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The Construction of Systems Thinking Pedagogy During a Professional Development Institute

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THE CONSTRUCTION OF SYSTEMS THINKING PEDAGOGY DURING A PROFESSIONAL DEVELOPMENT INSTITUTE

by

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Preface

The defended dissertation includes manuscripts for two journal submissions. The first journal submission is an empirical research article; the research purpose was to explore how participants privileged certain language and ways of knowing during a professional development institute on systems thinking pedagogy construction. This empirical article has been submitted to the *Journal of Language and Literacy Education*. It includes chapters one through five in the table of contents.

The second journal submission is a practitioner article; the purpose of this article is an in-depth explanation of the systems mapping process as designed and used by the participants in the empirical article. This practitioner article has been submitted to *Childhood Education*. It is included as chapter 6 in the table of contents. This article is referenced in the findings section of the empirical article (p. 20), as it is an extended explanation for practitioners of one of the sub-findings. Thus, the introduction and the conclusion of the empirical article serve as the introduction and conclusion to the dissertation as a whole.

Both journals use APA guidelines; thus, the dissertation is presented in APA format.

Abstract

The prevalence of systems thinking is growing in classrooms because of its inclusion in the Next Generation Science Standards and its potential as a tool for addressing complex, global problems (Capra & Luisi, 2014). While most of the research on systems thinking pedagogy targets the ways students develop system thinking skills (Cabrera & Cabrera, 2015; Curwen, Ardell, MacGillivray, & Lambert, 2018), this study explores teachers' construction of systems thinking as a pedagogy. Using social constructionism, discourse analysis, and systems theory, I conducted an exploratory case study to analyze how teachers privileged certain language and ways of knowing during a professional development institute on systems thinking. I found that the teachers considered systems thinking as a catalyst for shifting their thinking, curriculum, and classroom dynamics, including how they understood their roles as teachers, their instructional goals, how they could both personalize and deepen their curriculum, and the ways they could connect their classrooms to the community and the environment. Imperative to this shift was the implementation of systems mapping as the central activity of the pedagogy. Their model of systems thinking pedagogy respected both teachers and students as capable academics; additionally, it privileged a professional development culture of "becoming" in which the power of the collective was a point of leverage for teachers to disrupt what can be perceived as low expectations for their students and themselves as professionals.

Table of Contents

List of Figures

The Construction of Systems Thinking Pedagogy During a Professional Development Institute

> "I can be dropped in any grade, any subject, and [systems thinking] is gonna be there for me in a way that…other tools and PD's [haven't been]. This one really feels like, like kind of Mary Poppins! Like I got my bag!"
>
> —Zia, elementary teacher, new to systems thinking

The integration of systems thinking into education is on the rise, especially after its inclusion in the Next Generation Science Standards (NGSS Lead States, 2013). Additionally, researchers (Checkland, 1981; Curwen, Ardell, MacGillivray, & Lambert, 2018), scientists (Capra & Luisi, 2014), and theorists (Cabrera & Cabrera, 2015; Senge et al., 2000) argue that systems thinking abilities are necessary for addressing the complex problems the world faces—and will continue to face—in an ever-more-integrated world.

Capra and Luisi (2014) describe systems thinking as a conceptual framework that integrates four dimensions of life: biological, cognitive, social, and ecological. Systems thinking is an inherently transdisciplinary view of life that centers on relationships, patterns, connectedness, and context (Davis, Sumara, & Luce-Kapler, 2015). It is prevalent in sciences such as biology and ecology (Capra & Luisi, 2014; Maturana & Varela, 1987), engineering (Checkland, 1994; Madni & Sievers, 2018), psychology and counseling (Chen, Hughes, & Austin, 2017) business (Checkland, 1994; Gharajedaghi, 2011), and, more recently, pedagogy (Cabrera & Colosi, 2009; Capra & Luisi, 2014; Curwen et al., 2018; Davis et al., 2015). Systems thinking has the potential to help us deal with global crises and protect the flourishing of life on Earth (Capra & Luisi, 2014; Curwen et al., 2018).

With the integration of systems thinking into classrooms, Chinn (2017) argues, "It is critical to develop means of preparing teachers to orchestrate learning adeptly with the innovative student learning environments that researchers are developing" because "there are

challenges for teachers as they must learn new ideas…as well as facilitate students' learning" (p. 127). Because systems thinking pedagogy is relatively new to classrooms (Yoon & Hmelo-Silver, 2017), exploring teacher learning processes will shed light on the values and perspectives that are foregrounded in this paradigm-shifting pedagogy as teachers integrate it into their personal and collective understandings of education.

One method of investigating teacher learning processes is through analysis of teacher talk. By analyzing teacher talk, educational researchers can better understand teachers' beliefs, perceptions, social contexts, pedagogical concerns, and educational discourses (Kosko & Herbst, 2012; Liefshitz, 2015). This is important because teacher learning is "situated," involving "interactive systems that include individuals as participants, interacting with each another, as well as materials and representational systems" (Putnam & Borko, 2000, p. 4). Additionally, teacher learning is "multidimensional," and includes content knowledge, pedagogy knowledge, and classroom and student context (Leko et al., 2015, p. 39).

In this article, I analyze teachers' discourse in a professional development institute to expand the understanding of how systems thinking pedagogy can be constructed (Berger & Luckman, 1966) as a method of teaching. I will first give some background for the study and explain my methodology, including the setting, data collection, and analysis, before moving into my findings and discussion.

Background of the Study

Studies on systems thinking often focus on student responses to systems thinking instruction, mostly within science classrooms (Ben-Zvi Assaraf & Orion, 2005, 2010; Danish, Saleh, Andrade, & Bryan, 2017; Hmelo-Silver, Jordan, Eberbach, & Sinha, 2017). While they note the importance of teachers in the classroom (Chinn, 2017; Danish et al., 2017), most of this

research targets students' systems thinking development; this study focuses instead on teachers' discourse during an institute on systems thinking as a pedagogy. Along these lines, I first explore the potential of research on teacher discourse as a method of analyzing teacher understandings. Next, I synthesize the strands of research on systems thinking in classroom instruction, highlighting the need for additional research on teacher understandings of systems thinking pedagogy.

Teacher Discourses

Discourse, how language is used to enact social activities and identities (Gee, 1999), is a primary mechanism through which collaborative teacher learning occurs. Language has a vital role within the social construction of knowledge, as it both "produces and constructs our experiences" (Burr, 1995, p. 44) while we "communicate our intentions, our thoughts, our attitudes, and our values" (Soter & Conners, 2017, p. 45). Furthermore, we use words to influence and impact our own and others' behaviors, as well as to influence emotions and events (Soter & Conners, 2017). According to Gee (1999), discourse and its ensuing meaning is situation-based: it is actively constructed in various contexts and influenced by social groups. These meanings privilege certain language and ways of knowing.

Because learning is both situated and social (Gee, 1999; Gergen, 1998; Putnam & Borko, 2000) and because "teacher talk provides a representation of the work of teaching," (Liefshitz, 2015, p. 10), there has been continued interest in studying discussions among teachers in various professional development contexts (e.g. Kosko & Herbst, 2012; Liefshitz, 2015). Analysis of teacher talk during the exchange of ideas and critical reflection allows educational researchers to better understand "teachers' beliefs and values, …pedagogical and social aspects of teaching practice, and specific aspects of…teacher discourse" (Kosko & Herbst, 2012, p. 589).

Accordingly, attending to the discourses in a systems thinking pedagogy institute can provide insight into the teachers' thoughts and values; additionally, it can provide understandings of how the discourses influence the teachers' emotions and pedagogical behaviors.

Within discourse, metaphor is especially salient to understanding teacher talk about the connections between teaching, learning, and systems thinking (Liefshitz, 2015). Metaphors are not only a matter of language, but a matter of thought, values, and reason (Lakoff, 1992; Lakoff & Johnson, 2008). A tool for understanding teaching and learning, metaphor analysis attends to "the experience of teaching, teacher identity, and teachers' professional knowledge" (Liefshitz, 2015, p. 16). Considering the metaphors used in a professional development means "considering teacher talk about teaching as both the reflection and the making of teaching" (Liefshitz, 2015, p. 17). This is useful because the teachers, regardless of their experience, engaged in discourse about their developing pedagogical knowledge, making their talk both a creation and a reflection of systems thinking pedagogy.

Systems Thinking in the Classroom

Much of the research on systems thinking in education has focused on students' responses to learning systems thinking content and skills in science classes (Ben-Zvi Assaraf & Orion, 2005, 2010; Danish et al., 2017; Hmelo-Silver et al., 2017). As new developments are made in integrating systems thinking into teaching (Ardell & Curwen, 2019; Cabrera & Cabrera, 2015), research can help us understand the meanings of these ideas in correlation to pedagogy. I differentiate between systems thinking as curriculum content and systems thinking as a pedagogy: as content, systems thinking may be taught using any method of teaching; as pedagogy, it involves integrating systems thinking into the process and procedures of teaching and learning. I borrow from Tintiangco-Cubales' (2010) definition of pedagogy:

> Pedagogy is a philosophy of education informed by positionalities, ideologies, and standpoints (of both teacher and learner). It takes into account the critical relationships between the PURPOSE of education, the CONTEXT of education, the CONTENT of what is being taught, and the METHODS of how it is taught. It also includes (the IDENTITY of) who is being taught, who is teaching, [and] their relationship to each other… (as cited in Tintiangco-Cubales, Kiango, & Museus, 2010, p. viii-ix, emphasis in original).

Students learning within a systems thinking pedagogy have studied such wicked problems as modern-day slavery, drought, and pollution (Ardell & Curwen, 2019; Curwen, et al, 2018; Curwen, Ardell, & MacGillivray, in press). Teachers and students generate systems thinking principles, or general "rules" of systems, as they discuss systems; they then apply and revise these generated principles as they further study interdependent systems, using them to address imbalances, inequalities, and injustices within social and environmental systems (Curwen et al., 2018; Curwen et al., in press). Examples of systems principles include ideas such as "systems are made of wholes and their components" and "the components have dynamic relationships" (Ardell & Curwen, 2019; Ben-Zvi Assaraf & Orion, 2010, p. 541; Cabrera & Cabrera, 2015). Within these classrooms, researchers have found that students and teachers are able to develop a holistic worldview, reimagine a different world, and alter the existing educational discourse (Curwen et al., in press).

The potential for students to make sense of the world through systems thinking signals the power of the teachers' role in this process (Ardell & Curwen, 2019; Curwen, et al, 2018; Curwen et al., in press; Senge et al., 2000). However, while studies acknowledge the importance of teachers in constructing systems thinking lessons (Chinn, 2017; Danish et al., 2017; Wilson, 2013; Yoon et al., 2017), other researchers have found that teachers need to develop their own systems thinking skills (Hmelo-Silver, Marathe, & Liu, 2007; Yoon & Klopfer, 2006). Learning about systems can be challenging (Hmelo-Silver & Azevedo, 2006), and reaching expertise in

complex systems thinking requires that teachers know not only the deep principles of their domain (in this case, content, teaching standards, and pedagogy) but also the deep principles of systems thinking (Hmelo-Silver et al., 2007). Both Chinn (2017) and Yoon et al. (2017) recently noted that there is a lack of research on teacher understandings of systems thinking as theory and pedagogy. Yoon et al. (2017) explain that while research studies have focused on designing learning environments for students, "only a handful have studied teacher understanding of complex systems" and systems instruction (p. 101). Chinn (2017) asserts, "it is vital for research on systems education to include a strong focus on preparing teachers" (p. 127). Systems thinking pedagogy requires a paradigm shift (Yoon et al., 2017) that involves developing altered views and discourses (Curwen et al., in press).

To explore the complexity of teacher learning about systems thinking as called for above, we framed this study in social constructionism, discourse analysis, and systems theory. The interplay between the three frameworks provided the perspective for us as researchers to analyze the ways in which the teachers developed understandings of systems thinking pedagogy and its application to their teaching. In this article, we explore how participants privileged certain language and ways of knowing during a professional development institute on systems thinking pedagogy construction.

To address this purpose, we posed the following research questions:

1. How do the participants use discourse of and about systems thinking?
2. How do the participants use discourse of and about teaching and learning?

Methodology

To address our research questions, we conducted an exploratory case study of a four-day professional development on systems thinking.

Case study methodology (Yin, 2018) was appropriate because it invites in-depth investigation of a topic within its real-world context (Gee, 1999; Yin, 2018) by deconstructing and subsequently reconstructing various phenomena (Baxter & Jack, 2008). The "naturalistic social unit" (Dyson & Genishi, 2005, p. 2) of a professional development provided the opportunity to study the details of the subjects' constructed understandings of systems thinking pedagogy. I was able to "gain insight into some of the factors that shape, and the processes through which people interpret or make meaningful" systems thinking as a pedagogy (Dyson & Genishi, 2005, p. 3).

Holistic case study methodology (Yin, 2018) allowed for the intense scrutiny of learning interactions within the situation, enabling me to attend to the construction of knowledge within the system of a professional development. I bound the case to one specific professional development because of the varying definitions and applications of systems thinking in educational research (Ardell & Curwen, 2019; Cabrera & Cabrera, 2015; Danish et al., 2017; Hmelo-Silver & Azevedo, 2006; Ison, 2008). It would be impossible to have a true picture of this specific, unique systems thinking pedagogy construction without an in-depth consideration of the context in which the construction occurred (Baxter & Jack, 2008).

Setting and Data Collection

We collected data as members of a research team during a four-day summer professional development on systems thinking pedagogy hosted at an independent school in Southern California The research team consisted of three white, former teachers who now work in higher education.

On site, [First Author] was a learner as well as a researcher. Though I was interested immediately when I was first introduced to systems thinking by [Second Author] (as the theory

fits my worldview as well as my pedagogical leanings), I was still becoming familiar with the theory and knew little about systems thinking as a pedagogy. My role during the data collection was as a participant-researcher, making the days replete with both learning and data. As academics with K-12 teaching experience, our interests centered around the literacy events and practices; throughout the week, we found ourselves considering how we might use this pedagogy in our own classrooms with undergraduate and graduate students as well as how we might use systems thinking in our analysis.

After gaining IRB approval and the informed consent of all participants, the research team participated equally in collecting data through twenty semi-structured interviews (Appendix A and Appendix B) with the participants (deMarrais, 2004), field notes from a combined sixty hours of observation (Emerson, Fretz, & Shaw, 1995), and artifact collection (Yin, 2018), including personal research journals, handouts, and over 100 photos. We audio-recorded all observations and interviews. We rotated during the sessions, giving each member of the research team opportunities throughout the day to elaborate her field notes about observations and interviews. At least two members of the research team were present for all whole-group discussions, and one member observed during each breakout sessions. For this paper, we drew from the entire pool of data.

The institute was organized and run by a team of ten facilitators, and it was attended by seventeen teachers; all facilitators and attendees participated voluntarily in the study. All names used in this article are pseudonyms. The institute's facilitation team was a collaborative of three teachers from the independent school, four teachers from a local public school, two consultants who had been working with the teachers for three years on implementing systems thinking pedagogy, and the institute director. The team had been meeting regularly for nine months to

create the teachers-teaching-teachers professional development. The nine women and one man had between seven and thirty-five years of teaching experience, and they self-identified as racially and ethnically diverse: four white, two Hispanic, one black, one Chinese-American, one multiracial, and one who did not self-identify. The director often started and ended the days, refocusing participants on group and personal goals. The facilitators took turns guiding whole and small group activities throughout the institute, and they presented examples of student work from their classrooms (see schedule in Figure 1).

Time	Day One	Day Two	Day Three	Day Four
9:00	Introduction to conference	Both/and thinking practice	Teacher presentation on systems thinking and political action	Relating objects practice; Small group map 2
9:30	Introduction to systems thinking by the consultants	Systems thinking theory and research	Social justice guest speaker	Text-based reading protocol
11:00	Group systems map 1: Morning systems	Systems thinking for all learners	Breakout sessions	Keynote about beauty
12:00	Lunch	Lunch	Lunch	Lunch
1:00	Making observations and asking systems questions	Breakout sessions	Breakout sessions	Introduction of planning maps
2:15	Defining and generating systems principles	Breakout sessions	Using questioning; Group systems map 2: broken pencil; Small group map 1	Independent planning time; Planning for future contact
3:30	Group Reflection	Group reflection	Group reflection	Group reflection

Figure 1: The institute's four-day schedule included whole group and small group sessions.

The institute's seventeen attendees had varying experience as teachers, with three participants just finishing their teacher education degrees, most with four to ten years of classroom teaching, and one teacher with more than thirty years in the classroom. Additionally,

they all had varying familiarity with systems thinking pedagogy, ranging from no prior knowledge to four years of classroom implementation. The attendees were racially and ethnically diverse, including four Latinx, four white, three biracial, two black, and one Asian-American (three opted not to self-identify). There were fourteen women and three men.

Data Analysis

[First Author] performed the majority of the coding with regular meetings and feedback from [Second Author]. To analyze the data, I began with an inductive thematic analysis method that "theorizes language as constitutive of meaning and meaning as social" (Braun & Clarke, 2006, p. 81). I used systems thinking as an analytical lens: I read/examined the data—fieldnotes, interview transcripts, session transcripts, and photos—and started making maps of the systems of discourse I saw. For example, in my first map of the data, I focused on mapping "language of systems thinking pedagogy"; my second map focused on "moments of systems thinking pedagogy learning." I created five separate initial maps; I started each map from scratch so I could look for the patterns in my own thinking by comparing the maps to one another.

After five cycles of re-reading the data, focusing on transcripts of the sessions, and making maps, [First Author] kept returning to the ways the participants, through their discourse, constructed a pedagogy that valued shifts in thinking, systems mapping, teachers, students, and community action. With the focus on these values and with social constructionism and discourse analysis in mind, I began first-cycle coding of the data.

[First Author] used several first-cycle coding methods (Saldaña, 2009) to thoroughly theoretically analyze the data (Braun & Clarke, 2006). To begin, I used initial coding to grasp basic themes and issues (Charmaz, 2006). In this phase of coding, I read through the data to start breaking it into pieces, giving me a beginning point to start memo writing about the codes I was

creating (Saldaña, 2009). Examples of initial coding include “systems language,” “movement language,” and “teaching language.”

As I attended to the data during first-cycle coding, I also applied in vivo coding to capture and honor participant voices (Charmaz, 2006). As I read through the data, I “attuned” myself “to words and phrases that seemed to call for bolding, underlining, italicizing, highlighting, or vocal emphasis,” as well as words and phrases that were repeated (Saldaña, 2009, p. 75). With a constructionist lens, the emphasis is on the shared language of the participants; focusing on in vivo coding helped me keep their discourse central to the analysis. One example of this type of coding is “everything’s connected,” a phrase repeated by many participants throughout the week.

For the final stage of first-cycle coding, I went back through the data to complete descriptive coding (Miles & Huberman, 1994), working to identify the basic topic of data pieces using the prompt, “This comment talks about _____.” The goal in this phase of coding was to develop the language of the data, with a focus on the topics and not the content of the data (Saldaña, 2009). Examples of this coding include “beginnings,” “systems principles,” and “teachers.”

While I was completing first-cycle coding, I regularly wrote analytic memos (Saldaña, 2009). These memos ranged from one sentence to more than a page, with the majority ranging in length from four to six sentences. After my first-cycle coding, I had more than 400 analytic memos. Some memos came spontaneously; others were scheduled times to write about my research questions after coding a block of data, such as a day’s field notes, photos from a session, or an interview.

For the second cycle of coding, I used pattern coding and axial coding to reorganize and reanalyze the data to "develop a coherent synthesis" (Saldaña, 2009, p. 149). During pattern coding, I analyzed for patterns in the first cycle codes (Miles & Huberman, 1994); in axial coding (Charmaz, 2006), I explored how the coding categories related to each other in both properties and dimensions (Saldaña, 2009). As I analyzed, I used Gee's (1999) explanations of situated meanings, including metaphors (Lakoff, 1992), to attend to the language and ways of knowing privileged in the teachers' discourse.

During this stage of coding, I again employed systems maps to map the connections and relationships between the codes (Braun & Clarke, 2006), continually revising until I had several "network centers" (Davis et al., 2015); these centers became my findings. For example, I realized that my first cycle codes of "micro systems," "macro systems," "finding patterns," "personalized systems," "common systems," and "unfamiliar systems components," as well as the metaphors of "tall," "wide," and "organic" learning were all related to breadth and depth in the curriculum; thus, "breadth and depth of systems learning" became a second-cycle code that included those first-cycle codes. Later, I connected the "breadth and depth" to the idea of integrating curriculum when I began mapping my second-cycle codes. Through this kind of analysis, I was able to understand the ways in which the teachers used discourse to create a cultural model (Gee, 1999) of systems thinking pedagogy. After writing my final codes as findings and sharing yet another draft with [Second Author], I shared them with the third member of the research team to confirm that they were an accurate representation of the institute (Savin-Baden & Howell Major, 2013).

Findings

Our first question, "How do the participants use discourse of and about systems thinking to construct systems thinking pedagogy?," called for a theoretical analysis (Braun & Clarke,

2006) of the qualities of the teachers' situated meanings and actions surrounding their understandings of systems theory. We first present the dynamic ways in which the teachers used metaphors of movement when talking of and about systems thinking; we then explore two of the main systems thinking concepts—maps and emergence—that dominated the discourse. For our second question, "How do the participants use discourse of and about teaching and learning in their systems thinking pedagogy construction?," we focused our analysis on the key components of pedagogy (Tintiangco-Cubales et al., 2010) that the participants emphasized in their discourse: teacher identity, views of students, curriculum, and classroom environment.

Systems thinking pedagogy as constructed by the participants was an interactive, recursive process influenced by multiple perspectives. Ideas led back to other ideas, and often multiple ideas built on one another. This recursive element reflected systems thinking theory's exchange of linear thought in favor of interconnected, cyclical thinking (Cabrera & Cabrera, 2015; Davis et al., 2015). Because of this, we circle back to previous findings often to make additional connections.

The teachers talked from multiple perspectives throughout the institute. At times, their perspective seemed clear as they talked "as learners" and/or "as teachers." Their complex voices were fluid; therefore, we move back and forth between these voices in my findings.

Research Question 1: How do the participants use discourse of and about systems thinking?

The institute participants, both facilitators and attendees with experience with systems thinking pedagogy, framed systems thinking as a catalyst for shifts in their thinking, curriculum, and dynamics as they moved toward a systems thinking pedagogy. Most of those attendees who were newer to systems thinking quickly began to take up this perspective. The participants' discourse emphasized the perceived transformation that understanding systems thinking theory

required. They also used the discourse of systems thinking to understand the institute as an emerging collective, mimicking the instructors' descriptions of their classrooms as collectives. In four of the five findings below, the teachers' language about systems thinking theory was steeped in metaphor.

Language of "transformation." The institute facilitators used language that framed systems thinking as a catalyst for change in themselves and their classrooms. They described the process of learning the pedagogy as a "transformation"; this concept developed during the first group session and was repeated throughout the four days. Most attendees integrated this metaphor into their own talk during the institute.

Metaphors of movement permeated the conversations throughout the institute. The participants described thinking directionally, as "moving up," "moving down," and "expanding out," as is often the case in education. Participants described the struggle to understand as a "brick wall" that stopped their movement. Teachers described feeling "pushed" by systems thinking and "pushing back" when they felt the pedagogy was not working for them, in contrast to other professional development (Webster-Wright, 2009). Overall, though, the metaphors of movement were a positive contrast to the constraints of previous teaching experiences. Denise, an experienced systems teacher, described the implementation as "freeing" and "liberating" because, as opposed to scripted curriculum and pedagogies that emphasize "telling" over "teaching." Other attendees feeling like the pedagogy allowed teachers to "take different routes" to achieve learning goals, meet standards, and prepare students for they end-of-year tests. In the words of Zia, an institute participant who had little understanding of systems thinking prior to the conference, "Systems thinking is a vehicle, and it's taking you somewhere." In contrast to

learning how to implement a rigid curriculum, the teachers felt the possibilities of movement in implementing systems thinking pedagogy.

Movement and transformation were referred to as a journey. In fact, consultants and presenters described their transformation as "evolving." The facilitators told the metaphorical "stories" of their systems thinking "journeys" in whole-groups and breakout sessions. As they told these stories, they talked about their "beginnings" and the learning "process." They all described the beginnings as full of frustration and doubt, with a lack of clarity and a struggle to "get their heads around it." But these feeling became more complicated with time. With a growing understanding of systems thinking, the plots were filled with recursive feelings of frustration and "hope." As the stories were forever "developing," the presenters described themselves as "always learning" and "changing" as they began to appreciate the effects systems thinking had on student learning and community involvement. The participants deviated from the traditional "story" metaphor, however, by not telling of an end to their stories; instead, they looked toward the future, noting that even with years of practice they were "learning still." One of the consultants explained that she thought "you can never know all of [systems thinking]." Thus, even the experienced teachers spoke as if they were in a state of transformation as systems thinking teachers. It is striking that participants referenced learning from each other. It was simply the act of telling one's story, but also being in a community in which stories were valued and exchanged. Listening was integral to the evolution.

Importantly, the facilitators not only reflected on the transformation of their teaching in the past but also on the powerful impact of the institute. The facilitators were participants in the institute, sitting among the attendees, working with the small groups, and joining other breakout sessions. During the last day of the institute, many of the ten presenters shared how they had

changed during the four days after hearing the ideas, explanations, and language of the other presenters. They talked about re-assessing and adjusting lessons for the upcoming school year. Because they knew their own development was ongoing, the members of the facilitating team recognized the need for recursive learning after this professional development. Thus, they planned for further support of the attendees: each member of the team made plans with attendees to form mentoring relationships, which would involve ongoing communication, classroom visits, and another day of professional development in the fall.

Shifting from "either/or" thinking to "both/and" thinking. The facilitation team selected the principle of "both/and" thinking (Cabrera & Colosi, 2009) as a goal for the institute. It was included on the list of goals included in the attendees' materials. During the conference introduction, a member of the facilitating team explained that "both/and" thinking was a shift in typical thinking patterns: while people often think in terms of "either/or" and "but" when discussing seemingly opposing ideas, the facilitators wanted the attendees to use "both/and" instead. They further shared that using "both/and" represented a shift to make connections instead of separations between ideas. For example, an activity does not have to be fun *but* difficult; it can be *both* fun *and* difficult; the two ideas do not have to be exclusionary. To give the participants practice in shifting toward "both/and" thinking, the second day of the institute began with an activity about having a mindset of being "in," or being committed to the day's work. Everyone shared something that happened to them before arriving at the institute that morning, and then followed the statement with "and I'm in." The example given was, "I stayed up late, so I'm tired…and I'm in." The activity highlighted that "both/and" thinking is not about a shift in situation but a shift in the way of thinking about situations as well as a commitment to embracing the philosophy in the institute.

The phrase “both/and” arose in multiple discussions throughout the four days, such as describing systems thinking as both “hard and beautiful at the same time.” This combination revealed how teachers found systems thinking challenging to learn and teach while simultaneously recognizing the results of implementing the pedagogy. Systems thinking was also described as encouraging both “united” and “divergent” thinking because it provided a focus for everyone to share while stimulating individual thinkers to explore their own ideas. Additionally, the teachers recognized systems thinking to be both “simple” and “complex”: simple in its focus and complex in its all-encompassing nature, because “eventually everything connects.”

The participants also used the notion of both/and thinking to understand how they found systems thinking to be a “natural” way of thinking and, at the same time, it required a shift in their teaching practice. As the participants described systems thinking as “all around us,” they also explained that applying it to teaching has “transformative power” because it is not a dominant educational theory.

Shifting the emphasis from “broken” to “beauty.” Beginning with the first group discussion, the term “broken” was often used when describing systems. The potential of systems to be “broken” was one of the systems “principles” that the facilitators shared with the attendees. Systems “principles” were how the experienced teachers described the patterns that emerged across systems maps; they were themes that applied to most, if not, all systems (Figure 2). “Brokenness” was a principle that many of the experienced teachers described as emerging frequently in their classroom studies of systems. During the breakout sessions, multiple teachers described “broken systems” as the focus of their classroom systems studies. From the pollution system to the immigration system, all systems examples had elements of brokenness. In fact,

some teachers asserted that "fixing" broken systems was the reason to teach using systems thinking pedagogy.

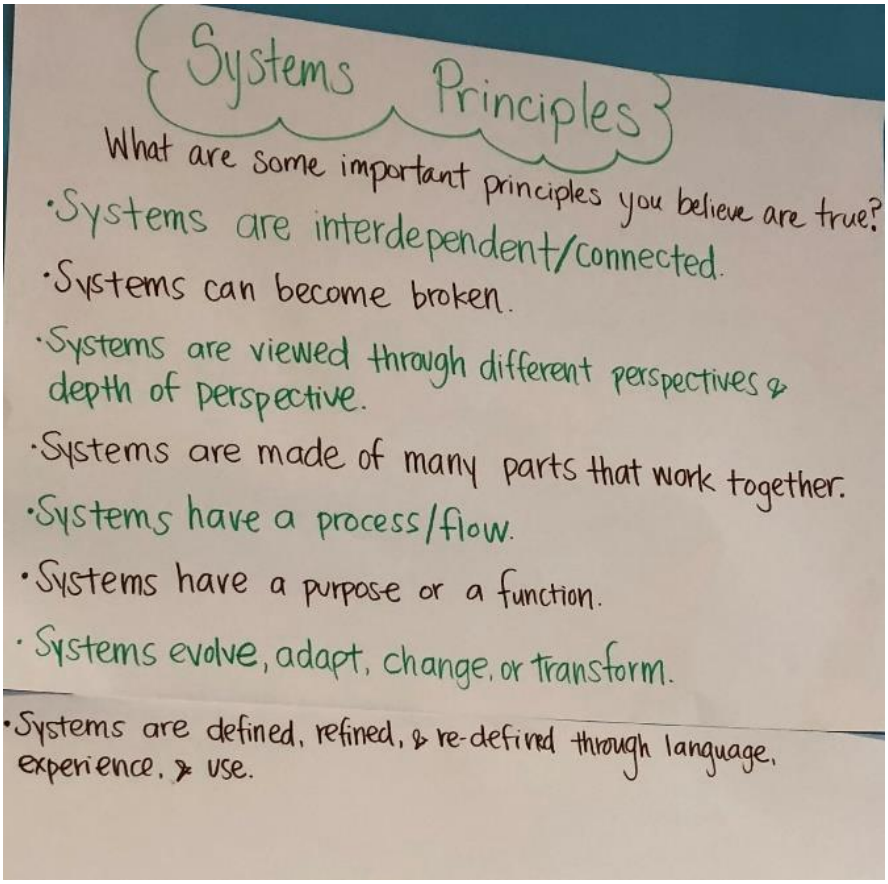

Figure 2: The systems principles generated after a group mapping session. The facilitators shared that the lists of principles their students produce are similar to this list, though the sophistication of the vocabulary and concepts varies depending on the age of the students.

Fixing "broken" systems aligned with the institute's emphasis on social justice and activism as an integral purpose (Tintiangco-Cubales et al., 2010) of systems thinking pedagogy. The facilitators all included culminating projects that required student action as a way to nurture agency as a response to social inequalities or environmental issues. For example, Charlotte gave the example of using the central question "How might [we] help fix an unfair immigration system?" in her third-grade classroom. The unit ended with the students writing letters about immigration laws to their political leaders, as well as designing informational brochures about

resources for learning English to give to new neighborhood immigrants. Other facilitators gave examples of beach litter clean-ups and campaigning for local ecosystem preservation.

The metaphorical shift away from "broken" as a key term happened in waves during the institute; it started with a few comments, built momentum, and became a shared value. The first disruption happened when a participant asked, "How do you define how a system is broken?" Maya, who had been serving as the map scribe for the discussion, offered an alternative: "Instead of saying broken, I say that systems can be interrupted or re-routed or out-of-balance." Later, Jacob, a participant who had just finished his first year of implementing systems thinking pedagogy, offered his thoughts: "I use the term 'systems malfunction' because it feels less linear than 'broken.'"

On the final morning, Stacy, who had been an early adopter of systems thinking at the host school, offered a counter vision of systems thinking pedagogy. She explained that her systems thinking "story" leveraged the pedagogy as a way to have her students "connect to the beauty around them" in the natural world. While she agreed that addressing "brokenness" was critical, she argued that it was "imperative that students [connect with beauty] first," so they could understand their place in the world. She called for "a balance" of addressing both beauty and brokenness in systems thinking pedagogy. She argued that students' need to "celebrate [the world's] beauty every day" by going outdoors and integrating the natural world as part of the classroom.

Stacy's words brought the shift away from "brokenness" to an apex, provoking emotional responses in the attendees and facilitators. Maya choked up in the follow-up discussion when describing the times she and her students were "fearful" while studying the brokenness of systems and her desire for them to have the "hope" of beauty instead of fear. Over the course of

the day, other teachers shared that they wanted to now "start with beauty" and "use that language [of beauty]" in their classrooms. Carmela, another facilitator, explained that Stacy's talk about "broken" systems made her realize she needed to include "happier" systems in her first-grade curriculum. Marisol, one of the systems thinking researchers who attended the institute, even named the notion of "going towards beauty" as one of her main takeaways from the institute. Seeing beauty became a purpose for systems thinking and a motivation for addressing brokenness. The attendees' incorporation of the new perspective of "beauty" into their thinking captured the importance of having a flexible, inclusive mindset.

Shifting the curriculum: "Be as open-ended as possible." Systems maps were the dominant material throughout the conference. The systems maps were distinct from traditional curriculum maps (a phrase not used at the institute) in two significant ways: first, they are created with the students; second, they capture on-going conceptual understanding (see Goode & MacGillivray, 2019 for a detailed discussed of mapping in systems thinking pedagogy).

Throughout the institute, systems mapping provided a way of showing that "everything is connected." Participants described systems maps as an "interaction on paper" and as a visual of what learners "do know" instead of what they "should" know. During the mapping, a facilitator took on the role of questioner, posing open-ended questions to prompt a group's knowledge about the system of study. The map facilitator focused on listening to the responses from the participants, then guided the participants into naming new systems components and addressing connections within the system. After the participants mapped a system, the map became a prompt for reflecting on and discussing the systems principles that emerged from the map. Beatriz described the significant connection between the maps and the principles: "The principles are the syllabus; [the] maps are the curriculum." Within this pedagogy, an

understanding of systems thinking principles is the main goal; systems maps are the materials used to build these understandings.

In the classroom, the facilitators explained, the map became a guide for deciding topics for further study. The institute facilitators both recommended and demonstrated leaving systems maps on the walls for learners to refer to, add to, and revise as they learned more about both the system and the systems principles, in a process of recursive learning. The systems mapping process sparked positive reactions in some participants who connected it to discovery: both Zia and Rachel compared it to the methods of ancient humans who created and revised maps of the "stars," the "seas," and the "human body" as they explored and became "experts" in their fields.

The idea of mapping during the school year, as the topics and questions arise from student discussions, was not accepted immediately by all the teachers. Tension arose as some teachers questioned the feasibility of "not knowing where [the map] was going" because it was supposed to "be as open-ended as possible" and their responsibility for teaching specific content. The teachers shared the pressures they felt with the metaphor of needing to "get somewhere" specific in their lessons, whether that "somewhere" was "the end of year test," "the standards," or "life skills." Experienced teachers offered some suggestions. Stacy tried to ease their concerns by explaining that she had the same feeling when she first saw the pedagogy demonstrated, but that as she gained experience in systems thinking, the "standards and objectives across subjects [were] woven into systems thinking" naturally. Adriana described having the "standards checklist in [her] head" so she could find places to teach them during mapping. Carmela presented a breakout session on standardized writing assessment and systems thinking, describing how she used the topics of the yearly assessments as systems she taught in her

classroom. Jane, one of the consultants, briefly mentioned that the use of novels as evidence to prove or disprove systems principles naturally addressed a Common Core standard.

While some participants seemed to accept these suggestions, one teacher continued to question the mapping method, wanting more direct examples of meeting specific standards using systems maps. While Mark had implemented some systems mapping in his classroom the previous year, he was unconvinced that he should use it with (or instead of) the more traditional forms of instruction, like direct instruction and memorization, that he preferred. Overall, the metaphorical shift toward open-ended mapping was a shift in curriculum that held tensions for some teachers.

Emergence of the collective: "Out of the mess comes something wonderful."

"Collectivity" is a way of describing the power of groups to be more together than any individual is on their own (Davis et al., 2015, p. 133). The notion of the collective reflects the emphasis on the interconnectedness between system components (Capra & Luisi, 2014) in which the relationships transform pieces into a single entity (Davis et al., 2015). Collectivity "emerges" out of the interactions between the components: the properties of the collective cannot be found in any one component alone (Capra & Luisi, 2014, p.155). A collective can be a group of people who are smarter together than even the smartest is alone; it can also be a project, like Wikipedia, that is a whole made of many ideas from many people (Davis et al., 2015). Collectives do not have a single center; instead, they are networks of connections between all members (Castro, 2015). Cooperative learning methods are the application of the collective to the classroom (Davis et al., 2015).

During the institute, the participants used language referring to themselves as an emergent collective. The teachers used the pronoun "we" frequently, referring to all institute

participants, both facilitators and researchers. The two systems thinking researchers, Marisol and Abigail, confirmed this discourse, saying, “Systems thinking is about the collective learner.” By the last day, new participants were talking about the work that had been done as a “collective conscious” and appreciating Stacy’s presentation because of her emphasis on “the collective.” They took up the language of the whole that emerged throughout the conference as they recognized they had more knowledge together than any one did alone. The teachers and consultants also made references to their classrooms as a “collective learner” and “collective consciousness”; additionally, several experienced teachers used “we” while describing the systems learning in their classrooms, including themselves in their classroom collectives.

In some sessions, the institute participants were specifically asked to function as a collective. For example, in a breakout session on the second day, participants were asked to draw independently the steps in a daily routine (like making toast or toothbrushing). Then, they were instructed to work in small groups to make a shared decision and create one “collective drawing” of the routine. Their final products drew from all of the individual drawings, using the ideas that were often repeated and concepts that the group agreed upon. At other times, the participants formed a collective teacher. For example, the institute director called on the teachers as a collective to address a participant’s question about how to teach early childhood students what a “broken” system is, saying, “you all have a lot of collective wisdom.” Four teachers responded with suggestions that connected to and built on one another’s ideas, including using systems students already know can have problems (for example, the “classroom listening system” is broken when students are talking instead of listening) and ideas students already know (for example, even early childhood students have an understanding of what “fair and unfair” are). In

moments like these, the collective had more wisdom than any one participant had alone, and everyone's voice contributed to the total understanding.

The institute participants as a collective learner differed from traditional professional development in that it emphasized developing the interconnectedness between the teachers while simultaneously developing teacher knowledge about content and pedagogy. Throughout this professional development, the teachers were invited to share both their thoughts and feelings about systems thinking pedagogy; these times of reflection provided times to both share and create feelings of community (Goode, Bailey-Tarbett, & MacGillivray, 2019). The interconnectedness of components is a key principle of systems thinking (Capra & Luisi, 2014), so developing it among the attendees reiterated the nature of systems thinking and reflected the pedagogy in the moment.

The discourse about the institute collective focused on three main qualities. One of these qualities was "trust." First, trust emerged in talk about the student-teacher relationship within the classroom collective. Teachers had to "trust" the students to lead the maps, and teachers "learned to let go" so they could capitalize on the potential of students to think in new ways. Second, participants noticed that the experienced teachers had to "trust" that systems thinking pedagogy would produce results. While some expressed admiration that the consultants had "trusted the process" in their own classrooms, this kind of pedagogical trust made some participants wary. Madalyn explained trying a new pedagogy was challenging to her because, "I want to prove all my decisions with research." However, experiencing systems thinking pedagogy together helped form a collective that trusted in the process to produce intentional results. Beatriz ended the conference saying that even if the process looks messy on paper, "we can trust that…out of the

mess comes something wonderful." The participants collectively agreed, nodding and murmuring, even those who were initially skeptical.

Another emergent quality of the collective was the interpersonal connection. Cordelia, a graduate student, explained after the first group discussion, "I feel strangely closer to everyone in this room now." Cordelia's feeling was reflected in the repeated use of the word "community" by other participants, both in talking about the institute and in describing the individual classrooms of the presenters. Teachers talked about "classroom community" and presenters identified their desire to "get a community feel" in the group sessions. On the last day, multiple teachers shared their appreciation for the community that developed. Rosie described how wonderful it felt to be with people who had a similar worldview, to which Kimberly exclaimed, "You found your people!" The room echoed with agreement.

A third quality of the institute was energy. In addition to feeling energized by being part of a collective who shared their worldviews, the participants also described feeling energized by the professional development's content and process. Colleen described it as a feeling of being "alive": "Systems keeps you alive. I feel alive. I am thinking and sharing and questioning. Questioning keeps you alive! This is the most alive I've been in a meeting in years." Other teachers echoed this word choice, later describing themselves as "feeling alive with systems thinking" and describing their students as "thinking and alive" when mapping. Others described feeling "broken open," "expanded," and "free." The declaration from Stacy on the final day that students have a "right to learn this way" and that teachers have a "right to teach this way" added to the emotional energy of the institute. These properties—trust, interpersonal connection, and energy—all emerged through the development of interconnections between the institute's components, including participants and theory.

While the facilitators frequently emphasized the need for developing an interconnected classroom community that brought learners together as a collective, the presenters addressed individual student needs as both for the good of those individuals and for the good of the collective. During the group reflection after the first mapping practice, both participants and presenters talked about the mapping activity having the ability to "engage different kinds of learners" because it "helps visual learners" and builds on students' interests. One facilitator explained that in her special day class, she designed different "entry points" for her students to access learning about the hearing system so they could all participate in discussions. Additionally, the teachers shared the gains English language learners made by revisiting the vocabulary posted on the wall often. However, there was some tension with one special education teacher who wanted more "practical" examples of how to adjust the pedagogy for some of his students. During the institute, the leaders addressed the needs of individual participants. One of the ways they did this was by posting the individual goals of all participants and inviting everyone to "check off" their goal on the wall as it was met. Everyone could see what others needed, and the leaders worked to meet all those needs. In this way, the facilitators attended to individual needs while developing the interconnectedness of the participants.

Overall, the discourse of the institute positioned systems thinking as a catalyst for transformation. The participants used the language of movement and transformation as they constructed understandings about elements and principles of systems thinking, such as both/and thinking with the beauty and the brokenness of the natural world, the use of systems mapping, and the concepts of emergence and classroom collectives. These systems thinking understandings built the foundation of the purpose of education (Tintiangco-Cubales et al., 2010)

within systems thinking pedagogy: to understand and act upon the complexities of a world that is both beautiful and, at times, broken.

Research Question 2: How do the participants use discourse of and about teaching and learning?

The participants' discourse about teaching and learning positioned systems thinking as a catalyst to transform many aspects of their pedagogy, including the purpose and context of education, the content and methods of teaching, and the identity of the teacher and the learner (Tintiangco-Cubales et al., 2010). Specifically, the participants' discourse reflected their developing understandings of teachers as complex, whole people; their esteeming of students; their abilities and "right" to personalize an integrated curriculum that has breadth and depth; and their locating the classroom as part of the larger community and environment.

The systems thinking teacher: A whole person. One aspect of pedagogy is the development of an understanding of the identity of the teacher (Tintiangco-Cubales et al., 2010). Throughout the institute, the participants' discourse reflected the identity of a teacher as both a teacher and a learner with physical, emotional, and intellectual needs. Systems thinking views a person as a system; for the whole person to perform their best, the needs of each system component must be met (Capra & Luisi, 2014). This perspective motivated the facilitators to consider the needs of teachers learning a new pedagogy. Additionally, the facilitators designed parts of the systems thinking pedagogy institute to model systems thinking pedagogy as they simultaneously taught about it. One way they modeled systems thinking pedagogy was in the way they designed the professional development to both welcome and address the whole teacher-learner. The facilitators planned to address participants' physical and emotional needs as a part of preparing for the intellectual work.

In considering the teachers' physical needs, the institute provided daily breakfasts, snacks, and lunches, catered to fit the dietary preferences of the participants. The conference's main room was filled with natural light from a wall of windows and a skylight, and participants were shown multiple outdoor locations where they could take breaks and eat. Upon realizing that the chairs provided were less than comfortable, the director of the institute stayed late the first afternoon to exchange the chairs for wider, more comfortable ones. At one point, a facilitator led the whole group in a mindfulness exercise, encouraging mental and physical focus prior to a time of reflection. These practices show esteem for the body as part of the learning process, a shift from what the attendees had previously experienced.

The facilitators continued to attend to the teachers' needs by planning to address possible negative and positive emotions as related to attending the institute. As mentioned previously, the facilitators shared their initial doubts and anxieties about the pedagogy before they shared their successes. It was a distinct story line for most of the presenters, and one that positioned them as emotional, vulnerable, and successful, which is arguably counter to how emotions typically are perceived in professional development. The language of the facilitators assigned positive, strong character descriptions of systems thinking teachers as "brave," "honest," "willing to be vulnerable," "risk-takers," "flexible," and "persistent." Also, as described earlier, the facilitators addressed participant emotions by planning times of reflection that invited participants to share their feelings, both positive and negative.

In addition to considering the attendees' physical and emotional needs, the facilitators considered the intellectual needs of the participants as teachers and learners. The facilitators regarded the attendees as intellectuals who could decide what topics would be interesting in their classrooms. Unlike a prescribed curriculum, the teachers were encouraged to bring their interests

and expertise into their classroom curriculum. The facilitators all selected what topics they would teach within the institute, and they all described bringing their interests into their own classrooms. Charlotte advised that the best way to start with systems thinking is to "pick an area of interest and go for it." Another experienced systems teacher attending the conference, Denise, explained that she used parts of history she found interesting, such as the Gold Rush, to make connections between historical issues and current events. Maya, one of the presenters, described using her favorite childhood books to read to her students and "talk about the systems inherent in the book." In these ways, systems thinking pedagogy included teachers' individual interests as a positive instead of something to avoid. The notion of separating the curriculum from teacher interests was actively dismantled.

At the same time, teachers were also seen as theoretical learners. Stacy explained that deducing systems principles from systems maps was "theorizing," and the facilitators trusted that the teachers could do this kind of theorizing quickly. In fact, the act of theorizing was how the consultants taught the theory systems thinking; they avoided direct instruction, instead using questioning techniques to prompt the participants to look for patterns and principles within the systems maps. Ironically, one of the guest facilitators apologized for "talking about theories" in one of the sessions when multiple teachers had already voiced their desire for more theoretical grounding. Zia expressed, "I see theory behind every action." Mark went as far as saying "I can't teach…without theory." The attendees' discourse positioned themselves as desiring theory in addition to practical application. When some teachers voiced their desire to understand the theory thoroughly before they implemented the pedagogy, the facilitators emphasized that the teachers did not need to learn everything about the theory beforehand. In fact, systems thinking is so complex, according to Beatriz, that "you are never going to know all of it." Beatriz and

Jane, in talking about their first year of co-teaching systems thinking, described themselves as being "just a couple blocks ahead" of their students the whole year. Because of the complexity of systems thinking, teachers described themselves as learners alongside their students. Beatriz affirmed that after decades of being a systems thinking teacher, she is "always learning…I've learned so much this year." Stacy explained that being able to see herself as a learner was significant, because "I still question principles myself." In this way, teachers can be part of the classroom collective as described in the previous finding, participating in the classroom alongside students as teacher, learner, researcher, and theorist.

Overall, teachers reacted to systems thinking not just as a pedagogy as practiced in this institute, but as an all-encompassing, holistic, theoretically-informed understanding of the world. Several teachers described systems thinking as being natural to the way they understood the world. Kelly concluded that "finding patterns" and "making connections" is what "our brains are eager" to do, and Chloe, a teacher new to systems, described systems thinking as "how [my] brain works." Denise explained that systems thinking was "organic" to her because it was "how I see things." Systems thinking pedagogy was a catalyst for teachers to consider the roles of their interests and preferences in their classrooms and with their teaching methods. Within the institute, the facilitators aimed to meet the attendees' needs as learners, teachers, and theoretical thinkers; this understanding of teachers as having complex identities within the classroom was a piece of systems thinking pedagogy.

Esteeming students: "They are natural systems thinkers." A second aspect of pedagogy that was reflected in the participants' discourse during the institute was the identity of students as complex beings (Tintiangco-Cubales et al., 2010). Both facilitators and attendees shared an esteem of students. Importantly, the discourse established students as already highly

knowledgeable. Stacy nurtured this idea within the institute, reflecting on her first experience with a systems map, was astonished that the students "knew so much [that] I didn't know they knew." Because students have knowledge and are aware of their own knowledge, they can be a participant in deciding what to study; they can be "active in writing the curriculum," according to Stacy. The participants also spoke of how their students knew about themselves and were aware of their learning. Adriana emphasized that she had seen her third and fourth grade students "get very metacognitive" when thinking with systems, explaining their thoughts well.

According to the participants, students are not "vessels to be filled," as Rachel described, but "natural" systems thinkers who have their own wealth of knowledge to contribute. Participants suggested that students "have the power to ask why" because their "curious nature" has not been "beaten out of them." Beatriz described students as having a "natural ability…to understand deeply" because "children have always been systems thinkers." David noted that even his kindergarten students "easily" understood that wholes are bigger than their parts. Systems thinking pedagogy includes an esteem for students to encourage their "natural" abilities by using their interests and their strengths.

In this pedagogy, students not only had the ability to use their interests and strengths to change the curriculum, but also the power to make the world a better place to live. Both Carmela and Ginger described students as "little activists," with Ginger claiming, "Students want to take action and make statements." Both Danita and Rosie posited students as good "citizens" who can put systems thinking skills to work in their local communities. Systems thinking pedagogy was one way of helping students have the "esteem" and "confidence" to take action.

Specifically, participants asserted that implementing the pedagogy had the potential to "empower" students to learn and teach others about their own needs. Adriana, who teaches

students who are hearing-impaired, related that her students "wanted to be experts at the hearing system." Some of her students shared that they did not understand what was "broken" with their own hearing systems; several did not know how their parents first realized that their hearing was impaired. These students gained "the tools and words to talk and share" with others, including future teachers, about their needs; they became self-advocates, seeing their special needs as something in which they could be an "expert."

While talk centered on giving students the opportunity to select topics and guide the learning, there were some questions about how to be "comfortable" with allowing students so much decision-making ability with the curriculum. Notably, the teachers frequently explained map-making strategies that kept them firmly in control of the activity: they described asking the questions and recording the maps as well as selecting which ideas to write and where to place them on the maps. In keeping with these classroom descriptions, the map scribe during the first group mapping session modeled having this kind of control as she recorded some responses while others were seemingly ignored. The learners were not in control of the map. However, on the afternoon of the third day, Stacy modeled a different way of making maps that shared the control, asking learners where they wanted their responses on the map. She explained, "I always ask where they [the students] want it [their response]." In the debriefing that followed, several experienced teachers commented that they had not previously included such a student-centered strategy in map-making, and several teachers began implementing the method in the small group map-making that followed. The change gave the learners more control of the mapping than previous experiences. The teachers were willing to "give up control" and the "confidence" that comes with being in control to trust students with more power during classroom discussions.

Overall, the language of systems thinking pedagogy established students as more than just learners, but as natural systems thinkers, activists, and experts. Just as the facilitators talked about teachers having passions, so they talked about "making room for students' passion"; the participants agreed that passion—both theirs and their students—should be a part of learning. The new-to-systems teachers noticed that the experienced teachers "found the students' interests" by using the pedagogy, giving them the ability to "go where the students' passion is." This approach to teaching placed students as important in the classroom discussions and gave teachers, according to Stacy, the ability "to see where [the students'] hearts are at." This humanizing language is a catalyst to positioning students as capable, strong, and empathetic. In these ways, students' identities are esteemed as a powerful part of systems thinking pedagogy (Tintiangco-Cubales et al., 2010).

Mapping an integrated curriculum: "Learning is bigger and taller and deeper." The systems thinking pedagogy that the facilitators and attendees developed focused on the purpose, content, and methods of teaching and learning (Tintiangco-Cubales et al., 2010). Systems thinking pedagogy was also presented as a catalyst for integrating curriculum that is deep and broad, with learning applied repeatedly in multiple situations (Bogard, Consalvo, & Worthy, 2018). Several map properties led to increased breadth and depth. Most apparent was the way the maps could spread rapidly to multiple topics. A group map that centered on a broken pencil quickly branched across ideas like factory workers, transportation, and health care. The wide scope of the maps provided a range of options for integrating subject lessons using a map, and institute presenters demonstrated how they did this in their classrooms. For example, Carmela described centering one of her first-grade units on the ocean; topics included ocean animals, environmental pollution, and water conservation. Lessons for these topics integrated science

lessons on animal habitats, ecology lessons on the impacts of pollution, and writing lessons on informative paragraphs; the integration of multiple subjects provided depth to the curriculum. Carmela asserted, and other facilitators agreed that this kind of curriculum integration happened naturally as learners found connections between the system components that crossed traditional subject boundaries.

Another property that added depth and breadth to the curriculum was the way the discourse during the discussions expanded the maps from familiar content into unfamiliar content. To introduce systems, facilitators suggested starting with a system with which students are familiar (such as the "naming system," having students talk about how and why they were named). Using systems that are personal and well-known provided a starting point for understanding systems. Presenters described "slowing [the learners] down" when the map moved into less familiar material, and facilitators modeled slowing down in the institute's mapping sessions. For example, the broken pencil map moved quickly until someone mentioned "logging." When Beatriz, the consultant, asked for more information about logging, the conversation quieted. One participant admitted, "I don't understand the assembly line" for how trees became pencils. Beatriz responded, "Okay, let's go" and began acting out logging production, demonstrating how to prompt students instead of telling them. The map grew in depth surrounding the more distant (to this group of learners) topic of logging. Presenters explained that these areas of the map can indicate places for future learning.

The fluid movement between micro and macro systems was another map quality that added to the complexity of the discussions. Whether starting maps with a broken pencil or a toy truck, discussions integrated global and local systems. For example, during the first group mapping session on the morning routine system (Figure 3), local details such as using "an app to

order my coffee" were included as well as global ideas like environmental protection (because pre-ordered coffee will not be filled in reusable containers). Allowing discussion to take its natural path led to ebbs and flows in curriculum scope and depth, and, ultimately, as one participant noted, to "learning [that] is bigger and taller and deeper." Such depth of discussion about principles led to perceived tension at times. Debate about whether a chair or lint could be considered systems had teachers offering multiple ideas both sides of the question, and no final decision was concluded. Some teachers strongly believed that students needed to be able to recognize things that were not systems, while others felt thinking about systems was more important. Even without consensus, the discussion prompted deep thinking and rich communication about systems principles.

Figure 3: The map created during the first whole-group mapping session on morning routines.

A final map property that increased breadth and depth of learning came in finding patterns across time. The facilitators explained that systems maps can connect past, present, and future. The broken pencil map illustrated the potential for these connections. When discussing the production of the pencil, someone suggested factory workers. Another participant, David, jumped in, questioning whether pencil factories still need many workers or if the assembly line is

fully automated now; debate followed about the history and future of factory workers. Facilitators gave more examples of incorporating history with units they had taught in their classrooms, including making connections between the political environment of the 1950's and current American politics. Facilitators stressed that connections across time provided more depth to the curriculum.

Teachers voiced concerns about how to manage classroom time when integrating curriculum that centers on student discussions. Maddie, one of the technology teachers, expressed that she felt "we had enough time here" to do systems maps, but she was not certain about classrooms where there is "pressure…to get to the end goal." This concern was validated by the daily press for time in a professional development with adults, most of whom had previous experience with the pedagogy. However, the experienced teachers validated using classroom time for students to "discover" knowledge, to "think and discuss" as a class, and to have "a time in the day when the class can be one." Charlotte explained that some students struggled with changing the structure of class time, but even the ones who "wanted to stay on schedule" adapted to the less "regimented" time when they saw "important things being talked about." Prioritizing systems mapping was a use of class time that several teachers described as urgent. Danita impressed on the group, "The time to act is now." Denise agreed, saying "don't postpone." Abigail, one of the systems thinking researchers attending, urged that students already "deal with real problems now" and "are participating in democracy right now." She concluded with, "We don't get lifelong learners who wait for the clock to tick twenty-one years old." In the end, implementing systems thinking pedagogy required a change in managing classroom time to provide learners with meaningful, integrated curriculum.

The environment: Knowledge inside of, outside of, and on the classroom walls. The discourse at the institute focused on the importance of enacting a pedagogy that integrated the world inside and outside of the classroom by providing wide applications of systems theory. The teachers at the institute connected the classroom to nature, seeing the world as a place where systems learning was abundant. Both facilitators and participants gave suggestions of systems units centered on the natural world, such as forests, flowers, oceans, and insects. The facilitators and participants talked of the systems thinking classroom being "a part of" and "connected to" the natural world. The consultants shared the story of starting their very first systems lesson with a local ecosystem, and Beatriz used gardens as the introductory lesson to systems when she began her work as a consultant at the independent school. Stacy recommended "bringing [the] outside world in" and "taking the kids outside" often to "show [them] how beautiful the world is." The participants responded to her words, and many of them planned to start their systems maps with nature. At the conclusion of the institute, the participants decided that "we are connected to the world" was one of the most important principles of systems thinking that emerged from the group discussions because it is the basis of systems thinking theory and the motivation for taking environmental action.

Learning from the local community was another element from outside the classroom that teachers who had implemented STP included in their systems thinking curriculum. Adriana and David recommended taking a "community walk" and mapping the students' observations. After learning about systems, Rachel adjusted her curriculum to have students create neighborhood photojournals as part of a citywide study of immigration. The participants also wanted students to know that they are members of their communities. Maya and Ginger described students studying the "systems broken in the community" so they could "find their place in fixing" it.

Multiple teachers recommended field trips so students could learn about and be active in the world. After the field trips, they explained, students revisited the systems maps and principles to discuss what they had observed and make revisions.

Many of the experienced teachers also included parents in systems thinking pedagogy. Denise warned that she had experienced "push back" from some parents because systems thinking was "not their school experience," and Stacy agreed, sharing that "at first it gave me anxiety [when] the parents were asking about the maps." However, she also had parents give positive feedback after seeing their students' practice systems thinking at home. Both Ginger and Jane advised informing parents about systems thinking early in the year. Jane specifically recommended assigning homework having the students write about the systems principles after the first systems map to "serve as a way to share with the parents." The new-to-teaching participants embraced the inclusion of parents and asked for more ways to "bring parents into the mix." Stacy shared that she had "parents send photos of systems maps at home." Carmela recommended definitely "informing parents" because "students will act on what they are learning at home," such as the student who kept turning off the water "to conserve it" when his mother was trying to get hot water out of the faucet for washing the dishes. Notably, studying systems can spur discussions at home, as Ginger found out when a parent thanked her for talking to her students about refugees because the parent did not know how to start that discussion at home.

As teachers brought the outside in and took students out into the world, the classroom walls, instead of being a simple boundary, became a more permeable space for displaying systems learning. The teachers talked of turning the walls of the classroom into the "curriculum," with the systems maps and principles posted as "living documents" with which to engage. Stacy

recommended that teachers "put everything on the wall," and Adriana explained that "labelling the walls" is "important for English language learners." The ability to "read the walls" with the "classroom as curriculum" de-centered the teacher as the main source of learning. In systems thinking classrooms, Jane professed, "I learn from teachers, from children, from the room." Significantly, during the institute itself, the walls became covered with butcher paper showing systems maps, systems principles, participant goals, and open-ended question stems (Figure 4). It was an immersive experience, just as they proposed systems classrooms should be. There was no designated space from which to teach; speakers moved to different learning documents depending on the topic, using the whole space as a learning environment. The pedagogical approaches and strategies that they were learning how to implement in their own classrooms were modeled throughout their time at the institute.

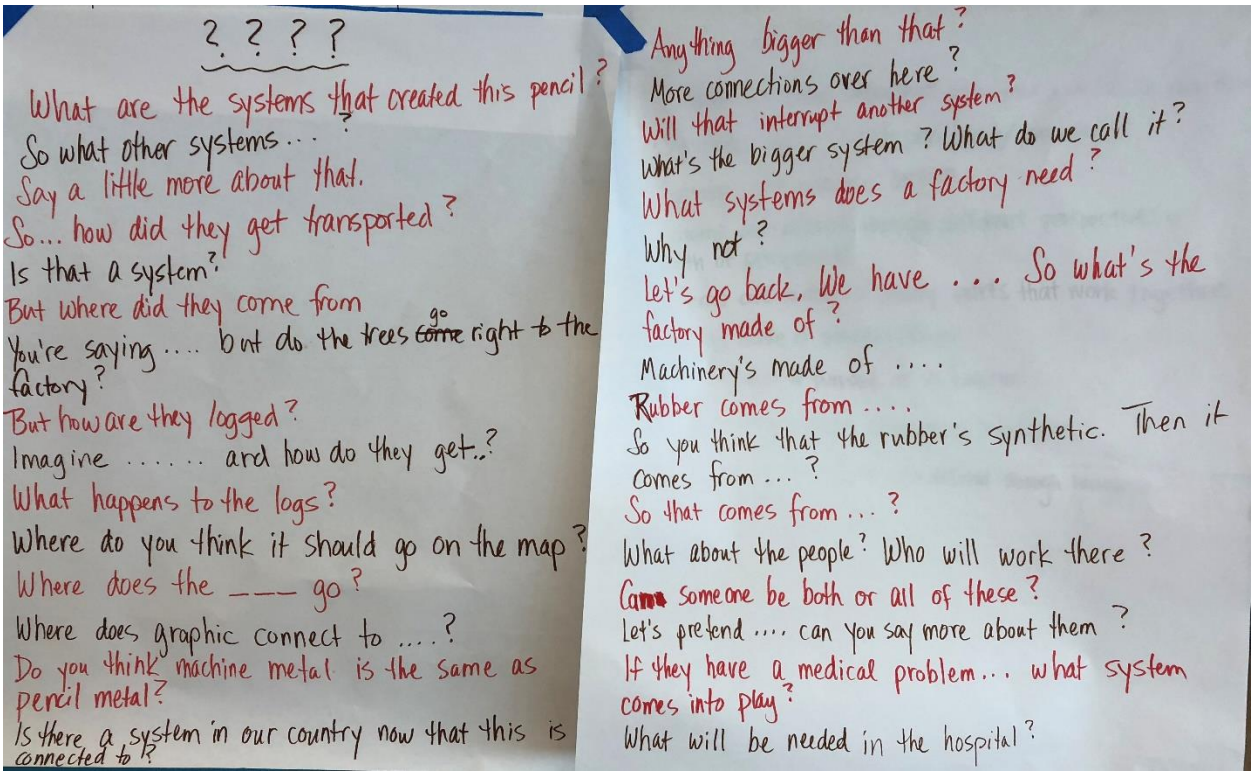

Figure 4: One of five sets of question stems posted on the institute walls; by the end of the four days, such learning artifacts covered the walls.

Overall, the participants' discourse about teaching and learning addressed many aspects of pedagogy development (Tintiangco-Cubales et al., 2010) as it positioned systems thinking as a pedagogy that attends to teacher needs, capitalizes on the strengths of students, personalizes a curriculum that has breadth and depth, and connects classrooms to the community and environment.

Discussion

I drew on discourse within a professional development institute to explore the construction and enactment of systems thinking pedagogy. I showed in my findings that teachers were integrating systems thinking into their pedagogies and worldviews. In the institute attendees and facilitators furthered their understanding of systems thinking and co-constructed a related discourse (of systems thinking pedagogy).

Within the systems thinking pedagogy institute, the discourse included pivotal situated meanings of both pedagogy and systems thinking, including systems maps and principles. The participants "assembled" (Gee, 1999, p. 46-47) these situated meanings as they spoke, listened, and acted within the institute context. I addressed these assembled meanings of the pedagogy in the findings, including the purpose and methods of the pedagogy, important aspects of the identities of teachers and learners, and the context of learning; now I will draw on Gee (1999) to consider the ramifications to the current educational models of teaching, learning, and teacher discourse.

The participants' discourse of systems thinking pedagogy challenged the prevailing cultural deficit models of teachers as incompetent instructors in need of scripted curriculum (Davis et al., 2015) and students as broken learners in need of interventions (Gay, 2010; Rodriguez, 2012). Instead, the participants' cultural model of systems thinking pedagogy situated

the identities of both teachers and students as capable academics. The model privileged a professional development culture of "becoming" where the power of the collective was a point of leverage (Meadows, 2008) for teachers to cultivate community and disrupt rigidity in what often counts as curriculum (Davis et al., 2015).

Privileging the Complex Identities of Teachers and Students

The discourse of systems thinking pedagogy situated teachers and students as capable academics, disrupting the cultural models (Gee, 1999) in Western education that posit deficit models (Gay, 2010; Rodriguez, 2012). Systems thinking pedagogy challenged the "habitualized actions" (Berger & Luckman, 1966, p. 71) of traditional teaching in which teachers are experts who explain knowledge to learners, instead considering teachers to be guides who prompt learners to build knowledge.

The discourse of the facilitators positioned teachers as capable by framing them as theorist-practitioners, meaning they drew from systems thinking to implement system thinking pedagogy. For example, the teachers developed their understanding of systems principles as they participated in the systems mapping activities. This view of "everyday people" having the ability to "form, transform, and deal with 'theories' just as much as scientists" (Gee, 1999, p. 45) was seen in the institute's mapping sessions, where the systems principles emerged as "theories" from the group discussions. The teachers formed theories about different systems, noticing and articulating systems principles just as they would ask students to do in the classroom. Positioning teachers as theorists who could deduce systems thinking principles without much prior understanding of systems theories recognized them as systems thinkers, and it also modeled for them how they should reconceptualize their students as active, agential learners. The institute's discourse about teachers demonstrated a valuing of the teachers' abilities to develop high levels

of systems thinking (Ben-Zvi Assaraf & Orion, 2005), that, once learned, can become transferrable schema to address “wicked” problems (Cabrera & Cabrera, 2015), according to the facilitators. This discourse challenges the notion that professional development should primarily involve “practical" classroom strategies that merely link back to theory instead of enacting theory (Korthagen, 2017), suggesting instead that a balance of the practical and the theoretical is important, especially when asking teachers to change their classroom instruction.

Teachers were also considered to be capable academics who could integrate systems thinking pedagogy with other pedagogies that aligned with its principles, including Systemic Sustainability Education (Davis et al., 2015) and design thinking (Noel & Liub, 2017). Interestingly, the reality of integrating systems thinking pedagogy into the current requirements of the educational system was not addressed with many specifics. Possible systemic barriers, like scripted curriculum, regimented schedules, and standardized tests, were mentioned but not addressed in-depth (there was one breakout session that focused on standardized writing assessments was an exception), though they remain issues that most teachers will continue to face.

The discourse of systems thinking pedagogy also esteemed students as natural systems thinkers. It encouraged teachers to build on students’ “natural” abilities to think about the world (Curwen et al., 2018; Koski & De Vries, 2013; Senge et al., 2000), instead of forcing them into a mechanistic worldview that attempts to explain the world by analyzing its parts (Capra & Luisi, 2014). The participants asserted their belief that, if students lack understanding of systems (Ben-Zvi Assaraf & Orion, 2010; Hmelo-Silver et al., 2007), it is not because they do not have the ability but because their inherent abilities to understand systems have gone unnurtured—or even squashed. From this perspective, beginning systems thinking pedagogy in primary schools is

important not only because young students can develop systems thinking (Ben-Zvi Assaraf & Orion, 2010; Danish et al., 2017) but because schools should foster students' natural abilities.

This study provided a view of both teachers and learners as capable academics who work as researchers and theorists, learning alongside one another. This reflects the findings in classroom studies on systems thinking pedagogy in which students and teachers worked together to understand and develop solutions to statewide drought (Curwen et al., 2018) and modern-day slavery (Curwen et al., in press). Such collaborative learning is empowering for both teachers and students (Ardell & Curwen, 2019). Teachers and learners both were considered capable academics whose thinking added to the collective's growth.

Privileging the Language of "Becoming"

The "realized" world (Berger & Luckmann, 1966) of the institute was one of "becoming" a systems thinking teacher. The teachers' language of shifting, moving, and transforming placed them in the process of change. While they had the words to explain their beginnings of "becoming" a systems thinking teacher, they did not use the language of "ending" or "arrival." The teachers discourse suggested that the goal was not to reach an "end," but instead to make continual movement within becoming a systems thinking teacher.

"Becoming" a systems thinking teacher involved ways of talking and knowing that allowed teachers to be recognized by others as "systems thinking teachers." Such recognition did not require being finished with learning about systems thinking, but using specific concepts, language, objects, times, and places (Gee, 1999). The ways of identifying oneself as a systems thinking teacher included posting systems maps and principles on the walls, spending class time in discussion, connecting places inside and outside the classroom, asking open-ended questions, addressing broken systems and addressing beauty.

Another way that these teachers framed themselves as still "becoming" was in their use of language connected to the future (Gee, 1999). The teachers described using systems thinking pedagogy as having the potential to enact change both in classrooms, communities, and the world. The teachers, through talk of systems thinking and pedagogy, "built a future together" (Gergen, 1998) that focused on appreciating the world and using systems thinking to address its problems.

This process toward "becoming" was both planned for and spontaneous during the institute. For example, the institute's facilitators planned for the participants to begin shifting toward "both/and" thinking. The shift in emphasis from brokenness to beauty was spontaneous as both attendees and presenters responded enthusiastically to the words of Stacy, when she presented on her own classroom and evolution as a systems thinker.

Reflecting this quality of "becoming," the institute's systems thinking pedagogy was recursive and non-linear, with learners returning continually to previous learning to reflect and revise. Current curriculum in school subjects is traditionally linear or spiral, focusing on movement toward new material and mastery of old material. In contrast, systems thinking pedagogy emphasized a continual recursive process of learning by regularly revisiting, revising, and re-learning "old learnings." Learning is never "finished," but is instead in a continual state of being increased, enhanced, and connected to other learning. This sense of "ever-becoming" was evidenced in the institute's plans to continue professional development with the attendees throughout the next school year.

Important to this discourse of "becoming" was the framework of social constructionism on which the systems thinking pedagogy was built. We used social constructionist theory to consider how the pedagogy of systems thinking was communicated throughout the institute,

looking at the purpose of activities and the order of the activities. We did not realize how much the consultants directly combined constructionism and systems theories to create a pedagogy until we were analyzing the data. According to constructionist thought, to really know something means to be able to "recognize patterns…and act on" them "in a range of contexts" (Gee, 1999, p. 51). Instead of using direct instruction to move linearly through the curriculum, the institute facilitators designed the institute to have participants construct ideas from hearing stories, discussing ideas, making maps, finding patterns, generalizing principles, and reflecting together. The facilitators frequently did not use direct instruction to teach systems thinking and its principles because they wanted the teachers, like their students, to construct their understandings and "negotiate" meanings together. This combination of systems thinking with constructionism provided the basis for centralizing discussions and maps as the core activities of the pedagogy. The participants constructed (Berger & Luckmann, 1966) their systems thinking understandings and then applied them to their pedagogical understandings and beliefs, gaining skill in both areas simultaneously by tying assembled understandings to real situations (Gee, 1999).

Privileging Collectivity: Classrooms and Curriculum as Points of Leverage

The participants imagined several different collectives: the teachers in the institute, the teachers and students in a classroom, and the integrated curriculum. The power of these collectives was a point of leverage (Meadows, 2008) for teachers both to balance an educational culture that emphasizes individuality and to disrupt rigidity in what counts as curriculum. Acknowledging these collectives is a small change that has a potentially large impact in teaching and learning.

The collective learner: Power in combined strength. Working together, having discussions, and building on one another led to the emergence of a collective learner at the

institute that mirrored what the experienced teachers had encountered in their own classrooms. In a time when a continued "hot topic" in education remains the need to differentiate instruction (International Literacy Association, 2018), the teachers in the systems thinking institute recognized the power in developing the classroom collective learner while simultaneously providing "variable entry" points for diverse learners (Davis et al., 2015, p. 219).

This idea, on the surface, seems counterintuitive to the personalization of curriculum; however, the use of "both/and" thinking demonstrates that the two methods can coexist. Nurturing the development of the collective learner did not replace differentiated instruction; instead, it provided space for teachers to talk about bringing learners together in community while also differentiating for individual learners. This recognition of the collective reflects the systems principles of relationship and synthesis (Capra & Luisi, 2014; Davis et al., 2015), which are a needed balance to the current educational principles of individuality, differentiation, and analysis (Bertram, 2012; Capra & Luisi, 2014; Davis et al., 2015). The teachers still considered students' individual needs, and they shared ways in which systems thinking pedagogy had been both culturally relevant (Ladson-Billings, 1995) and inclusive of diverse learners (Curwen et al., in press).

The balance was modeled throughout the institute, with teachers spending time in discussion but also having time to ask individual questions, adapting systems thinking pedagogy for different students, and working in small groups on areas of need and interest. The teachers did not focus solely on the current emphasis of individual needs. Instead, they used the idea of the collective as a point of leverage (Meadows, 2008) to balance individualization with the development of a community. The collective was comprised of individual learners that became stronger together in dynamic conversation.

The integrated curriculum: Transdisciplinary power. A parallel collective emerged in talk about the curriculum. The discourse of systems thinking pedagogy disrupted the rigidity in the current educational "cultural model" (Gee, 1999) of curriculum and replaced it with integrated, organic curricula developed by teachers alongside their students.

The teachers described a collective curriculum that was a holistic "transdisciplinarity" (Davis et al., 2015) instead of multiple, artificially separated subjects divided into discrete times of the day. According to the teachers, mapping organically allowed for discussion and the emergence of the systems principles. The institute leaders modeled an organic, integrated systems mapping curriculum during the four days of the institute (Ardell & Curwen, 2019; Curwen et al., 2018). This mapping supports other research stressing the necessity of mental models (Hmelo-Silver et al., 2017; Senge et al., 2000) as conceptual representations of systems thinking and curriculum integration.

The consultants and experienced teachers employed open-ended questioning to integrate subjects across the systems maps. Their open-ended questions included questions about distinctions, systems of part-whole, relationships between ideas, and taking different perspectives (Cabrera & Cabrera, 2015). Other studies have shown the effectiveness of using open-ended questions to encourage deep thinking about complex topics (Ardell & Curwen, 2019). Posting the questions on the walls of the institute made them a part of the curriculum as much as the content knowledge on the maps and the systems thinking principles.

There was, however, some tension in the discourse about mapping the curriculum: some teachers proposed the idea of having a map with a central question that would guide the whole year, while others described using multiple "central" questions. The model of multiple but connected "central" questions reflects the current understanding of complex learning as a

decentralized network structure (Davis et al., 2015). The topic, in the end, remained open for personal choice.

The teachers emphasized the importance of including student involvement in solving social and political problems as part of the curriculum (Cabrera & Cabrera, 2015; Capra & Luisi, 2014; Davis et al., 2015). The inclusion of social justice (Curwen et al., 2018; Rong, Unger, & Scullion, 2014) as a part of the constructed pedagogy was evident in the ways the teachers enacted interactions (Gee, 1999) with the community and their invitation of a social justice guest speaker. While taking up social justice, environmental issues, and community involvement was a key purpose of the pedagogy according to the participants' discourse, it is a purpose not foregrounded in all studies of systems thinking in the classroom.

Implications

This study contributes to the field of professional development by highlighting the value of teaching community in addressing the needs of teachers in a professional development institute. The structure of the systems thinking institute allowed teachers to experience the systems thinking principles of interconnectedness and relationship (Capra & Luisi, 2014). The time spent in discussion was time spent constructing shared knowledge (Gergen, 1999) when the teachers could learn and adjust their thinking. Importantly, time spent in group conversations was time for teachers to continue "becoming." By adopting a "becoming" mindset, with expectations of growth instead of perfection, the institute modeled recursive learning (Davis et al., 2015). In contrast, one-time professional developments rarely provide the time necessary for teachers' "becoming," especially when learning complex content and pedagogy like systems thinking. In this vein, there is power in having experienced teachers serve as facilitator as well as

learning alongside attendees, as it emphasizes the importance of "becoming" rather than mastering material.

The transdisciplinary nature (Capra & Luisi, 2014; Davis et al., 2015) of systems thinking and its potential for nurturing the connections between students and the world highlight the significance of integrating systems thinking across all subjects (Ardell & Curwen, 2019), not only the sciences. "If your aim is to change society," wrote Myles Horton (1997), "you have to think in terms of which small groups have the potential to multiply themselves and fundamentally change society" (p. 57). The more students and teachers can understand interconnectedness (Capra & Luisi, 2014), the more they can address problems in both social and natural systems (Cabrera & Cabrera, 2015).

To understand the potential of developing teacher understandings of systems thinking pedagogy, future research could explore teachers' short-term and long-term implementation of the pedagogy. Additionally, examining the dynamics of the planned long-term mentorship of the teachers from this study could offer an extended understanding of the dynamics of "becoming" systems thinking teachers.

Conclusion

The systems thinking pedagogy used and developed by the facilitators and teachers in the institute is one that created a learning culture that privileged teachers and students as capable academics, valued learning as "becoming," and honored the collective as emerging from individual parts.

The teachers shared in the discourse of systems thinking pedagogy, situating meanings about many educational ideas. Their discourse integrated social construction and systems thinking into a cultural model of systems thinking pedagogy. Overall, the teachers' development

of systems thinking pedagogy discourse disrupted the bigger "storyline" (Gee, 1999, p. 44) of Western education. Their constructed pedagogy shifted situated meanings around the complex identities of teachers and students and emphasized the importance of creating an emergent integrated curriculum together. Additionally, their discourse cultivated professional development as a place for teachers to learn alongside each other as they developed a pedagogy that can help them and their students prepare to face wicked problems.

"Everything's Connected": Using Systems Maps to Introduce Systems Thinking

Systems thinking? [First Author] was not introduced to the idea until one year ago. [Second Author] started investigating it just a few years ago. Now, however, we recognize its potential to engage teachers and students in deep discussions about the complexity of life. The prevalence of systems thinking is growing in schools, especially science classrooms, because of its inclusion in the Next Generation Science Standards for all ages (NGSS Lead States, 2013). Beginning in kindergarten, students are expected to track patterns across time, argue how humans and animals can change the environment to fit their needs, and compare sustainability solutions.

So, what is systems thinking? It is an inherently transdisciplinary understanding of life as complex networks of relationships, patterns, connectedness, and context (Davis, Sumara, & Luce-Kapler, 2015). For example, a school is an interdependent system that requires multiple interacting parts. Systems thinking is a focus on holistic, contextual views of life that emphasizes the connections and interactions of systems components (Capra & Luisi, 2014).

Learning to think in systems is a process (Ben-Zvi Assaraf & Orion, 2005). While systems thinking is often considered a higher-order thinking skill (Ben-Zvi Assaraf & Orion, 2010), young children are able to do this type of thinking (Ardell & Curwen, 2019; Danish, Saleh, Andrade, & Bryan, 2017). We have research that demonstrates the potential for student learning about complexity (Ben-Zvi Assaraf & Orion, 2005, 2010) in science (Hmelo-Silver, Jordan, Eberbach, & Sinha, 2014) and social systems (Curwen, Ardell, MacGillvray, & Lambert, 2018) in classrooms of all ages (Brandstädter, Harms, & Großschedl, 2012; Hipkins, Bull, & Joyce, 2008).

Systems thinking seems to be learned in stages (Ben-Zvi Assaraf & Orion, 2005, 2010; Hmelo-Silver, Marathe, & Liu, 2007). The first stage involves understanding the wholes and parts that make up systems (Ben-Zvi Assaraf & Orion, 2005; Cabrera & Cabrera, 2015). Closely related to the whole-part relationship, the second and third stages involve gaining understandings of the different relationships—first simple ones and later more complex ones—between the system components (Ben-Zvi Assaraf & Orion, 2005; Cabrera & Cabrera, 2015; Hmelo-Silver et al., 2007). One pedagogical strategy for introducing these stages—recognizing a system as comprised of a whole and its parts and then identifying the relationships between the parts—is to introduce systems mapping.

The mapping method we will describe here came from research we conducted on a professional development institute on systems thinking (Goode, Bailey-Tarbett, & MacGillivray, 2019; Goode & MacGillivray, 2019). The four-day professional development was led by experienced systems thinking teachers who described using systems maps regularly in their classrooms. During the institute, systems mapping was the central activity for introducing any learner—including teachers—to systems thinking pedagogy.

Systems Maps: An Overview

Systems maps are one kind of graphic organizer that document systems thinking. They often look like webs: they begin from a central question, object, or event and move outward to document the components and connections surrounding the central item. Systems maps are similar to other mapping techniques in that they provide a visual representation of ideas. However, they differ from traditional graphic organizers because they are generated by students during class discussion (Stull & Mayer, 2007). They are also distinct from similar web graphic organizers, like those created with Thinking Maps (Hyerle, 2008), because the emphasis is not

on organizing information, but on student discovery of complexities in relationships within (and between) natural and social systems. Additionally, this method of systems mapping emphasizes revising the maps repeatedly as new learning occurs. With this method, the maps are organic because the students are not given pre-determined parts to arrange as a system; instead, the map parts are written down as students discuss the system. Maps on the same topic may look different from classroom to classroom as different students emphasize different system components and relationships and have varying conceptions of what makes up a particular system (Checkland, 1994).

Systems maps can take different forms with different names, like network maps (Davis, et al., 2015), part-whole diagrams (Cabrera & Cabrera, 2015), or semantic networks (Senge et al., 2000). They are written artifacts of classroom discussion (Cabrera & Colosi, 2009) about the networks of relationships in a system (Curwen et al., 2018); one teacher in the institute described them as a "conversation on paper." All systems maps document thinking about structure and function: the parts of a whole, the parts of the parts, the relationships between the parts and the whole, and the relationships between the parts themselves.

Using systems mapping is a pivotal classroom activity to begin systems instruction because it provides a foundation for all systems thinking. Systems mapping helps students with content learning (Danish et al., 2017), problem-solving (Curwen et al., 2018), perspective-taking (Ardell & Curwen, 2019), and vocabulary development, notably with English Language Learners (Curwen, Ardell, & MacGillivray, in press). Importantly, systems mapping helps students make connections between their own lives and the curriculum (Ardell & Curwen, 2019), which is vital to engaging students in learning (Egbert & Roe, 2014; McMahon & Portelli, 2004; Schultz, 2008).

During the institute, the teachers learned that systems mapping does not come as a packaged curriculum; it is a context-based product of interactive class discussions. Completing these maps during class discussion is critical (Curwen et al., in press), because the combination of oral and written exchanges provides the space for students "to make their ideas visible while being malleable and available for discussion, which enables students to make meaning out of systems" (Hmelo-Silver et al., 2017, p. 53). Because maps are a student-teacher collaborative activity (Ardell & Curwen, 2019), teachers are integral for developing systems thinking in the classroom (Cabrera & Cabrera, 2015; Chinn, 2017; Davis, et al., 2015; Hipkins et al., 2008; Hmelo-Silver et al., 2007). Completing systems maps with students is one way for teachers to develop their skills along with their students' skills (Goode & MacGillivray, 2019).

In what follows, I will use one of the maps the participants created about a broken pencil (Figure 5) to explain how teachers and learners can co-produce systems maps that reflect their systems thinking. During the institute, one person served as map leader, asking questions to prompt the participants; a second person served as map scribe, recording the responses on large sheets of butcher paper posted. I will give suggestions for beginning a first map, expanding the map, and later revising the map, all of which are important pieces to implementing systems thinking pedagogy.

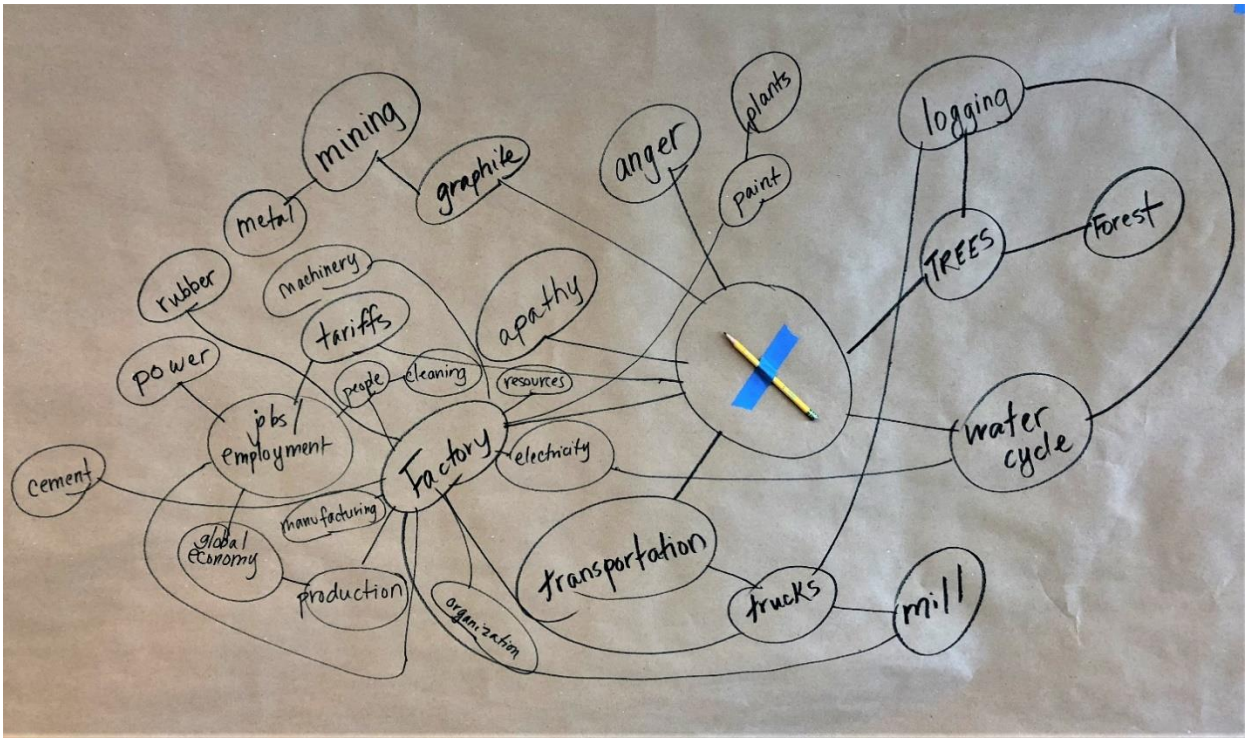

Figure 5: A systems map created by a group of teachers during a systems thinking pedagogy professional development.

Beginning the Map

In the institute, it was stressed that teachers can introduce systems thinking at any point in a unit of study. There is no need to do any lessons about systems thinking before beginning the first map; the ideas will emerge from the discussion. As teachers use the word "systems" when talking to their students, the students will begin to construct an understanding of what "systems" are. To begin the first systems map, teachers need a large space to write, like a piece of butcher paper or a white board. Then, the teachers select an item or event familiar to them and their students. Some suggestions from the experienced teachers in this study included using a "favorite thing" for the center of the first map, an activity such as taking a walk, or a classroom read-aloud. During the institute, a second-grade teacher shared a map that started with a carrot because the class had been studying gardens; a first-grade teacher used the ocean because it tied

into the social studies unit. For the map above, one of the institute consultants used a broken pencil as the center of the map during a whole-group activity.

According to the institute facilitators, the goal of the first systems map is to get students to conclude on their own that everything is connected. The first step is to get them talking. So, once teachers have the center item and paper, they pose a question to their students about the item. For example, if the teacher is using a favorite object, they might ask, "Where did _____ come from?" Similarly, if using an activity like a neighborhood walk, they might ask, "What did you notice while we were _____?" For the broken pencil map, the first question posed was, "What do you think…created that pencil?" Below is a snippet of the discussion that followed the initial question:

> Teacher Participant (TP) 1: "Forests. Water Cycle."
> TP 2: "Are you talking about the broken pencil or a whole pencil?"
> Group Leader (L): "We have both kinds."
> TP 2: "Trees."
> Map Scribe (MS): "Where do you want that to go?"
> TP 2: "Over there [with forests]."
> L: "Okay, so we have forests, the water cycle, and trees. What else?"
> MS: "Wait, do you want the water cycle to go up here or separate?"
> TP 1: "Down there. On its own."
> TP 3: "What about the not-caring system? For the broken pencil?"
> TP 4: "The apathy system."
> MS: "Okay, where does that go?"
> TP 5: "The anger system? Someone broke it?"
> L: "Okay, what other systems created this pencil?"
> TP 6: "Transportation?"
> L: "Okay, do you want to say a little more about that?"
> TP 6: "Uh, yeah, because it had to get from one place to another for, uh, consumers to buy it. For the children to have it."
> MS: "What system did you say?"
> TP 6: "Transportation." [gestures to the open space on the left side for placement]
> L: "So how did they get transported?"
> TP 6: "It could be by….trucks?"
> L: "Okay, so truck. Is that a system?"
> TP 7: "The truck system?"
> TP 6: "Well, when I said transportation, that would include the trucking system."

MS: [draws a line from trucks to transportation]
L: “Okay, where did they come *from* on the trucks?” [calls on a TP with a hand raised]
TP 8: “Well, I was going to talk about the manufacturing system. So, after the forest and before the transportation it had to be transformed from raw materials into a product. So, um, in between the forest and trucks, I guess?” [gestures to the map]
L: “Okay, so you’re saying the factory system? And so do the trees go straight to the factory?”
TP 9: “The logging system.”
L: “Ah, the logging system. So what system is the logging system a part of?”

The example shows how, from one question, the conversation expanded quickly into many topics. As teachers responded, the scribe wrote them down and used lines to connect them appropriately. The broken pencil system map above included factories, transportation, trees, and water as the main responses about the system, so those were connected to the broken pencil in the center. As students respond with ideas, the teacher’s primary role at this point is to record the ideas on the map, branching out to include the suggestions from learners about what is “connected to” and “a part of” the system. To prompt students’ responses, the teacher asks questions.

Using Questions to Prompt Students

As the teacher records the students’ ideas, their other role is to act as questioner. Asking open-ended questions is critical for developing systems maps. The discussion might seem unfocused at first because it is more reliant on students’ thinking than most traditional instruction; however, the teacher is guiding the discussion through their questions. The goal is to prompt students to think of as many of system components as they can, so they will begin developing their understanding of connections. To initiate conversation about the broken pencil system, the map leader asked questions like, “What else?,” “Where does that go?.” “Can you say more?,” and “What other systems are a part of that?”

Once students have identified some components, the teacher's questions can expand to asking about relationships between components as well as sub-components of the original components. The questions serve to deepen students' understandings of both a specific system and systems thinking. It is important that the questions remain open-ended (Buchanan, 2016) so students do the thinking. Open-ended questions provide prompting and support for students to make distinctions between systems components, identify influences on a system, and develop suggestions about the system (Curwen et al., 2018). Asking questions is the time when the instructor can scaffold (Wells, 1999) the discussion so learners can progress in their understandings about relationships between components as well as the relationships between wholes and parts (Ben-Zvi Assaraf & Orion, 2005). Students progress in their understandings of complex systems as teachers' questions become more sophisticated (Danish et al., 2017). Teachers should take time asking the questions and recording the students' responses; it is a way to show them they are a part of the classroom community (Goode & MacGillivray, 2019).

Questions asked during the broken pencil map included what people and natural elements are connected to the pencil; what the connection(s) between two components, like trees and transportation, might be; and what pencil factories included. The teachers agreed that learning to ask open-ended, strategic questions was challenging at first, and they also agreed it was valuable because, as one teacher stated, "Telling isn't teaching. Teaching is about thinking." They found that having a list of question stems was a helpful resource, and I am including a chart of open-ended question stems that the teachers produced during their practice (Figure 6).

What…		Who/Where…	How…
What are the systems in this?	What other connections does that have?	Who is a part of this?	How did/does that happen?
What happens next?	What else could you say about that?	Who would be there?	How do those things connect?
What do we call that?	What happens in between those parts?	Who would that affect?	How are those things similar/ different?
What does this need?	What other parts does that have?	Where does that come from?	How could that interrupt another system?
What would that affect?	What problems are in this system?	Who makes that decision?	How should that be mapped?
What comes into play with that problem?	What systems in our country does this connect to?	Where does that connect?	How would that happen?
What is the source of that?	What is something bigger/smaller than that?	Where have we seen this before?	How could this make an impact?

Figure 6: A chart of question stems useful for promoting student thinking while making a systems map.

Systems mapping in this manner takes some time to complete. Teachers should plan at least thirty minutes for the first session. One teacher explained that she initially thought that mapping was a waste of time when she saw the process demonstrated in her classroom because it seemed aimless and time-consuming; however, after watching her students become engaged she decided to try it, and it "transformed" her curriculum.

There are a few options for organizing systems maps. One option is to ask students where they would like their suggestions to be placed on the map. This helps to communicate to the students that the map is "theirs," and it reflects their thinking instead of yours. Other teachers suggested spending the first mapping session having learners "just throw out ideas," then

returning later to let the students revise the map's organization. The important thing is for teachers to know that this process might feel foreign at first but, with practice it feels natural.

Revising the Map

Systems map are not created and tucked away in a closet. They document the students' thinking at a certain point in time. Revisions to the map come as students continue to learn more about the system through activities such as classroom lessons, readings, experiments, or field trips. According to the experienced teachers in this case study, systems maps are "living documents" that need revising. It is "okay to return to maps over and over" because "understanding…deepens as we revisit them." One teacher explained that "it's important to signpost back" to the maps after learning activities, asking what needs to be changed on the map. The students work together to recursively revise the map as a collective. Using new learning as feedback for recursive revisions "strengthens neural pathways" (Davis et al., 2015, p. 215).

Importantly, returning to the maps provides time to strengthen their systems thinking skills of understanding connections and relationships between the components. Students can go back to the maps to add to, remove from, and adjust them, showcasing how their thinking has changed. By continually revising maps, students develop a deep understanding of the notion that "everything's connected" and they begin to understand wholes, parts, and the relationships. They also begin to develop key understandings about other systems principles, such as systems energy and emergence.

For example, when making the broken pencils systems map, the discussion stopped when the map leader prompted, "Tell me more about logging." One participant admitted she did not know much about it, and others agreed. The teachers explained that, in the classroom, this would be a possible direction for future lessons. In this way, the process of mapping also provides

points of interest as possible topics for future learning. For example, the teachers in the institute spent a lot of time discussing factories, wages, and the global economy as they completed the broken pencil map. In the classroom, teachers can take these opportunities to use students' natural interests to engage them in learning (Egbert & Roe, 2014; McMahon & Portelli, 2004).

The teachers emphasized the need to leave the maps posted on the walls. In fact, one presenter brought over a dozen maps from her classroom walls that related to literature the students read during the year. By leaving the systems maps on the walls, they become a resource for students to revisit often "to deepen their investigations individually and collectively" (Curwen et al., 2018). This type of recursive elaboration (Curwen et al., 2018) teaches thinking as something that develops over time, nonlinearly, with making and correcting mistakes a natural part of the process. Additionally, the process of recursively revisiting maps provides a natural way to return to a topic if students need more practice.

Conclusion

Mapping provides an entry point for improving teacher and student understandings of systems thinking. While systems mapping was challenging for the teachers in the beginning, with practice they described it as "life-changing" and "inspiring." The teachers at the institute reported the process of mapping was one way "to develop systems thinkers." The topics are up to the individual teacher. The institute participants gave examples of the water system for first graders, the immigration system for third graders, and the systems in a novel for fourth graders. The task of integrating systems thinking into one's practice can feel daunting. However, mapping is one easy entry point that can have a great impact on the student thinking.

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Appendix A

Facilitator Interview Guide

Before Institute:

- What was the impetus for this teacher-led institute on systems thinking?
- What did the planning look like?
- How do you think your role as a teacher has impacted the designing/planning of this workshop? (if appropriate)
- How did you decide the program structure/schedule/topics/speakers/activities?
- How did you recruit teachers to be a part of the institute?
- What are your goals for the PD?
- What do you hope to gain from the workshop?
- What do you think are the most critical understandings attendees must gain in order to understand systems thinking pedagogy?
- What is your understanding of the role reading, writing, listening and speaking in systems thinking pedagogy?

During Institute:

- How is the workshop going?
- What insights have you had about the planning and implementation so far?
- How do you think the information is being received by the attendees?
- What changes (if any) are you currently making?
- Is there a moment of learning/insight that stands out to you?
- What activities/interactions provided new insights into professional development?
- What activities/interactions provided new insights into systems thinking pedagogy?
- Please describe your experience of teaching other teachers.

After Institute:

- What was your overall impression of the institute?
- Is there a moment of learning/insight that stands out to you?
- What was a challenge that you faced as an instructor?
- Upon reflection, what do you think attendees understand about systems thinking pedagogy?
- What is your understanding of the role reading, writing, listening and speaking in systems thinking pedagogy?
- How did the institute impact your own understandings of systems thinking pedagogy?
- What kind of support do attendees need in the future to continue to develop their ability to implement a systems thinking pedagogy?
- What was the impact of having teachers design, plan, and implement the institute? And what are the ramifications for continuing professional development?
- Is there anything else you would like to share?

Appendix B

Attendee Interview Guide

Before Institute:

- What brought you to this professional development?
- What do you know about systems thinking?
- What do you hope to gain from this PD experience?
- What were key components of your language arts instruction in the past?
- How have you integrated reading, writing, listening and speaking across the curriculum?

During Institute:

- What are you learning about systems thinking?
- How is this PD the same/different than other PD you have experienced?
- How are your developing understandings of systems thinking similar/different than your teaching style/philosophy/ pedagogy?
- What are you learning about yourself as learner and educator?
- Please describe a moment of learning/insight that stands out to you.
- Please describe your experience of attending a professional development designed and conducted by teachers.

After Institute:

- What did you learn about systems thinking?
- What activity, discussion, reading was pivotal to your learning?
- What did you learn about yourself as a learner and teacher?
- What short-term and long-term goals do you have in relation to systems thinking pedagogy?
- How might you implement systems thinking pedagogy in your classroom?
- What supports and challenges will impact your ability to implement a systems thinking pedagogy?
- What kind of support do you and other attendees need in the future to continue to develop their ability to implement a systems thinking pedagogy?
- What was the impact of having teachers design, plan, and implement the institute? And what are the ramifications for continuing professional development?
- Is there anything else you would like to share?