is nobody there that is going to help them.
Cyber Charter School D Teacher:	I really haven't found a good way. Either a parent is going to be involved or not going to be involved, and maybe it is just the type of student I am dealing with, but they are not involved, period.

From our findings, **it was clear that students took it upon themselves to find out what they thought they needed to know to successfully complete the lab.** Cabrera's et al. (2008) model shows that from the student perspective, the system included the Internet, and students viewed this resource as an essential part of their lab experience. However, the school administrators separated the larger internet from the student's learning management system by limiting permissions that prevented such student empowerment. The students were in a connected environment for every aspect of their schooling. However, the broader system not only prevented maximal use of their environment through students design, and it also limited their ability to take ownership of their learning. Oftentimes, the school had placed limits that blocked students' ability to successfully complete the labs.

Researcher:	Do you ever get blocked from sites you are trying to look at?
Emily:	Yes.
Researcher:	Because it says it is a game?
Emily:	All the time, I hate it.
Researcher:	Yeah, . . . do you think that frustrates and delays your learning?
Emily:	Yeah, it really does.

As we have explored the perspective of a thinker (learners too) in a system matters. The perspective of these students sharply contrasted the perspective of the school and the top-down instructional design decisions made for virtual lab. For example, the school wanted to block distracting or potentially controversial websites. In the cyber charter schools studied here, it was found that many learners were provided with a computer and a stipend for their internet use and yet schools could (and did) exercise their authority to limit what websites the students could visit. From the perspective of the school as a system, the administration of charter schools were, by policy, preventing students from engaging in non-school activities on a school machine and were helping to focus them on the course content. This emerged as a significant issue for students completing their labs online, often in isolation or outside the learning system, learning designers would have thought they were creating. Building in rich learning experiences requires thinking of the learner who would be completing these virtual labs on their own. Is there appropriate scaffolding? Are students supported in their own self-discovery? Are the labs accessible to students regardless of their needs? It takes longer to design with these considerations in mind as user design admits (Carr-Chellman & Savoy, 2004), but this systems thinking improves the learner experience for everyone.

Furthermore, this more coercive learning model also moved away from a user-designed solution (Cabrera, 2006), which would be much more likely to enhance a culture of learner engagement. Cabrera et al. (2008) stresses that all perspectives need to be considered in the system with regard to their relationships and distinguishers. There was no boundary for the students between their virtual lab and Google. For the school, there was a clear distinction between the two, and this could also have contributed to the same disengagement that boys feel when they experience a rejection of their culture within brick and mortar school experiences (Yan, Mun, Engerman, & Carr-Chellman, 2017).

Summary of Themes from Research Projects 1 and 2

Project 1. A Playcology Emerged. The first project revealed four themes that shed light on why and how boys perceived their online gaming experiences and the social meaning and values of those practices. These included (1) social peer bonding, (2) competing in CoD, (3) learner identity formation through playcologies, and (4) showcasing expertise through Flow states.

Socializing with peers activity provided learners with opportunities to build tighter bonds in their active communities and learn new methods of bonding. The participants were able to broaden social boundaries and perspectives. By competing in *CoD*, the boys were freely able to engage in activities that were native to their deep desires to engage in themes of power and dominance, violent fantasy, and aggressive play. *CoD* further provide an environment where boy participants could test, assess, and retest values and beliefs within socially supportive peer psychomotor activities. Identity formation is traditionally formed in isolated peer-group activities in accordance with their adolescent development stages through role-play and exploration (Erikson, 1954; Woolfolk, 2011). As a result of gameplay, we found that both Brad and Blake demonstrated that they were evolving into deeper metacognitive and self-conscious decisions about identity through distinctions of identity and other and perspective taking of (Cabrera, 2006). This metacognitive event, along with organizing systems of parts and wholes as well as relationshipsof action and reactions, gave players a unique personal understanding of their capabilities that became fully realized in a state of Flow. Players were able to draw from their acquired talents on command with uninterrupted access and precision and therefore showcased their talents to their social peer community.

This research discovered four primary themes and crafted a cohesive meaning-making ecosystem about the study, a play ecosystem concept. The combination of the themes and learning ecosystem as a function of play was termed a ***playcology***. The playcology represented the most interactive and engaging elements within the players learning ecosystem of both physical and virtual communities, thus forming a powerful network of sociocultural knowledge sharing in a learning system.

Project 2. A Need for Systems Thinking in Virtual Lab Design. Our second project researched students completing virtual science labs in a learning environment that has not previously been studied. Cyber charter school students have unique needs in their learning. From a systems thinking perspective, we find that these students are indeed learning in an environment that has the *potential* to give them significant control over their learning. They have flexibility over when, where, and how they complete their schoolwork. This is the case for the virtual labs assigned online. However, there is a disconnect between the rhetoric of what cyber charter schools could theoretically offer to students in a student-centered learning environment and the reality or practice of the learning environment designs that are actually implemented. In practice, the indigenous knowledge of students in these schools is not recognized as an asset, so little user design is at play (Carr-Chellman & Savoy, 2004). Students are told which labs to complete and how to complete them. Most of these virtual labs deliver content knowledge but do a poor job of engaging students with science practices or crosscutting concepts according to the Next Generation Science Standards. In addition, students do not feel like the interactive components with strong relationships within these virtual labs that should feel hands-on. Due to the limitations in the software design, instruction is often not scaffolded to the student ability and students do not have a voice in how or what they are learning. Baek, Cagiltay, and Frick (2008) specify two groups impacted by the affordances of technology: primary users and stakeholders. To hand over, this control requires a lot of intentional planning on the part of the designer and instructor.

The labs in this study that had the highest degree of learner empowerment featured ill-structured problem solving, multiple variables, student written research questions, and self-directed learning. From these findings, we recommend a balance between meeting specified learning objectives, providing necessary instructional support, and empowering learners to take ownership of their learning. **Project 2 is a good example that learning environment/system designers must consider more the entire system of learning when designing virtual simulations** to create experiences where students have control and yet can be guided with appropriate learning scaffolds and feedback mechanisms. Such a systems and user design approach allows designers, learners, and teachers to consider the assets and interests that students are bringing into the classroom and are more in line with a user design frame, taking steps toward the more indigenous knowledge spaces of boys playing video games in the informal learning environment.

Prioritizing Indigenous Domains with User Design

User design is an open approach to learner-centered structure systems of instructional design that is centered within indigenous knowledge centers. However, learner values and perceptions can vary greatly especially when considering their learning pathways. These learning systems can become incredibly interrelated and complex as these two studies suggest especially for the twenty-first-century virtual landscapes as seen in our described learning studies. For analysis, both Project 1 and 2 research studies required unpacking systems of "parts to the whole" by articulating elements and processes through divisions of labor, digital and physical tool use, content analysis, and rules within the online community (Altheide & Schneider, 2013; Cabrera et al., 2015; Engeström, 1987). Both Projects also found *participants (learners) that were* c*onstantly evolving while changing digital tool*s (console systems and games), language tools, online and offline peer groups, as well as their desires and reasons for engagement). Considering the complexity of open design in user design instructional systems, the ***playcology*** gave some conceptual and design structure to designers and also revealed the social functionality and potential importance of virtual learning communities for building peer relationships, exercising power, developing agency in self-awareness, and for syncing learning within a highly engaging indigenous learning environment of play. The primary principles of a playcology allowed us to identify the specific *context* under which our studies could evolve as we unpacked learning ecosystems. Next, we seek to conceptualize user design through the findings, in particular its relationship to playcology, and the impact of learning ecosystems through systems thinking frame of DSRP (Cabrera, 2006; Cabrera et al., 2015).

Indigenous knowledge, as we've discussed earlier is not referring to the colloquial use of the term, but rather the more expansive understanding of the knowledge resident within a given learner culture. To pursue user design using systems thinking is to begin to deny that power and expertise lie solely in the hands of the instructional designer and educators, the public who insist on high levels of testing accountability, or the policy-makers who pass legislative unfunded mandates to limit a curriculum to a coercive positionality (Carr-Chellman & Savoy, 2004). Pursuing user design approaches instead allows for expertise and decision-making to be actualized through the learner (Carr-Chellman, 2007; Carr-Chellman & Savoy, 2004).

DSRP and Playcology

The DSRP model helped to inform our positions on the relationships between user design and the impact that learning ecosystems can have. An ecological approach helps understand sociocultural impacts and decision-making patterns within an indigenous environment. In addition, identifying learning ecosystems can prove useful to user design as they help the learners further understand themselves through reflective learning practices. Boundary-crossing activities were driven by their own sociocultural interests (Barron, 2004, 2006). The playcology revealed sustained interests based on a variety of resources as players utilized a variety of mediating artifacts to enhance their performance. Meaning-making opportunities emerged, driven by competitive activity within indigenous domains.

Playcologies acknowledge sociocultural and historical systems of human activity. Parts to wholes are implied, as these complex *systems* are further distinguished through primary permeable boundaries. For the boys and gaming study, the network was viewed as a holistic system of activity spaces within the learners' learning ecosystem. As for the cyber charter school study organizing systems of virtual labs for online learning required supplementation of virtual labs where content was lacking and alignment with the overall curriculum (did not always happen).

Both studies demonstrated *distinctions* of things and the other. In the cyber charter, students were able to make clear distinctions between the boundaries of physical labs and virtual labs. The playcology expanded these distinctions further as it relied on the systemic construct of *distinctions* (Cabrera et al., 2015) within not only tools and rules of language use but the primary permeable boundary of their gaming community. The learners drew from their lived experiences to articulate the meaning-making practices within their nuanced gaming space of Call of Duty and its *distinctions*. Distinguishing thoughts from feelings is imperative for developing emotional intelligence (Cabrera et al., 2015). In fact, some scholars would suggest that physical play can enhance emotion-regulation and emotion-encoding skills (Cabrera et al., 2015) while also improving communication skills to attain desired outcomes.

Cabrera (2006) speaks to the dynamic complexity of the minimal concept theory which cross-references the interrelationships between the foundational elements of the DSRP model. Between *relationships* and *distinctions*, he mentions that it is "A relationship is a distinction between the causes of one object and the effects on another" (Cabrera, 2006, p. 179). The playcology demonstrated a primary permeable boundary of virtual game play as the primary location for the indigenous knowledge to be investigated. Within these complex systems, we see distinctions between things and ideas within the lived experiences were necessary (Cabrera et al., 2015) and were made for both studies. Relationships were negotiated between both local and online community members of actions and reactions. These relate to organization systems by organizing related parts to their wholes and creating nested relationships with wholes as parts within still larger wholes. So the *relationship* of systems, being parts to wholes, was articulated through mediating artifacts share time, space, identity formation through self-awareness, and attributes in relation to the central activity (Cabrera et al., 2015; Engerman, 2016).

The perspective and context of learner experience need to be considered in the literature. Context matters in online learning (Lowenthal, Wilson, & Parrish, 2009). *Perspective* taking can lead us to examining our own beliefs in critical ways. Perspective taking builds our awareness of the *perspectives* we take and do not and therefore build upon *distinction* (Cabera et al., 2015). In a playcology, Flow states are primary drivers of the human activity throughout the learning ecosystem. Because the Flow state is so immersive, instinctual, and a prime motivating factor of game play, perspective taking was enhanced through the Flow state. In the current study, Flow culminated an ultimate view of *perspective* with the boy participants owning their points of view toward mastery.

The learning environment should foster networked learning through collective application of *perspectives* subject view and viewed object, *relationship* of action, and reactions and *distinction* between things/ideas and other within organized systems of parts to wholes (Cabrera, 2006).

User design embraces investigation tactics that illuminate student voice and amplify its affect. The playcology reviewed perspective taking between learners and especially through multivoicedness, which established that the perspective used to describe the narrative impacted the very nature of the narrative itself (Engerman, 2016). By choosing any other member of the engagement, we acknowledged that the perspective and narrative could have changed within the learning system (Cabrera et al., 2015). This was seen more clearly through the structure of a playcology as its results emphasized perspectives of user design through self-sustaining meaning-making environments within their own digital communities.

Beyond Indigenous Knowledge Domains

Outside of the use of a playcology, students in online learning environments like cyber charters may not see their indigenous knowledge or natural interests valued. As illustrated in Project 2, student perceptions of their choices and engagement with the learning experience are considered differently than how it has been discussed in literature. The learning environment was not designed with the end user in mind. Despite, cyber charter schools having the freedom to be innovative in their curriculum and are under fewer constraints than a traditional brick-and-mortar school. The students in this study were blocked in their learning ecosystem by design decisions made without their involvement.

For students in cyber charter schools, systems of parts to wholes were viewed with the virtual lab was considered in the whole of the science curriculum. The relationships prescribed for the students in the labs did not connect with the actual relationships they had when completing their work. Their relationship was limited to themselves and the lab software, with artificial boundaries and the reality of their home situation affecting other relationships. The perspective taken throughout the cyber charter school studies was that of the student. This happened both directly and indirectly: directly through student interviews and indirectly through completion of the virtual labs from a student perspective to identify potential markers of engagement and interviews with teachers to contextualize how students complete their labs. The student perspective and the resultant findings could have changed if any other stakeholder or activity within the system was selected to be a focus. Bringing students into the design of the labs can bring an alternative perspective as to whether the virtual labs are sufficient for meeting learning goals or whether other types of activities are necessary to create a holistic system of learning that values the students' ecosystem.

Practitioners should consider the implications of this for the engagement of learners. There needs to be a balance in the formal learning environment because the system does place external requirements on the content that needs to be covered with learners. How can the learner ecosystem be structured to empower indigenous knowledge while covering necessary information? What was particularly lacking from a learning ecosystem perspective was the lack of time, freedom, and resources to learn in Conjecture 2 and that there are no interest-driven learning activities from Conjecture 3. When thinking about DSRP, what is the perspective of the learner and how is the cyber charter school environment limiting it? (Cabrera, 2006) Are the distinctions, systems, relationships, and perspectives perpetuated through cyber charter schools in conflict with what students expected when they chose this type of learning environment? The practitioner should read this project as studies of limitations in the learner's indigenous culture.

Improving Indigenous Engagements

When we consider improving the academic engagement experiences of students, professionals need to also consider traditional social power structures. Research approaches that focus on learner centeredness could benefit from including learning ecosystems that emphasize a playcology encouraging the learner voice through authentic user design. User design requires an authentic respect for learner interests and indigenous knowledge (Carr-Chellman, 2007; Carr-Chellman & Savoy, 2004). Playcologies have shown to pervade learning ecosystems within the primary permeable boundary of engaging virtual communities of online video games and as a result warrant further investigation. The voices of these learners enlightened us to valuable indigenous knowledge within their own social spaces. Further, these findings support current game-based learning theories that would suggest commercial online virtual communities can provide enhanced learning opportunities (Engerman, 2016; Gee, 2007; Shaffer et al., 2005).

The two cyber charter studies in particular did demonstrate the importance of student voice in science education through virtual simulations. Prior research in science education has shown that there was no preference when students completed a virtual lab or a hands-on lab (Klahr, Triona & Williams, 2006; Pyatt & Sims, 2011). There were little to no previous research that had empowered students to create their own learning experiences with virtual science labs or other experimental settings completely. Considering the student perspectives here, the studies presented showed that students did not actually perceive their virtual labs as "hands-on" and preferred physical labs they had completed in the past at their old schools. Students were not designers as user design encourages, nor were their concerns met within the instructional design process.

In line with user design (Carr-Chellman & Savoy, 2004), we need to ask if the *perspective* of the student in their environment been considered in by designers when structuring their learning environments? A researcher completing the virtual labs from the role of student noticed that the labs were not designed specifically for the

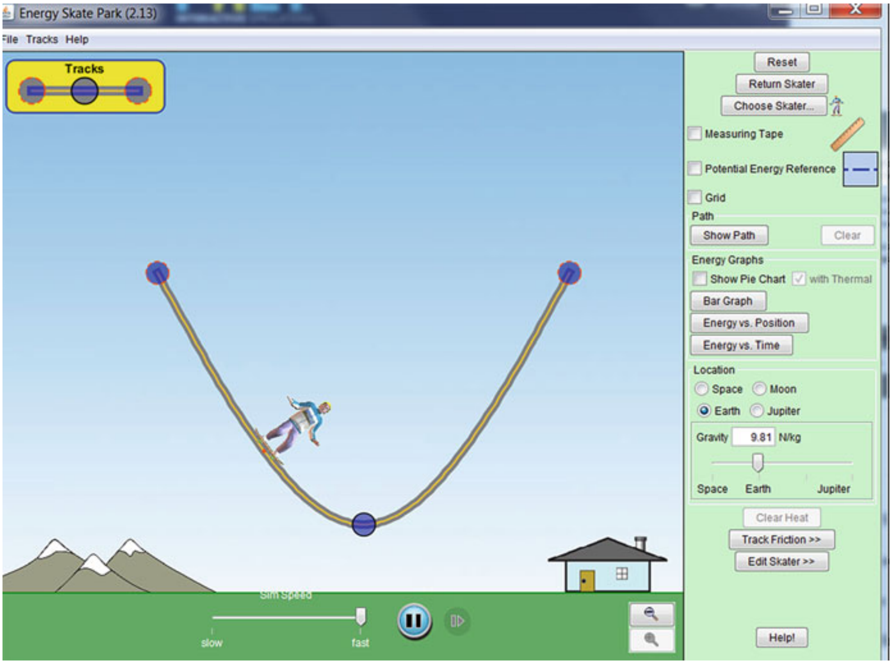

Fig. 7 Students manipulate a skateboarder to represent energy types

context these students were in. The labs expected a teacher and peers to be located in the same time and place to complete the experience of the virtual lab. The lab in Fig. 7 allowed for confounding variables to be used by the learners to manipulate the skateboarder's pathway in the simulation on energy types. This gave a significant amount of control over cause and effects as students learned about the relationships of action and reaction within the environment (Cabrera, 2006). However, there were no scaffolds or supports built for students within the lab. Without the assistance of their teacher and support of the physical classroom, these students were left to an open-ended inquiry environment without the participation of design by the end user. As a result of these thoughts, questions then emerge for designers and instructors around science teaching for students in cyber charter spaces and can be applied to education generally from a universal design perspective. These questions may include, What would students design if given the opportunity to invest in their own learning? What are the systemic boundaries that are blocking this way of engaging online students about science learning? What does the optimal science lab experience look like in the online K-12 classroom?

Playcologies can play a critical role in capturing the most engaging spaces within a learners meaning-making environment and lead to more insight for learners within the user design frame as they build their own meaning-making pathways. As Barron (2006) suggests, the procedure of capturing players' playographies examines the collective "pathways of participation and to provide an account of the kinds of events, activities and processes that spark interest in learning" (p. 200). Furthermore, learners not only chose but developed and created learning opportunities for themselves within *CoD* (Barron, 2006) based on role-playing activities. Ultimately, play ecosystem have the potential to describe metacognitive practices for the participants through distinctions of things and ideas, recognizing system parts and wholes, relationships of action and reaction, and finally perspective taking of differing points of view (Cabrera et al., 2015).

Discussion and Conclusions

In this chapter, we have unpacked experiences from the examples of boys and videogames and cyber charter science labs, with a focus on the student culture to better understand and mitigate learner disengagement. While doing this, **we made visible different systems and systems thinking processes for designers and school leaders**.

Learning designers, education system researchers, and educational researchers could benefit from these findings by recognizing the evidence we offer for accessing the many advantages of a user design systems thinking approach to change educational systems. When leveraging indigenous domains within user design, learning designers may be able to overcome systemic boundaries and obstacles that typically plague student-centered learning models. Taken together, these research studies highlight the value of indigenous knowledge constructs within learner ecosystems, toward re-engagement in traditional classroom settings. In fact, taken together, these two investigations are almost studies in contrast as we further discussed the evidence of disengaged learners as an argument for design of disruptive systemic change through learning ecosystems and system thinking.

Project 2, the gaming study of a nonformal learning setting and illustrated some of the most powerful potentials of learner *engagement* providing a new frame of ecology of play, while the traditionally bound curriculum of the online science labs illustrated the *disengagement* that coercive learning tends to foster. This playcology then forms an end user ecosystem of play that can allow the user an opportunity to recognize his or her **meaning-making ecosystem**. Through the DSRP model for systems thinking, we were able to see the interrelated applications of a systems thinking frame for a playcology within a user design approach, which recognized distinctions between identity parts and other parts, organizing systems were learners related parts to wholes, relationships that metacognitively reflect causes and effects through subjective and objective perspectives (Cabrera et al., 2015). Therefore, our work here sheds light on the position of learner-centered, user design as a systemic, theory-based approach to addressing unacceptable levels of learner disengagement for an audience of learning designers and researchers. It further gives instructional designers as well as end users a personalized learning ecosystem to own design through a playcology.

For educational researchers and learning designers, **learner-centered approaches** need to invest in student empowerment and allow native learning spaces to inform the instruction. Life spaces not only provide resources that spark sustained interest but also enable engaged learners to both develop and create learning opportunities and leverage sustainable interdisciplinary skills development (Barron, 2006). Particularly the **playcology** shaped the basis of the learning ecosystem through a CoD learning network. The online virtual CoD community seemed to provide an environment that encouraged peer bonding, collaborative play through aggressive competition, engagement in autonomous forms of metacognitive self-evaluation, and increased Flow-seeking activities. These features, as determined by the boy participants, seemed to be critical for engagement and highly preferred environments that shape meaning-making through knowledge sharing activities.

Traditional schools rarely allow boys to engage in activities that encourage peer bonding or emulate the ways in which boy peers interact normally and naturally (Yan et al., 2017). The environments that **engage** boys are located within athletic spaces such as football, wrestling, basketball, and others, and these help shape boys' most meaningful connections to school (Engerman, 2016). Within the mainstream educational system, however, academics and athletics are often perceived as mutually exclusive, and athletics have historically been viewed as "less than" when compared to academics. As for cyber charters, neglecting student engagement centers leaves students feeling isolated and unable to successfully complete online learning labs.

Investing in **student centeredness** in cyber charter schools would mean understanding the environment in which these students are completing their schoolwork and capitalizing on opportunities for user design. Students are in a networked learning environment in which access to information and expertise could be at their fingertips but is currently limited through technology blocks. The way the labs were structured did not foster an environment in which students could learn in naturally engaged ways (Raish, 2016). By naturally engaged, we mean activities that fit into the students' preferred activities, such as hands-on activities, and utilizing the Internet to learn when needed. For boys, their naturally engaged playcology centered the native digital online community that formed around the video game Call of Duty. Alternatively, using canned virtual labs that did not value the learning environment or context of the student, decreased ownership over learning and thus student engagement (Raish, 2016). Understanding the culture of the students within learning ecosystems and under the guise of user design learning designers and educators may uncover untold dividends for understanding why students prefer physical labs over virtual labs and how the boundaries can shift to empower students.

We've actualized the position of learner-centered user design as a potential system theory-based approach to reducing high levels of learner disengagement. Giving students' control of a curriculum and the decisions about what they should learn through a user design approach is very foreign to most expert educators. There is much more comfort with policies that nail down a common curriculum, even though educators may object to parts of the curriculum, or to the overly restrictive nature of the curriculum standards. In addition, expert educators may understand that over-testing is contributing to increased alienation and dissatisfaction among students, teachers, parents, and the general public. To address these concerns, systemic change becomes essential as an antidote. Here, in these two cases, we see two excellent examples of why it may be necessary to engage learners in their own learning decision-making. We come to an understanding of why engagement "works" in the case of gaming and doesn't "work" in the case of cyber charter science labs. These foundations offer excellent illustrations into the lived experiences of learners who are in coercive and noncoercive learning ecologies.

For **an audience of learning designers and educator**s, the contrasts between Project 1 and Project 2 research provides researchers and designers an important opportunity to re-examine the essential nature and need for systemic change in our schools by using and by knowing systems thinking.

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