Young Children’s Authentic Inquiry Practices

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Abstract

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This dissertation is comprised of three interlinked studies investigating young children’s authentic inquiry practices. The first article provides a literature synthesis of over two hundred and fifty in-depth cases of K-6 facilitated authentic inquiry learning environments. These cases reveal the wide-ranging authentic inquiry practices that are a vital feature of the inquiry process including the practices young learners use to conduct research, organize their workload, motivate each other, collaborate together, innovate upon practices, and promote equitable learning conditions. The second article investigates how young learners leverage each of the above practices to advance their collective inquiry on a novel and complex project in an afterschool learning environment called Mancala Club. The third article, an extension of the second, empirically examines the moment-to-moment interactional moves that young learners used to re-mediate relations of power, affect, social positioning, and spatial orientation in Mancala Club in order to promote more equitable learning conditions for themselves. Taken together, these articles demonstrate that the process of authentic inquiry is holistic and contentious, yet within-the-grasp of young learners. These findings push back on dominant models of what counts as an inquiry practice and what counts as competency, especially for young children.

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DEDICATION

In memory of Drew Chapin

Introduction

Inquiry-based learning is increasingly championed as a way to make education much more authentic to the complexities of real-world problems, to the interests of learners, and to the practices of professional researchers (Shaffer & Resnick, 1999). As such, proponents argue that authentic inquiry is more meaningful for learners, better prepares them to face collective open-ended real-world problems, and helps to develop their 21st century skills compared to traditional approaches (Barron & Darling-Hammond, 2008; Hmelo-Silver, Duncan, & Chinn, 2007; Voogt & Roblin, 2012). Yet, few studies have systematically investigated what it takes for young learners to be successful in these settings. Specifically, what kinds of practices do young learners actually leverage to support and sustain their authentic inquiries? Furthermore, how do young learners work to productively navigate the tensions and conflicts that are inherent in any open-ended and collective process?

Studies that systematically take on these questions can reveal a layer of work that young learners perform to advance their collective inquiry that is under-recognized yet vital to the inquiry process (Jennings & Mills, 2009; Kafai & Peppler, 2011; Takeuchi, 2008). A working list of young learners' authentic inquiry practices can inform theory-level discussions around what counts as an authentic inquiry practice and what counts as competency. It can also inform practice-level discussions around how best to support learners to be successful in inquiry-based settings. It can also inform policy-based discussions around the viability and value of the inquiry-based learning model. Making visible the layer of work that young learners perform during the inquiry process, then, is a necessary and important step to not just better understanding inquiry-based learning, but to better appreciate the under-recognized capabilities and competencies of young learners as inquirers.

These issues are addressed in a series of three research articles that are designed to successively build a substantive and holistic portrait of young learners' inquiry competencies and capabilities. The first article presents a synthesis of the current research literature on the manifold challenging learning practices that authentic inquiry activities entail of elementary age children. This dialogue with the research literature lays the groundwork for the second manuscript, an empirical analysis that attends to how a specific community of learners simultaneously encounters and addresses the challenges of research, organization, motivation, collaboration, innovation, and equity while working on a specific authentic inquiry task. The final article, extends this empirical analysis by zooming in on one particularly rich interactive hour-long session of the inquiry process in the above study to reveal the work that young learners performed to re-configure contentious relations of power, affect, social positioning, and spatial orientation that had, at the beginning of the session, constrained their agency and authority as inquirers.

These two empirical pieces complement one another by providing a holistic survey of young learners' in-situ attempts to meet the challenges of authentic inquiry and by offering a fine-grained account of how young learners came to navigate and transform contentious relations of power, affect, and social forces that underlie and shape the possibilities of who gets to use which inquiry practices to what ends.

Taken together, these articles make visible the ways in which authentic inquiry is a holistic and contentious process that is challenging, yet within-the-grasp of young children. The resultant list of authentic inquiry practices that occur both across learning environments and within the learning environment featured in these studies provides a working understanding of what it takes for learners to be successful in authentic inquiry learning environments. The theoretical orientation, study design, and findings of each research article are described in the synopses below.

Article 1: Young Children's Authentic Inquiry Practices: A Literature Synthesis

This literature synthesis examines the range of practices that young learners leverage to advance their collective inquiry. 267 research studies that present in-depth and typically socio-culturally informed cases of young learners in facilitated authentic inquiry learning environments were compiled. A thematic analysis across these research studies reveals a vast array of authentic inquiry practices that young learners perform in order to support and sustain their work. These practices form a holistic ecology in which learners perform inquiry by conducting research, organizing their workload, motivating each other, collaborating together, innovating upon resources, and promoting equitable learning conditions. Taken together, the authentic inquiry practices identified in this study reveal a wide-ranging yet under-recognized layer of work that young leaners perform in order to support and sustain their investigations. These findings present an expansive view of inquiry that treats inquiry as a holistic process rather than as a set of research tools and techniques to be mastered. Likewise, these findings present a viable alternative to dominant models of competency that focus solely on discipline-specific or cognitive-general outcomes. Competency, across these research studies, can be found in the resourceful ways that young learners leverage a wide range of practices in order to advance their collective inquiry.

Article 2: Authentic Inquiry as a Holistic Accomplishment in Mancala Club

This empirical study makes visible the wide-ranging learning practices that young learners developed as they worked on an authentic inquiry task within the context of an afterschool game-based learning environment called Mancala Club. The analytic resources of Activity Theory were used to empirically investigate the mediators that facilitators of Mancala Club used to support learners, the ways that learners drew upon and innovated upon these mediators to support their inquiry, and how this work transformed learners' ways of knowing, doing, and being in the process. Findings illustrate the ways that young children within the context of Mancala Club developed the following authentic inquiry practices to support their extended inquiry: Conducting investigations, negotiating inquiry norms, interpreting phenomenon, managing investigations, documenting work, enhancing workflow, taking interest, engaging feelings, navigating fragility, coordinating joint work, constructing meaning, building trust, generating novel insights, building capacity, iterating progressively, expanding who gets to participate, expanding who benefits from participation, and expanding what counts as valued participation. By making visible these learning practices (rather than focusing on cognitive-general or discipline-specific outcomes) this study pushes forward theoretical conceptualizations about young children's competencies and capabilities as inquirers while also providing guidance for practitioners on how to support the development of these manifold authentic inquiry practices in similar informal game-based authentic inquiry learning environments.

Article 3: Authentic Inquiry as a Contentious Accomplishment in Mancala Club

Authentic inquiry learning environments have been heralded as equitable alternatives to traditional learning environments for engaging learners in collective and meaningful inquiry work. Yet, scholars are increasingly making visible the ways that power dynamics and social interactions within these contexts work to constrain, undermine, and de-legitimize learners' authentic inquiry practices (i.e. Bang, Warren, Rosebery, & Medin, 2012; Esmonde & Booker, 2016; Langer-Osuna, 2016; Leander, 2002; Warren & Rosebery, 2011). Drawing on the theoretic resources of Activity Theory and Critical theory this study investigates three interrelated dimensions of equity that are relevant to participation in authentic inquiry practices: equity as the expansion of who gets to participate, equity as the expansion of who gets to benefit from participation, and equity as the expansion of what counts as valued participation in the first place. Using conversation and interaction analysis, this empirical study analyzes the work that a group of four 3rd and 4th graders performed to expand equitable interactions within an authentic inquiry learning environment called Mancala Club. Findings indicate that young learners can productively expand equitable interactions through specific moves that worked to re-configure and interrupt relations of power, affect, spatial orientation and social positioning that had, at the beginning of their cooperative work together, severely limited the opportunities for each learner to engage in authentic inquiry practices. The results attest to the capabilities and competencies of young learners who can work together to build relational equity and productively engage in authentic inquiry practices. The results also support practitioners in becoming more attuned to how the dynamic and contentious interactions between power, affect, spatial orientation and social positioning work to expand or restrict equitable moment-to-moment interactions in authentic inquiry learning environments.

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Article 1

Young Children's Authentic Inquiry Practices: A Literature Synthesis

Abstract

This literature synthesis examines the range of practices that young learners leverage to advance their collective inquiry. 267 research studies that present in-depth cases of young learners in facilitated authentic inquiry learning environments were compiled. A thematic analysis across these research studies reveals a vast array of authentic inquiry practices that young learners perform in order to support and sustain their work. These practices form a holistic ecology in which learners perform inquiry by conducting research, organizing their workload, motivating each other, collaborating together, innovating upon resources, and promoting equitable learning conditions. Taken together, the authentic inquiry practices identified in this study reveal a wide-ranging yet under-recognized layer of work that young leaners perform in order to support and sustain their investigations. These findings present an expansive view of inquiry that treats inquiry as a holistic process rather than as a set of research tools and techniques to be mastered. Likewise, these findings present a viable alternative to dominant models of competency that focus solely on discipline-specific or cognitive-general outcomes. Competency, across these research studies, can be found in the resourceful ways that young learners leverage a wide range of practices in order to advance their collective inquiry.

Introduction

How competence is conceptualized holds serious implications for educational theory and practice. Whether, for instance, competence is located in an individuals' recognized status, performance outcomes, or innate abilities changes who competency is ascribed to and how educators go about supporting learning (Hall & Stevens, 1995). Researchers who study learners' in-situ practices have begun to trouble these conventional locations of competency, demonstrating the tenuous nature of such constructs as status recognition (Gresalfi, Martin, Hand & Greeno, 2009), performance outcomes (Metz, 2011; Rogoff & Lave, 1984), and innate abilities (Chambliss, 1989). Rather than illuminating learners' competencies, scholars argue that these conventional locations of competency create deficit-thinking about learner's competencies (Engeström, 2011;

Flores, Cousin & Díaz, 1991; Hedegaard, 2012; Keifert & Stevens, 2019; McDermott & Varenne, 1995; Nasir, 2011; Valencia, 1997).

In place of these constructs, sociocultural researchers advocate for locating competency in the interactional and historical achievements of learners' in-situ practices (Edwards & D'Arcy, 2004; Engle & Conant, 2002; Gresalfi et al., 2009; Rogoff & Lave, 1984; Scribner & Cole, 1978; and many others). Under such a view, if learners lack expert status, performance mastery, or innate talent, they can still competently contribute to the collective activity of their shared endeavors. Yet, if this practice-based account of competency is to be a viable alternative to the conventional locations of competency it needs to be further developed in ways that continue to make visible learners' in-situ practice-based competencies.

One meaningful direction for developing accounts of learners' competencies that sociocultural scholars have identified is to create a more holistic vision of learners' inquiry practices. Scholars argue that only attending to the cognitive dimensions of inquiry practices or conceptualizing them as a series of research practices alone unnecessarily limits the scope of learners' inquiry work (Carlone et al., 2016; Edelson, 1998; Herrenkohl & Mertl, 2010). For example, Edelson (1998) points out, "in adapting science practice to the classroom, it is seductively easy to focus on scientific knowledge, tools, and techniques at the expense of other elements of scientific practice. However, scientists' attitudes and their social interactions are also defining features of scientific practice." (319). These arguments draw on and echo Vygotsky's vision for unifying the intellectual with the practical and affective dimensions of learning and development (1987/1934; see also Roth & Jornet, 2017).

Yet, despite the calls to create a more expansive view of inquiry practices, systematic attempts to formulate a working list are rare in the research literature. Three pre-existing systematic attempts to craft a taxonomy of inquiry practices that went beyond research practices were found (Jennings & Mills, 2009; Kafai & Peppler, 2011; Takeuchi, 2008). First, Lori Takeuchi (2008; see also 2010) presents a working list that she empirically derives from a year-long study of professional marine biologists in the field as well as studying students in an oceanography classroom. Her taxonomy identifies 45 different scientific practices organized by the frequency. Examples of the identified scientific practices that go beyond conventional research practices include "camaraderie," "save time and resources," "connecting the study to a world issue," "put safety first," and many others. Takeuchi invites scholars to continue building on her list by using empirical approaches that are longitudinal (to capture a complete cycle of inquiry) and/or focused on research sites of other natural scientists.

Second, Louise Jennings and Heidi Mills (2009) systematically and empirically examined the discourse in an inquiry-based elementary classroom over 5 years. Their resulting list of 18 codes feature practices that go beyond conventional research practices such as "celebrating" (classmate's achievements), "shifting perspectives," "strategy sharing," "social action," and many others. Like Takeuchi, Jennings and Mills view their taxonomy as a starting point and they call for researchers to investigate inquiry practices in additional contexts. Lastly, Yasmine Kafai and Kylie Peppler (2011) review the literature of youth who work on new media projects in affinity-based spaces (such as Scratch) to develop a list of participatory competencies. These include practices such as "debugging," "repurposing," "observing and deconstructing media," "connecting multimodal sign systems," and "crediting ownership." Although the contexts of inquiry differ—professional research sites (Takeuchi, 2008), facilitated inquiry-based learning environments (Jennings & Mills, 2009), and affinity-based settings (Kafai & Peppler, 2011)—taken together they paint a picture of inquiry as constitutive of intellectual, affective, and pragmatic dimensions.

The current study continues the work begun by Takeuchi (2008; 2010), Jennings and Mills (2009), and Kafai and Peppler (2011) by conducting a thematic analysis across hundreds of research articles that focus on the in-situ unfolding collective activity of K-6 learners in facilitated inquiry-based learning environments. The resultant list of inquiry practices makes visible the work young learners perform in order to conduct research, organize their workload, motivate themselves, collaborate with peers, innovate upon resources, and promote equitable learning conditions. The aim of such a list is not to exhaust all possible inquiry practices. Rather, it is to take an additional step forward to support both educational theory (by re-locating competency within the holistic achievements of young learners' inquiry practices) and practitioners (by making visible a holistic ecology of inquiry practices to be designed and supported for in inquiry-based learning environments).

Research Questions

This literature synthesis takes up the following two research question across the context of hundreds of cases of young learners' authentic inquiry work:

1. *What authentic inquiry practices do K-6 learners leverage to advance their collective inquiry in facilitated authentic inquiry learning environments?*

2. *What do these authentic inquiry practices tell us about young learners' capabilities and competencies as inquirers?*

To answer these research questions this study combines multiple methods—literature review, thematic analysis, and a dialectical process of discovery—in order to locate and make visible the authentic inquiry practices of young learners. A conceptual framework is provided to unpack the socio-cultural theoretical orientation of this investigation and to link it to the existing research base of what is known about (a) authentic and generative practices, (b) young children's capabilities and competencies as inquirers, and (d) holistic models of inquiry.

Conceptual Framework

Socio-cultural Perspective

This literature synthesis contextualizes young learners' inquiry competencies within the socio-cultural tradition. Under this view, inquiry practices are conceptualized as patterned ways of acting that (a) are situated within historical, social, and institutional relations (Cole, 1996; Lave & Wenger, 1991; Wertsch, 1991), and (b) resource specific beliefs, norms, rules, roles, and tools to achieve collective goals (Engeström, 2014; Leont'ev, 1981). Furthermore, this view posits that collective inquiry is a holistic, contentious, and cumulative achievement (Calabrese Barton et al., 2013; Carlone et al., 2016; Gresalfi et al., 2009; Herrenkohl & Mertl, 2010; Mercer, 2008) Socio-cultural theory, in short, frames knowing not as an isolated mental event but as an expansive ontological event that transforms how learners participate in and relate to collective activity (Packer & Goicoechea, 2000). Put differently, Activity Theory reveals the ways that practices draw together valued ways of knowing, doing, and being as learners engage in collective activity (Herrenkohl & Mertl, 2010).

When young learners engage in the authentic inquiry practice of representing scientific phenomenon, for example, they draw on a variety of features of their activity system including their own personal preferences and ambitions, the rules and instructions of the task, the norms and conventions that shape selection criteria, the assistance of their peers, and tools and techniques for drawing and formatting their representations (Danish & Enyedy, 2007). The specific concrete features of the activity system that the learners draw together into their practice are situated in historical, social, and institutional forces as well as in learners' and their peers' innovations upon this situated context (Danish & Enyedy, 2007). Taken together, this body of work demonstrates that practices do not occur in a vacuum nor are they static. Rather, practices are negotiated through dynamic processes that lead to transformations in the relationship between learners and their object of their collective inquiry.

Scholars, informed by socio-cultural research, are increasingly recognizing the advantages of using the term practices to describe learning in authentic inquiry environments (NRC, 2012). First, the term practices helps scholars to understand how communities-of-inquirers such as scientists or engineers go about performing their work. As one ethnographer of professional scientists puts it, "Much of what goes under the heading of "knowledge" in science studies can be decomposed into embodied practices of handling instruments, making experiments work, and presenting arguments in texts or demonstrations" (Lynch, 1993, p. 310). Second, the term practices (with an emphasis on a multiplicity of practices) interrupts the notion that inquiry proceeds along a given uniform trajectory (such as the use of the scientific method). Third, the term practices allows educators to focus on specific practices that are particularly consequential for inquiry in specific contexts (such as argumentation in science) (NRC, 2012).

Authentic and Generative Practices

The purpose of this literature synthesis is to create a working list of specific practices that are authentic and generative for young learners' collective inquiry. For the purposes of this literature synthesis, practices are characterized as authentic when they occur in learning environments that reflect some combination of (a) the challenges and complexities of real-world problems, (b) the genuine interests of the learners, and/or (c) the practices that professional inquirers themselves engage in (Shaffer & Resnick, 1999). The research studies examined in this literature review focus on facilitated inquiry-based learning environments that are authentic to the challenges and complexities of real-world problems. Novel, open-ended, long-term tasks tend to be challenging and complex for learners, especially if learners are steeped in conventional school tasks that are routine, close-ended, and short-term. The collective nature of inquiry can also be challenging and complex for learners as they learn to navigate relations of power (Herrenkohl & Mertl, 2010), affect (Roth & Walshaw, 2015), social positioning (McDermott, 1993), and other contentious dynamics inherent in interactions (Calabrese Barton et al., 2013).

This dimension of authenticity fits the context of the Danish and Enyedy (2007) study presented above. To extend that example, Danish and Enyedy (2007) tasked kindergarteners and first-graders to represent the process of pollination using clay sculptures. The novelty of attending to and representing the structures, behaviors, and functions of the scientific system itself is challenging for younger as well as older learners (Hmelo-Silver & Azevedo, 2006; Jacobson & Wilensky, 2006). The complexity of creating representations that balance personal preferences, representational conventions, and the affordances of the representational materials is also demanding for young learners (Tversky, Kugelmass, & Winter, 1991; Willats, 2005; DiSessa, 2004).

Inquiry practices can be generative at a moment-to-moment time-scale such as when a learner successfully leverages a practice to advance the collective inquiry of the group. Inquiry practices can also be generative across larger time-scales such as when a learner re-enacts an inquiry practice in a new activity structure (see the cumulative nature of inquiry practices in Calabrese Barton et al., 2013; Maher & Martino, 1996; Mercer, 2008). Empirical studies in this literature synthesis tend to focus on moment-to-moment interactions during the unfolding of collective inquiry within a single site. Extending the Danish and Enyedy (2007) example, the inquiry practice of enacting representation criteria was generative for the learners' collective inquiry because it allowed them to negotiate with one another what to include (e.g. specific details) in their representations, how to include it, and why (e.g. scientific fidelity, audience clarity). These moment-to-moment representation-criteria invoking negotiations helped to expand the group's collective inquiry into the pollination process. Although representing phenomenon is also a generative practice beyond moment-to-moment interactions—in that it allows learners to make contact with the practices of professional scientists (Lynch, 1988; Lehrer & Schauble, 2002), and that it is useful in domains beyond science (c.f. Bamberger & diSessa, 2003)—this dimension of generativity is not the focus of this literature synthesis.

Within the grasp of Young Learners

Activity Theory posits that learning environments can open up zones-of-proximal development for learners. Inquiry practices that are challenging for young learners to take up on their own without assistance, for example, may be within children's reach when learners are situated in a learning environment that elicits development and provides rich mediating resources (such as peer assistance) to facilitate this development. Scholars argue that traditional research has underestimated the inquiry capabilities and competencies of young learners by analyzing learners in mediator-impoverished learning environments such as laboratories and classrooms (Metz, 2011). When children as young as kindergarten and first-grade, however, are adequately supported in mediator-rich learning environments they are capable of more sophisticated inquiry than they are typically credited for (Metz, 2011). This is also true of the extended example above—representing scientific phenomenon is within the grasp of kindergarten and first-grade learners within the context of mediating tools and peer supports (Danish & Enyedy, 2007). These studies raise the question, what other authentic and generative inquiry practices are within the grasp of young learners?

Holistic Approach

Predominant models of inquiry focus almost exclusively on research practices. For example, in their synthesis of models of scientific inquiry, Rönnebeck, Bernholt, and Ropohl (2016) present the following list of nine inquiry activities: Identifying questions, searching for information, formulating hypotheses and generating predictions, planning along with designing and carrying out investigations, analyzing along with interpreting and evaluating data, developing explanations, constructing models, engaging in argumentation and reasoning, and communicating. Although the field is beginning to recognize the social dimension of many of these activities (Duschl, 2008), there is considerable work to be done to encompass the practices learners use to organize their work, motivate themselves, collaborate with peers, innovate upon resources, and promote equitable learning conditions during the course of their investigations.

In place of this narrow approach, scholars are drawing on the work of Vygotsky to offer a more holistic vision of the work entailed in performing authentic inquiry. Herrenkohl and Mertl's (2010) empirical research in a fourth grade science classroom presents a vision of authentic inquiry practices as simultaneously bringing together learners' developing ways of knowing, doing and being. Carlone and colleagues (2016) offer the 'unified perspective' which examines how learners themselves interpret their inquiry practices, finding that learners readily articulate the cognitive, emotional, and physical dimensions of their inquiry practices. Hod and Ben-Zvi (2018) present the Humanistic Knowledge Building Communities perspective to examine how knowledge, experiences, and selves are simultaneously transformed during inquiry. Additionally, scholars are increasingly attending to the ways that learners' motives, interests and inclinations take on critical and social justice dimensions within inquiry (Esmonde & Booker, 2016; Philip, Bang, & Jackson, 2018; The Politics of Learning Writing Collective, 2017).

Taken together, authentic inquiry practices include more than just research practices; they draw together learners' ways of knowing, doing, and being, and are experienced by learners as having more than just cognitive dimensions. Consistent with this socio-cultural framing, the categories presented in this study are conceptualized as a holistic ecology of practices rather than as a set of skills or cognitive abilities.

Methods

Multiple methods were used to fashion a holistic ecology of K-6 learners' authentic inquiry practices. Due to the absence of a bounded and unified body of research literature on the topic of K-6 learners' authentic inquiry practices, a literature review was conducted to draw together wide-ranging research studies relevant to this topic. Once drawn together, a thematic analysis (Braun & Clarke, 2006) was performed on this collection of research studies to name and define a holistic ecology of inquiry practices for K-6 learners at both a general and a specific level. Using a dialectical process of discovery (Packer & Goicoechea, 2000), additional bodies of relevant research literature along with an examination of an empirical K-6 study of the author and colleagues' own design were used to generate insights and cross-check general level categories. Combining these three methods—literature review, thematic analysis, and dialectical process of discovery—allowed for a robust literature synthesis. The procedures followed for each method is detailed below.

Literature Review

Following literature review guidelines (Jesson, Matheson & Lacey, 2011) inclusion and exclusion criteria were established (see Figure 1.1) to appropriately delimit the pre-existing research studies into a manageable and relevant collection. Decisions of which studies to include and which to exclude were determined based on the parameters of the topic and scope of the present study or based on the principles of Cultural-Historical Activity Theory. Following the parameters of the current study, only studies that featured learners in grades K-6 were included (in cases where a learners' grade level was unspecified, then studies featuring learners aged between 5 and 12 years were included).

Cultural-Historical Activity Theory posits that learners enact and develop inquiry practices in the presence of two stimuli: a task that is novel and challenging to them (first stimulus), and a mediator-rich learning environment (second stimulus). The first stimulus ensures that learners cannot simply rely on pre-existing content knowledge or problem-solving procedures to approach their task while giving them the space and resources to experiment with and fashion new practices for productively approaching their task. In order to capture learning settings that featured both types of stimulus, studies were included only if the learning environment positioned learners to work on novel and challenging (e.g. ill-structured, open-ended, long-term) tasks and was facilitated by teachers or researchers who worked to create a mediator-rich learning environment (as typically seen in teaching experiments and design-based research studies where the environment is modified in response to learners' ongoing development).

Yet, many studies within this inclusion criteria focus on student performance outcomes (such as content knowledge gains) or on teacher's professional development. These foci do not fit the topic and scope of this study nor do they fit Cultural-Historical Activity Theory's most basic and irreducible unit of analysis: collective activity. Therefore, studies were included only if they analyzed the collective activity of the learners. In tandem with this, studies were included only if they used a data source that provides an on-the-ground in-situ account (such as video data, audio data, or ethnographic fieldnotes) of learner's unfolding collective activity. Additional data sources were allowed (such as student interviews, student artifacts or pre-post assessments) only if they were positioned as triangulating or contextualizing the on-the-ground in-situ data source. Although inquiry practices could be inferred from other data sources (such as student interviews or student artifacts), this study aimed to keep inference levels as low as possible for analytic reliability.

In-depth cases of collective activity (Flyvbjerg, 2006) were included if the researcher provided detailed descriptions of the interactions through which the collective inquiry unfolded, of the features of the activity context that supported or constrained the collective inquiry, and of the specific practices that individuals enacted, and/or the interrelations between any of these. By attending to these different dimensions of collective activity, the in-depth case satisfies the methodological criteria laid out by Cobb, Stephan, McClain, and Gravemeijer (2001) regarding the analysis of collective learning. Furthermore, such in-depth cases make use of the Rogoff's (2008) recommended three planes of analysis (analysis of context, of interactions, and of individual trajectories) for observing sociocultural activity.

In addition to in-depth cases, theory building cases of collective activity (Hammer, Gouvea, & Watkins, 2018) were also included if the researcher's theorized phenomenon can be conceptualized as an inquiry practice and the researcher used one of their own empirical data sources (which also fit the parameters of this literature review) to clearly illuminate their phenomenon of interest. For example, Roth (2017) presents a theory building case of the role of 'astonishment' in collective learning amongst a group of second graders. Since astonishment can be conceptualized as an inquiry practice such as 'showing wonder' the article was included in this literature review. Finally, to keep the search parameters manageable only peer-reviewed journal articles, book chapter, and books were included, whereas dissertations and conference proceedings were excluded.

	Included	Excluded
Population	K-6^{th} grade learners	Preschoolers, 7^{th} grade or older
Setting	Designed and facilitated authentic inquiry-based learning environments	Everyday naturalistic non-facilitated settings
Data Source	In-situ accounts of learners' unfolding collective inquiry (can be triangulated or contextualized with student interview, artifact, and/or assessment data)	Sole data sources of student interviews, student artifacts, or student assessments.
Type of Case	In-depth cases of collective inquiry and/or Theory-building cases of collective inquiry	Focus on individual performance outcomes (such as content mastery)
Manuscript Type	Empirically-based peer-reviewed journal article, book chapter or book.	Dissertations, Conference Proceedings, White Papers, Practitioner Guides

Figure 1.1. Inclusion and Exclusion Criteria

With these inclusion and exclusion criteria in place, a preliminary database search was conducted to locate articles. Peer reviewed articles were searched for across ERIC (Ebscohost), Education Source, and PsychINFO using varying combinations of the database's suggested key search terms such as: inquiry-based learning, authentic inquiry, elementary school students, elementary, holistic approach. Yet, given that the topic of K-6 learners' authentic inquiry practices does not have a corresponding unified and bounded collection of research studies, additional methods were used to draw together wide-ranging research studies directly relevant to this topic.

Next, an intellectual social network analysis was conducted. The topic and scope of the literature review was shared with scholars in the field whose own work seeks to account for the holistic nature of young children's authentic inquiry practices. These scholars identified a number of researchers whose work directly addresses the topic and scope of the literature review. Studies from these authors that met the above criteria were included into the literature synthesis. For studies meeting the criteria, the social network analysis entailed three additional steps. Citations were traced forwards (using Google Scholar) to search for articles by scholars citing the included study. Second, citations were traced backwards (using the study's own reference list) to locate relevant studies that were cited by included scholars. Third, citations were traced sideways (using the study's methods and funding acknowledgement sections) to see if the study was part of a larger named research project which was then used to search for additional articles (for example, multiple studies were found from David Hammer's funded Novel Engineering research project).

Lastly, articles were re-read in full to double-check that they clearly met the inclusion and exclusion criteria. Additional meta-data was taken (such as content domain area and grade level) as each article was input into an excel file for organization and analytic purposes. In cases where it was unclear if a specific criteria was met (e.g. whether learners' inquiry activities were novel and challenging to them) the study was marked as a border case and subsequently removed. 267 criteria-meeting research studies of K-6 learners' in-situ collective inquiry activity remained. This large number of research studies represents dozens of learning settings at each grade level (K-6) and spans across a variety of content domains (STEM, language arts, fine arts, social studies and social action). Rather than limiting the search criteria further to reduce the number of studies to a more manageable number, the timeline for the study was substantially lengthened in order to adequately manage this large collection of studies. The decision to attend to hundreds of in-depth cases of collective inquiry across a variety of learning contexts helps to increase the ecological validity (Hammer, Gouvea, & Watkins, 2018) as well as the practical use value (Flyvbjerg, 2006) of the resultant list of authentic inquiry practices.

Thematic Analysis

Following the guidelines of thematic analysis (Braun and Clarke, 2006) a series of decisions were made about what counts as a theme and how these themes would be drawn from the articles in the literature review. When thematizing inquiry practices, three factors were taken into account: context, prevalence, and organization.

In terms of context, an inquiry practice is only thematized if the learner leverages it to advance the collective inquiry of the group (e.g. it is generative). For example, if an article describes how a learner shows empathy for the fictional dog she is designing a pet enclosure for, and then describes how this empathy leads her and her design partner to prototype a special passageway (not included in the original design task) that allows the dog's family to visit it, then the practice of showing empathy becomes thematized as an inquiry practice because it transformed the collective inquiry of this group (McCormick & Hammer, 2016). If a research study leaves the relationship between specific practices and the collective inquiry ambiguous or unspecified, then this practice was not thematized (unless another study clearly addresses the role of the practice).

In terms of prevalence, an inquiry practice was counted as a theme so long as it occurred in the collection of research studies at least once. This fits with the purpose of the current study which is to identify a broad spectrum of inquiry practices including under-recognized and under-documented inquiry practices. The purpose of this study is not to identify the most common inquiry practices nor the most commonly documented inquiry practices of young learners.

In terms of organization, an inductive process was used (see below for more detail on the decision to use an inductive process) to group inquiry practices into six categories: research, organization, motivation, collaboration, innovation, and equity. Furthermore, the inductive process was used to populate each category with both general level and specific level inquiry practices. Following Takeuchi's (2008) approach, similar practices were subsumed together. For example, the category of equity contains three general-level inquiry practices: ‘expanding who participates,’ ‘expanding who benefits,’ and ‘expanding what’s valued.’ Under the general-level inquiry practice of ‘expanding who participates’ are three specific-level practices: ‘accessing agentic opportunities,’ ‘accessing positive recognition,’ and ‘accessing a supportive climate.’ Further still, a specific-level category such as ‘accessing agentic opportunities’ contains a number of subsumed directly relevant practices such as ‘accessing the conversational floor,’ ‘accessing the means of the investigation,’ ‘accessing the documentation of learning,’ and so on (See Figure 1.2). Subsuming these additional practices maintains the readability of the working list (presented as a one-page table) and flexibility (it can account for context-specific instantiations of practices) of the working list.

In addition to determining what counts as a theme, multiple decisions were made regarding how to go about locating themes within the article collection and, then, formulating these themes as a heuristic for the reader (Braun & Clarke, 2006). Each decision was based on the purpose of this study: to provide a holistic ecology of K-6 learners’ authentic inquiry practices (including under-conceptualized and under-documented practices) in a way that can help support and inform future scholarship and practical teaching.

First, Inquiry practices were thematized at a broad survey level rather than at a detailed fine-grain level. This choice allows for a rich array of practices to be covered rather than an in-depth accounting of a select few. Second, inquiry practices were thematized through an inductive process rather than a deductive process. To determine the viability of a deductive approach (using pre-existing categories to determine the identification of inquiry practices), a number of research articles overviewing inquiry-based models of learning were consulted (e.g. Barron & Darling-Hammond, 2008; Edelson, Grover, & Pea, 1998; Hmelo-Silver, 2004). Ultimately, an inductive approach was chosen because it was well-suited to the purposes of this study (identifying under-recognized inquiry practices) and to the particularities of this study (a rich collection of in-depth cases that could be closely analyzed to generate themes).

Third, inquiry practices were thematized at an interpretive level rather than at an explicit level. This interpretive approach allows for an analysis that takes into account researchers' explicitly stated phenomenon of interest, yet provides the semantic flexibility to represent their phenomenon of interest using language appropriate for a lay audience. To this end, field-specific and idiosyncratic terminology was replaced with more self-evident language. For example, the term 'prolepsis' (which refers to the work learners perform to imagine their future identity within a given domain) which is not necessarily self-evident to a lay audience was thematized as the phrase, 'taking affiliation' and counted as a specific level instance of the more general level theme of 'taking interest.'

Furthermore, terminology that appears to group together or conflate multiple inquiry practices was broken down and re-presented into specific inquiry practices. For example, Neil Mercer (1996, p.369) describes his phenomenon of interest, exploratory talk, in the following ways "exploratory talk occurs when partners engage critically but constructively with each other's ideas" and further, "in exploratory talk knowledge is made more publicly accountable and reasoning is more visible in the talk." Exploratory talk then was interpreted as drawing together multiple specific inquiry practices including 'monitoring contributions,' 'building on contributions,' 'making thinking visible,' and, depending on how learners hold each other accountable, they are 'using evidentiary standards.'

Additionally, the interpretive approach allows for the discovery of inquiry practices that were not necessarily foregrounded in the researchers' explicitly stated phenomenon of interest, but nevertheless occurred during the case. For example, in her empirical study, “Arguing from experience,” María Paula Ghiso’s (2015) makes a compelling case that first-graders can productively make connections between their personal experiences and the social issues that they choose to write persuasive arguments about. By foregrounding the ways that young children make cross-connections between their experiences and social issues, Ghiso is able to successfully push back on the “dominant rationalities” found in writing standards and curricular mandates. Beyond this purpose, her study also shows that the invitation to write from personal experience about social issues supported first-graders in engaging in inquiry practices that this literature synthesis names as ‘deepening community relations,’ and ‘accessing positive recognition’ of themselves as competent due to their personal experiences of the issues they write about. The interpretive approach takes into account each of these co-occurring practices (so long as they are shown to be generative to the collective inquiry), even if the researcher emphasizes one over the others to fit their particular analytic foci and purpose.

Lastly, inquiry practices were thematized at a working level rather than an exhaustive level. The purpose of this study is to provide a starting point for future research, not to foreclose future research attempts by claiming to have identified a comprehensive and fully encompassing set of authentic inquiry practices.

Dialectic Process

Concurrent with the literature review and thematic analysis described above, a “dialectical process of discovery” (cf. Packer, & Gocioechea, 2000, p. 231) was used to help make visible authentic inquiry practices as well as to improve the ecological and construct validity of the identified inquiry practices. The dialectical process of discovery refers to the process of moving back and forth across multiple data sets so that as phenomenon become visible in one data set the researcher becomes better attuned to noticing the absence or presence of similar phenomenon in the other data sets. This process can be thought of as an insight generation strategy that supports researchers in making cross-connections between distinct data-sets allowing them to notice phenomenon within a data-set that they may not have been attuned to had they not first noticed the phenomenon in a different data set.

The empirically grounded data sets chosen for this dialectical process of discovery includes: (a) the aforementioned collection of research studies of K-6 learners pursuing inquiry activities that are novel and challenging within a facilitated setting, (b) a collection of research studies of working researchers pursuing inquiry activities within a professional setting, (c) a collection of research studies of youth and adolescents pursuing inquiry activities within an affinity setting, and (d) a robust empirical study (collected by the author and colleagues) of K-6 learners pursuing inquiry activities within a hybrid setting, called Mancala Club, that is both an affinity club and a facilitated design-based research learning environment. Each data set was chosen to highlight or combine different dimensions of authentic inquiry: inquiry that reflects the complexities of real-world problems directly maps onto data set (a) and (d), inquiry that reflects the genuine interests of the inquirers directly maps onto data set (c) and (d), and inquiry that reflects the working practices of professional inquirers directly maps on data set (b) (recall Shaffer & Resnick's, 1999, multi-dimensional construct of authenticity). This serves to improve the construct validity of the claim that these inquiry practices are authentic. Likewise the diversity of these data sets serves to improve the ecological validity of the resultant list of inquiry practices.

As insights into authentic inquiry practices were noticed in different data sets, these were then cross-checked within the literature review featured in this study. For example, the authentic inquiry practice of 'building capacity' was made visible in several empirical research articles of the working practices of professional researchers. In these articles, researchers wrote grants to visit experts in other laboratories in order to learn and bring back new research methodologies (Buxton, 2001), or they consulted with statisticians to determine the viability of learning new statistical methods to improve their work (Hall, Stevens, & Torralba, 2002; Hall, Wright, & Wieckert, 2007).

Once the ‘building capacity’ theme was salient, a cross-check was performed that subsequently identified this practice at work in quite a few K-6 facilitated inquiry-based settings. In these settings, learners were building capacity by actively mobilizing resources, inventing resources, and/or developing proficiency with new tools and methods. For example, Bouillion and Gomez (2001) report on how fifth graders, inquiring into restoring the health of the Chicago River, collaborated with local science and conservancy agencies to learn how to conduct water tests while also working with local artists to create landscape and beautification plans for the river site.

Although the current study flattens this dialectical process of discovery by focusing on the first data set, the additional data sets will be presented in other research articles (see Phelps, Dissertation Article 2 for the analysis of young learner’s inquiry practices in Mancala Club). The holistic ecology of authentic inquiry practices that resulted from this literature review, thematic analysis, and dialectical process of discovery are presented in Figure 1.2. The results section provides descriptions of each general level practice accompanied by a series of one-pager tables that provides a representative and illustrative sampling of 6 in-situ examples of each general level practice (organized into the constitutive specific practices of each general level practice).

Qualifiers

First, these categories are not mutually exclusive. They are interrelated, overlapping, and even co-constitutive. Research practices, for example, can be collaborative. Organization practices can be innovative, and so on. Second, these categories are not exhaustive. These categories are not

Research

Conducting Investigations

- Standardizing Procedures
- Operationalizing Constructs
- Generating Original Data
- Consulting Reference Materials

Negotiating Inquiry Norms

- Using Socio-epistemic Norms
- Using Evidentiary Standards
- Using Representation Criteria

Interpreting Phenomena

- Explicating Meanings
- Explaining Mechanisms
- Describing Systems
- Building Models
- Substantiating Claims

Organization

Managing Investigations

- Problem-Scoping
- Planning
- Orienting
- Handling Logistics
- Safekeeping

Documenting Work

- Recordkeeping
- Structuring Entries
- Tracking Progress
- Presenting

Enhancing Workflow

- Modularizing
- Streamlining
- Focusing

Motivation

Taking Interest

- Merging Interests
- Taking Excursions
- Taking Ownership
- Taking Affiliation

Engaging Feelings

- Showing Wonder
- Showing Pleasure
- Becoming Engrossed
- Showing Empathy

Navigating Fragility

- Processing Emotions
- Persisting
- Taking Risks
- Negotiating Conflicts

Collaboration

Coordinating Joint Work

- Creating a Shared Vision
- Monitoring Contributions
- Building on Contributions
- Apprenticing Peers

Constructing Meaning

- Checking Understanding
- Making Thinking Visible
- Building a Local Language
- Perspective Taking

Building Trust

- Showing Vulnerability
- Conferring Dignity
- Showing Solidarity
- Showing Commitment

Innovation

Generating Insights

- Reframing Fixed Ideas
- Playing with Ideas
- Moving across Settings
- Making Connections
- Taking a Break

Building Capacity

- Mobilizing Resources
- Inventing Resources
- Developing Proficiency

Iterating Progressively

- Prototyping
- Generating Feedback
- Evaluating
- Revising

Equity

Expanding Who Participates

- Accessing Agentic Opportunities
- Accessing Positive Recognition
- Accessing Supportive Climate

Expanding Who Benefits

- Improving Personal Livelihood
- Deepening Familial Relations
- Deepening Interpersonal Relations
- Deepening Intergenerational Ties
- Deepening Community Relations
- Deepening Bioregion Relations

Expanding What's Valued

- Dispelling Settled Ideologies
- Speaking Truth to Power
- Enacting New Possibilities

Figure 1.2. Authentic Inquiry Practices

offered as a complete set of practices within young children's grasp. Rather, these categories reflect the idiosyncratic agendas of various researchers contributing work to this topic. They also reflect the specific contexts of the inquiry-based learning environments that researchers and teachers designed. The designed contexts analyzed in this literature review tend to lend themselves to co-located and synchronous moment-to-moment interactions. As such, the resulting list of inquiry practices over-represent practices that occur in face-to-face moment-to-moment interactions while under-representing practices that occur in asynchronous interactions over larger time scales.

Finally, these categories are not unambiguous. Different researchers use different names, and certain names can have multiple meanings. Definitions and examples of each specific practice are given in the one-pager tables in the results section. With these qualifiers in mind, the categories presented here are intended to provide a holistic compilation across hundreds of research studies while also being readable and straightforward enough to allow scholars insights into what to look for when studying or designing for rich holistic ecologies of inquiry practices in the contexts of their own research and design.

Analysis

Research Practices

Young learners can enact multiple practices to perform research during authentic inquiry. These practices include conducting investigations, negotiating inquiry norms, and interpreting phenomenon. Each is described below.

First, young learners use a range of specific practices to conduct investigations. Young learners can establish consistent protocols for setting up experiments and performing trials (*standardizing procedures*). They can establish clear measures of variables that adequately represent their phenomenon of interest (*operationalizing constructs*). Additionally, young learners can perform experimental trials or use focused observations to collect data (*generating original data*). They can also supplement their investigations by reading secondary sources such as an encyclopedia or infographic (*consulting reference materials*). See Table 1.1 for descriptions, examples, and citations of each italicized practice.

Second, young learners express a variety of specific practices to negotiate inquiry norms. Young learners can figure out together what counts as an appropriate way to treat each other in relation to generating new knowledge. For example, is copying a peer's solution without understanding the underlying mathematics allowed? Is making a mistake encouraged as part of the learning process? (*using socio-epistemic norms*). Young learners can also figure out together what counts as an appropriate way to support a claim. For example, what are valid ways to link empirical data, evidence, and disciplinary principles to support a claim? (*using evidentiary standards*). Additionally, young learners can figure out together what counts as an appropriate way to represent a phenomena. For example, should representations aim for fidelity, elegance, audience clarity, and so on? (*using representation criteria*). See Table 1.2 for descriptions, examples, and citations of each italicized practice.

Third, young learners enact several specific practices to interpret phenomenon. Young learners can elucidate the meanings found in, for example, literary texts, data visualizations, or social interactions (*explicating meanings*). They can also make predictions or construct explanations of how, for example, scientific phenomenon or engineered designs work (*explaining mechanisms*). Additionally, young learners can describe the relations of different components in a system such as a mathematical equation or the relations of different levels of a system such as local-aggregate patterns in complex systems (*describing systems*). They can also create replicas or simulations of their phenomenon to better understand it (*building models*). Furthermore, young learners can support and warrant their interpretations by drawing together data and evidence (*substantiating claims*). See Table 1.3 for descriptions, examples, and citations of each italicized practice.

Organization Practices

Young learners can enact multiple practices to stay organized during authentic inquiry. These practices include managing investigations, documenting work, and enhancing workflow. Each is described below.

First, young learners use a range of specific practices to manage their investigations. Young learners can define the problem and solution space of a given inquiry by identifying the scope of work, the priority level of each task, the relevant needs and constraints of multiple stakeholders, along with the criteria of success (*problem-scoping*). They can also develop an executable plan, either in-advance or in-situ, to organize their activity (*planning*). Additionally, young learners can familiarize themselves with how to use and access the tools and resources that are relevant to their inquiry (*orienting*). They can also coordinate their schedules in order to figure out ways to work together in-person or remotely, and to trade off resources as needed (*handling logistics*). Furthermore, young learners can take precautions to keep themselves safe, their specimens healthy, and their equipment well maintained (*safekeeping*). See Table 1.4 for descriptions, examples, and citations of each italicized practice.

Second, young learners express a variety of specific practices to document their work. Young learners can keep logs of research questions, plans, data points, and reflections in a physical notebook or digital medium (*recordkeeping*). They can also order their notes into readable displays by using inscriptions such as charts, graphs, diagrams, storyboards, headings, labels, legends and so on (*structuring entries*). Additionally, young learners can take stock of what they have completed so far in their inquiry and monitor what they still have yet to complete (*tracking progress*). They can also curate their inquiry work into a suitable message for a specific audience (*presenting*). See Table 1.5 for descriptions, examples, and citations of each italicized practice.

Third, young learners enact several specific practices to enhance their workflow. Young learners can break down their workload into a series of manageable steps (*modularizing*). They can also speed up their work by eliminating redundant steps or by offloading the amount of effort needed to complete a step (*streamlining*). Additionally, young learners can hone their attention in the face of distraction (*focusing*). See Table 1.6 for descriptions, examples, and citations of each italicized practice.

Motivation Practices

Young learners can enact multiple practices to motivate each other during authentic inquiry. These practices include taking interest, engaging feelings, and navigating fragility. Each is described below.

First, young learners use a range of specific practices to take interest in an inquiry. Young learners can integrate passions, hobbies, and popular culture references that they enjoy into their original inquiry (*merging interests*). They can also generate side-questions and then explore these in ways that can inform their original inquiry (*taking excursions*). Additionally, young learners can become personally invested in defending and refining the theories and designs they feel personally or collectively responsible for (*taking ownership*). They can also situate their inquiry within a personal trajectory that aligns with a valued future goal such as becoming a scientist or artist (*taking affiliation*). See Table 1.7 for descriptions, examples, and citations of each italicized practice.

Second, young learners express a variety of specific practices to engage their feelings. Young learners can become genuinely puzzled and astonished about a phenomenon (*showing wonder*). They can also express positive feelings associated with the inquiry process such as excitement, joy, delight, pride, and satisfaction (*showing pleasure*). Additionally, young learners can become intensely enraptured by their work (*showing engrossment*). They can also care deeply about others, using their inquiry to better serve them (*showing empathy*). See Table 1.8 for descriptions, examples, and citations of each italicized practice.

Third, young learners enact several specific practices to navigate the setbacks and challenges that can undermine their inquiry, rending the process fragile. Young learners can productively cope with moodiness—such as the experience of confusion, inadequacy, frustration, disappointment, envy, impatience and so—that results from struggling with setbacks and difficulties during the inquiry process (*processing emotions*). They can also address setbacks by troubleshooting them, improvising new plans in light of them, are continuing to move forward despite them (*persisting*). Additionally, young learners can challenge themselves to push beyond their comfort zone to try out new approaches even if they harbor fears and doubts about whether they will be successful or not (*taking risks*). They can also handle logistical and interpersonal challenges by negotiating solutions and work-arounds that are satisfactory to all involved (*mediating conflicts*). See Table 1.9 for descriptions, examples, and citations of each italicized practice.

Collaboration Practices

Young learners can enact multiple practices to productively collaborate together. These practices include coordinating joint work, constructing meaning, and building trust. Each is described below.

First, young learners use a range of specific practices to coordinate joint work. Young learners can articulate the goals of their inquiry, the roles they will take up, and the expectations they have for working together (*creating a shared vision*). They can also attend to each other's ongoing work (*monitoring contributions*). Additionally, young learners can productively respond to each other's work by connecting it together and extending it further (*building on contributions*). They can also support their peers into becoming more full participants of the collective inquiry work (*apprenticing peers*). See Table 1.10 for descriptions, examples, and citations of each italicized practice.

Second, young learners express a variety of practices to construct meaning. Young learners can ask clarifying questions and try to unpack the meaning of each other's contributions (*checking understanding*). They can also explain the thoughts, reasons, and processes that generated their specific contributions (*making thinking visible*). Additionally, young learners can create a vernacular of agreed upon symbolic meanings associated with verbal and non-verbal signs—such as a series of arrows used to depict the force and direction of motion in a physics simulation—that are idiosyncratic to their specific collaboration (*building a local language*). They can also take the point of view of a peer in order to understand meanings from their peer's vantage point (*perspective taking*). See Table 1.11 for descriptions, examples, and citations of each italicized practice.

Third, young learners enact several specific practices to build trust. Young learners can build trust by openly and reciprocally revealing personal struggles and concerns to their peers (*showing vulnerability*). They can also respond to each other's vulnerability in ways that are life-affirming—showing each other that they matter and are worthy of their caring attention (*conferring dignity*).

Additionally, young learners can support each other by defending their peer's contributions, and ability to contribute, from others who might otherwise exploit, discredit, or exclude their work (*showing solidarity*). They can also show their peers that they are invested in supporting them and are unwilling to give up on them (*showing commitment*). See Table 1.12 for descriptions, examples, and citations of each italicized practice.

Innovation Practices

Young learners can enact multiple practices to productively innovate upon their inquiry work. These practices include generating novel insights, building capacity, and iterating progressively. Each is described below.

First, young learners use a range of specific practices to generate novel insights. Young learners can shift their frame of reference to overcome a fixation on a specific idea or design (*reframing fixed ideas*). They can also withhold evaluative judgment in order to generate and entertain a large number of possibilities—sometimes referred to as brainstorming, ideation, or free association (*playing with ideas*). Additionally, young learners can visit other groups or even other contexts to learn how similar work is done differently (*moving across settings*). They can also draw together ideas from multiple contexts—such as their everyday experience of a phenomenon and a hands-on demonstration of the same phenomenon—to see a phenomenon anew (*making cross-connections*). Furthermore, young learners can rest their minds which can make space for their non-self-willed thoughts to supply them with creative insights—sometimes referred to as aha moments (*taking a break*). See Table 1.13 for descriptions, examples, and citations of each italicized practice.

Second, young learners express a variety of specific practices to build capacity for their inquiry work. Young learners can seek out and share resources—ranging from physical tools to community member's expertise and labor—that allow them to take their inquiry work further than they would be able to otherwise (*mobilizing resources*). They can also invent resources that help them extend their capabilities, including reinventing tools that professional researchers use to support their inquiry work (*inventing resources*). Additionally, young learners can gain mastery over resources allowing them to have a level of felicity and control over the resources that they might not have otherwise (*developing proficiency*). See Table 1.14 for descriptions, examples, and citations of each italicized practice.

Third, young learners enact several specific practices to iterate their work progressively. Young learners can get started on their work by creating rough drafts and mock-ups to make their ideas tangible (*prototyping*). They can also put their tangible ideas to the test by deliberately soliciting feedback from others who are given an opportunity to see a demonstration of the latest version of the original prototype or to try it out for themselves (*generating feedback*). Additionally, young learners may supplement their feedback with persuasive and challenging arguments in order to make a case for what aspects of the latest version of the prototype need to be changed and why (*evaluating*). They can also draw on their own and other's assessments in order to transform their prototype into a newer and potentially improved version (*revising*). See Table 1.15 for descriptions, examples, and citations of each italicized practice.

Equity Practices

Young learners can enact multiple practices to promote equitable learning conditions during authentic inquiry. These practices include expanding who gets to participate, expanding who gets to benefit from participation, and expanding what gets counted as valued participation.

First, young learners use a range of specific practices to expand who gets to participate. Young learners can work to reduce the barriers they face in accessing the means for conducting, sharing, and documenting their inquiry work (*accessing agentic opportunities*). They can also work to reduce perceptions and stereotypes that position them as deficit or incompetent (*accessing positive recognition*). Additionally, young learners can work to create a warm and welcoming learning environment that allows everyone to feel at ease and comfortable being themselves (*accessing supportive climate*). See Table 1.16 for descriptions, examples, and citations of each italicized practice.

Second, young learners express a variety of practices to expand who gets to benefit from participation. Young learners can expand the object of their inquiry to meet their own personal needs including access to safety, food, and toys (*improving personal livelihood*). They can also expand the object of their inquiry in ways that allow them to grow closer to—by making gifts, doing acts of service, sharing quality time, and so on—their families (*deepening familial relations*), their friends and mentors (*deepening interpersonal relations*), mixed-age groups (*deepening intergenerational ties*) local or distant communities (*deepening community relations*), as well as other species, the water and the land (*deepening bioregion relations*). See Table 1.17 for descriptions, examples, and citations of each italicized practice.

Third, young learners enact several specific practices to expand what gets counted as valued participation. Young learners can problematize the status quo by making visible the histories, contradictions, biases, and alternatives that belie idealized beliefs (*dispelling settled ideologies*). They can also make visible to others how they themselves are implicated by the status quo—as a victim, a perpetuator, or simultaneously both—and the role they play in reproducing its harmful effects (*speaking truth to power*). Additionally, young learners can legitimize and try out new ways of knowing, doing, and being in relation to their participation in collective inquiry

Table 1.1

Conducting Investigations

Sub-Practice	Description	Context	In-Situ Example	Citation
Standardizing Procedures	Learners use reliable protocols and methods for collecting and analyzing data	2nd Grade Physics Class Discussion	*Learners specify the set-up conditions for testing the speed of differently weighted balls rolling down a ramp. They specify the exact ramp height, ball starting position, and the force of the push.*	(Hapgood, Magnusson, & Palincsar, 2004)
Operationalizing Constructs	Learners use valid measures and definitions for studying variables and concepts	1st Grade Biology Class Discussion	*Learners compare the heights of plants across classrooms. In response to one class's claim that their plant is two pencils high, learners question the use of pencils and find a new way to measure.*	(Lehrer & Schauble, 2002)
		3rd Grade Biology Small Group Discussion	*Learners track the health of plants in their classroom. They question and define 'health' during a debate about whether a plant is losing leaves because it is dying or simply maturing.*	(Manz, 2012)
Generating Original Data	Learners perform tests, observations, and other methods to produce first-hand data	Kindergarten Biology Specimen Observation	*Learners collect data and evidence about snail's biological processes (such as digestion and regeneration) through focused, prolonged, and systematic observations.*	(Monteira & Jiménez-Aleixandre, 2016)
		4th Grade Engineering Parachute Field Trials	*Learners design parachutes—varying canopy size, canopy materials, and suspension line length. They systematically run trials to collect data on the rate at which the various parachutes fall.*	(Cunningham & Kelly, 2017)
Consulting Reference Materials	Learners use second-hand information and data sources to study phenomenon	1st-2nd Grade Biology Life Cycle Storyboards	*Learners review and select multiple infographics on loggerhead sea turtles. They synthesize these together to create novel storyboard representations of the turtles' life cycle.*	(Danish & Saleh, 2014)

Table 1.2

Negotiating Inquiry Norms

Sub-Practice	Description	Context	In-Situ Example	Citation
Enacting Socio-epistemic Norms	Learners evaluate which contributions count as different, promising, elegant, mistaken, etc.	2nd Grade Math Class Discussion	*Learners share multiple solutions paths to a mathematics problem, then debate with their teacher and each other which approaches are mathematically different from one another.*	(Yackel & Cobb, 1996)
		4th-5th Grade Math Problem-Solving	*Learners draw on their understandings of what counts as a good mathematical explanation as they describe their thinking, interrogate their mistakes and collaboratively reach a consensus.*	(Kazemi & Stipek, 2008)
Enacting Evidentiary Standards	Learners evaluate the veracity of evidence, data, and claims based on disciplinary principles	3rd-4th Grade Science Class Discussion	*Learners create norms for arguing: convincing others means backing up claims, backing up claims means showing evidence, and showing evidence means integrating data and claims.*	(Ryu & Sandoval, 2012)
		4th Grade Science Class Presentation	*Learners play audience roles to ask presenters questions that prompt them to clearly link their predictions and theories to the results of their investigations.*	(Herrenkohl & Mertl, 2010)
Enacting Representation Criteria	Learners evaluate a representation based on how well it follows relevant conventions	K-1st Grade Science Sculpture-Making	*Learners create representations of the act of pollination, negotiating with one another what to include (e.g. specific details), how to include it, and why (e.g. scientific fidelity, audience clarity).*	(Danish & Enyedy, 2007)
		6th Grade Motion Graphing Discussion	*Learners create static representations of motion. As they critique and refine their work they invoke criteria ranging from compactness to conceptual clarity; from transparency to consistency.*	(diSessa, Hammer, Sherin & Kolpakowski, 1991)

Table 1.3

Interpreting Phenomenon

Sub-Practice	Description	Context	In-Situ Example	Citation
Explicating Meanings	Learners unpack the distinction between a sign and what the sign signifies	4th Grade Math Discussion	*Learners pool their rocket launch height data together, noticing patterns in how data points clump together in the middle (a distribution curve) as well as how fewer data points extend far beyond the middle (anomalies).*	(Petrosino, Lehrer & Schauble, 2003)
		4th Grade Literature Discussion	*Learners debate how a prince can show love in The Paper Bag Princess. Some suggest buying candy or clothes. In response, a learner says, "Love ain't about candy. It's about how you treat somebody."*	(Clark, et al., 2003)
Explaining Mechanisms	Learners explain or predict the relationship between two events	3rd Grade Science NetLogo Simulation	*A learner runs a simulation of a butterfly ecosystem, noticing butterflies evade predation while visiting flowers of the same color. The learner posits camouflage as an explanatory mechanism.*	(Dickes, Sengupta, Farris, & Basu, 2016).
Describing Systems	Learners grasp one part of a system by relating it to other parts in the whole	1st-2nd Grade BeeSign Simulation	*Learners relate local behaviors of honeybees (such as the waggle dance) to aggregate behaviors (bees exponentially visiting high-nectar flowers) to make sense of the inner-workings of this biological system.*	(Danish, Peppler, Phelps, & Washington, 2010)
Building Models	Learners create models that allow them to simulate and explore phenomenon	4th Grade Science Small Group Modelling	*Learners model their understanding of the flow of energy in a system by using a whiteboard and 'energy' cubes. They apply their model to similar phenomenon, and revise it when they identify new forms of energy.*	(Tobin, Lacy, Crissman, & Haddad, 2018)
Substantiating Claims	Learners warrant their interpretations with appropriate evidence	2nd-3rd Grade Biology Small Group	*Learners are given the roots of a mystery object and make guesses about what it is. Peers use evidence (e.g. color, texture, viscosity, seed presence, etc.) to warrant their claims and to challenge other's claims.*	(Kim & Roth, 2018)

Table 1.4

Managing Investigations

Sub-Practice	Description	Context	In-Situ Example	Citation
Problem-Scoping	Learners define the problem and solution space such as goals, needs and constraints	4th Grade Engineering Small Group Prototyping	*Learners build testable prototypes for fictional clients (from children's books) to solve specific problems. They consider sub-problems, design constraints (from multiple perspectives) and the situation context.*	(Watkins, Spencer & Hammer, 2014)
Planning	Learners create action sequences in a top-down and/or bottom-up fashion	2nd-3rd Grade Literature Small Group Playwriting	*Learners write original plays from scratch. Their planning activities include planning themes, planning details within themes, improvisational planning, and procedural planning for how to plan.*	(Baker-Sennett, Matusov, & Rogoff, 2008)
		4th Grade Anti-Bullying Campaign	*Learners make a plan to study bullying by consulting online resources, surveying the school, and then interviewing the school counselor. This work informs an action plan to create "Befriend a Bully Week."*	(Vaughn & Oberchain, 2015)
Orienting	Learners familiarize themselves with how to navigate their context	6th Grade Science Small Group Computer	*Learners use a software program to study color and light. They figure out how to use the interface by clicking various buttons, and instructing each other, "wait, it has to give you the arrow first."*	(Valanides & Angeli, 2008)
Handling Logistics	Learners coordinate work schedules, platforms, and resources	5th Grade School Policy Advocacy	*Learners advocate for additional cafeteria menu items. They figure out a schedule to visit each classroom to poll their classmates. Then they create a shared online platform to co-work remotely on their presentation.*	(Mitra & Serriere, 2012)
Safekeeping	Learners ensure the safety and upkeep of materials, specimens, and themselves.	2nd-5th Grade Herpetology Small Group Observations	*Learners experience how to care for amphibians including not holding them too hard (lest they damage their ribs) and holding them with wet hands (lest they dry out their skin).*	(Scott, 2016)

Table 1.5

Documenting Work

Sub-Practice	Description	Context	In-Situ Example	Citation
Recordkeeping	Learners keep records of their work (such as questions, notes, reflections)	4th Grade Engineering Small Group Design Task	*Learners record plans and findings in notebooks. They refer to their written plans to refocus their work and hold themselves accountable. They refer to their data to inform decision-making and consensus.*	(Hertel, Cunningham, & Kelly, 2017)
Structuring Entries	Learners arrange their data and notes into orderly and readable formats	4th Grade Biology Field Observations	*Learners diagram the flora and fauna in specific quadrants of land in the Everglades. Their diagrams include dates, locations, technical drawings, precise measurements, descriptions, and notations.*	(Lewis & O'Brien, 2012)
		3rd Grade Engineering Small Group Modelling	*Learners perform endurance trials on a biomechanical model of an elbow. To record their results, they decide to construct a 4 by 4 table (muscle points and weight position) of 16 cells.*	(Penner, Lehrer & Schauble, 1998)
Tracking Progress	Learners take stock of what they have completed and have yet to complete	5th Grade Anatomy Knowledge Forum	*Learners create visual models of their own research cycles (e.g. ask a question, answer the question, make theories about the question, etc.), periodically locating the progression of their work over time.*	(Tao & Zhang, 2018)
		2nd Grade Biology Whole Class Discussion	*Learners examine the meta-data of their work, noticing how often they offered theories, questions, and facts. They discuss at which stage of an investigation is each appropriate and what to do next.*	(Resendes, et al. 2015)
Presenting	Learners present their questions, data, evidence, and reflections	2nd Grade Literacy School Celebration	*Learners perform their biographies of Harlem Renaissance individuals in persona—integrating life stories with the singing, dancing, and poetry that their chosen individuals were known for performing.*	(Sánchez, 2011)

Table 1.6

Enhancing Workflow

Sub-Practice	Description	Context	In-Situ Example	Citation
Modularizing	Learners create sub-tasks that are sequentially ordered or logically grouped	4th Grade Engineering Small Group Design Task	*A learner diagrams the sequence of steps entailed in creating her group's sophisticated paper airplane. She does this so that, "it's easier for me to do, and sometimes I can see if I do something wrong too."*	(English & King, 2015)
		3rd Grade Math Problem-Solving	*Learners take a difficult multiplication problem and break it down into a series of easier steps: recreating a square grid of both multipliers, counting half of the squares, then multiplying by two to find the answer.*	(Dekker, Elshout-Mohr, & Wood, 2006)
Streamlining	Learners reduce the number of steps or the effort it takes to complete a task	5th Grade Computer Programming Design Task	*Learners teach each other optimization strategies for programming their games. A learner, for example, rewrites her computer program to replace a long Boolean expression with a much shorter script.*	(Baytak & Land, 2011)
		2nd Grade Math Problem-Solving	*A learner helps a peer multiply 6 by 7 by holding up a finger each time her peer counts 6 more. They both stop when the 7th finger is held up and write down 42 as their answer.*	(Cobb, 1991)
Focusing	Learners shift and hone their attention towards priority tasks	1st-2nd Grade Literature Small Group Playwriting	*Learners become lost in the minutiae (props, costumes, character names) of planning their plays. Their peers use refocusing strategies to bring the group back to planning the main events of the play.*	(Baker-Sennett, Matusov, & Rogoff, 1992)
		9 year olds Measurement Pairs Touchscreen	*A learner is distracted by a peer while counting squares on a digital interface. She recounts, this time nodding her head in rhythm with her fingers tapping out her count, as well as silently moving her lips.*	(Davidsen & Ryberg, 2017))

Table 1.7

Taking Interest

Sub-Practice	Description	Context	In-Situ Example	Citation
Merging Interests	Learners pursue outside interests while studying a phenomenon	5th Grade Computer Programming Project	*A learner disinterested in computer programming creates a synchronized multimodal project that he treats as a "live performance" allowing him to bring together his love of acting and performing.*	(Farris & Sengupta, 2016)
Taking Excursions	Learners pursue related question while studying a phenomenon	4th Grade Magnetism Small Group Exploration	*A learner becomes fascinated by magnets and invites her group to use magnets to get a toy car moving. A group member suggests taping a magnet to the car, while they hold another magnet to move the car.*	(Jaber & Hammer 2016a)
		6th Grade Heredity Online discussion	*Learners originate and populate a sub-discussion titled "About Growing" with their personal interests and questions about growth. Learners find and post information about hormones and the pituitary gland.*	(Bereiter, Scardamalia, Cassells, & Hewitt, 1997)
Taking Ownership	Learners pursue original ideas while studying a phenomenon	4th-5th Grade Engineering Small Group Design Task	*Learners far more readily adopt the design features that originate from their peers (such as using flags for their tower constructions), than those given by their teachers. Learners take pride in originating ideas.*	(Roth, 1995)
		6th Grade Science Whole Class Discussion	*A learner positions her own theory as a collective accomplishment of her peers. She does this by citing prior evidence provided by her peers, then situating her new theory within this ongoing shared work.*	(Radinsky, Oliva & Alamar, 2010)
Taking Affiliation	Learners pursue future trajectories while studying a phenomenon	2nd Grade Engineering Whole Class Discussion	*Learners argue that even children can be materials engineers and cite their own design work in asking questions, creating systems, generating solutions, and being engaged as evidence of becoming engineers.*	(Kelly, Cunningham, & Ricketts, 2017)

Table 1.8

Engaging Feelings

Sub-Practice	Description	Context	Example	Citations
Showing Wonder	Learners express curiosity, puzzlement, and awe	4th Grade Science Group-Discussion	*A learner displays her puzzlement over her classmate's explanation of how clouds hold water. Her animated challenges lead to additional explanatory mechanisms to be posited.*	(Jaber & Hammer, 2016b)
		4th Grade Science *Quest Atlantis*	*Learners encounter an unexpected and mysterious artifact relevant to their inquiry. They speculate with each other about the origins and purpose of the artifact as they try to decipher its meaning.*	(Barab et al., 2007)
Showing Pleasure	Learners express joy, enthusiasm, and satisfaction	4th Grade Science Small Group Experiments	*Learners verbalize excitement as they find worms in a worm container. A plurilingual learner, who avoided speaking in German, discovers a worm cocoon and excitedly tells his teachers all about it in German.*	(Wilmes & Siry, 2018)
Showing Engrossment	Learners become absorbed and immersed in their work	6th Grade Epidemiology Simulation Discussion	*Learners create and share stories of how deer interact (e.g. travel in packs). They become involved in their story-making, using the stories to predict how fast disease will spread amongst deer in a simulation.*	(Levy & Wilensky, 2008)
Showing Empathy	Learners express care, concern, and compassion	4th Grade Engineering Design Task	*A group strongly identifies with the client they are designing a structure for. They adjust their design features and make additional calculations to take into account their client's many needs.*	(McCormick & Hammer, 2016)
		Various ages Informal Makerspace	*A young girl builds a light-up pillow for her baby sister. Her determination to make it aesthetic, safe, and practical for her sister leads her to selectively use others' ideas as she creates a functioning circuit.*	(Gutiérrez & Calabrese Barton, 2015)

Table 1.9

Navigating Fragility

Sub-Practice	Description	Context	In-Situ Example	Citation
Processing Emotions	Learners cope with emotions such as confusion, envy, and frustration	2nd Grade Math Problem-Solving	*Learners show envy (of other group's progress) and embarrassment (of needing help) as they struggle to complete their work. Their peers help them to reframe their struggles as positive and necessary for their work.*	(Cobb, Yackel & Wood, 1989)
Persisting	Learners work to troubleshoot issues, improvise solutions, and move forward	5th Grade Mathematics Small Group Task	*Learners become confused and stuck as they try out incorrect recursive functions to solve a complex math problem. Yet, they keep working and eventually piece together a correct non-recursive function.*	(Sengupta-Irving & Agarwal, 2017)
		6th Grade Ecology Small Group Modelling	*Learners revise their ecology experiment after their modelled aquatic ecosystem suddenly perishes. They turn this event into their new object of inquiry which leads them to learn about algal blooms in the process.*	(Lehrer, Schauble & Lucas, 2008)
Taking Risks	Learners push themselves to work beyond their comfort zone	Kindergarten Literacy Individual Drawing	*A learner shows angst and doubts his ability to draw when tasked to draw three important things. With support, he breaks down the task into little steps that he can successfully perform. After, he asks to draw more.*	(Binder & Kotsopoulos, 2011)
		4th Grade Literature Individual Writing	*A learner who struggles with his anxiety about writing makes this struggle the focus of his writing. This sustained openness about his struggles helps his writing to greatly improve, even as he shows anxiety.*	(Dutro, Kazemi & Balf, 2006)
Mediating Conflicts	Learners devise procedures or use persuasive talk to resolve issues	K-1st Grade Biology Individual Sculptures	*Learners question whether a peer's block sculpture of a leaf is scientific or artistic. Unable to reach agreement through discussion they enact a voting procedure to settle the conflict.*	(Danish & Enyedy, 2015)

Table 1.10

Coordinating Joint Work

Sub-Practice	Description	Context	In-Situ Example	Citation
Creating a Shared Vision	Learners articulate their goals, roles, and expectations for working together	6^{th} grade Mathematics Small Group Task	*Learners in successful problem-solving groups create a shared collaborative task alignment. This alignment allows them to play complementary roles, be sensitive to each other's roles, and to co-construct solutions.*	(Barron, 2000)
Monitoring Contributions	Learners attend to each other's ongoing work	K-1^{st} Grade Biology Individual Storyboards	*Learners create representations of how bees collect nectar. Although they work individually, they use their close proximity to notice each other's work and to provide timely suggestions for making improvements.*	(Danish & Phelps, 2010)
		3^{rd} Grade Anatomy Knowledge Forum	*Learners post claims to a computer interface about how worms sense their environment. After a peer highlights a posted claim about photoreceptors, other learners begin exploring this idea in their posts.*	(Chen, Scardamlia, & Bereiter, 2015)
Building on Contributions	Learners play off each other's work to achieve more than they could otherwise	3^{rd} Grade Science Whole Class Discussion	*A learner acts as a knowledge broker by repeating, extending and bridging his peers' ideas. By tapping into his peers' ideas he creates new knowledge that he then goes on to share with his peers.*	(Varelas, Tucker-Raymond, & Richards, 2015)
		3^{rd}-4^{th} Grade Science Whole Class Discussion	*Learners suggest a variety of ideas for how bacteria create tooth decay. Linking multiple contributions together, a learner suggests that it is bacteria's excrement that causes holes in teeth.*	(Clarà, 2019)
Apprenticing Peers	Learners help their peers move from peripheral to central participation	4^{th}-5^{th} Grade Small Group Software Design Task	*Learners monitor, field questions, and intervene to support the technical skills of their inexperienced peers. As a result, both the mentors and the mentees gain a greater breadth of understanding of their work.*	(Ching & Kafai, 2008)

Table 1.11

Constructing Meaning

Sub-Practice	Description	Context	In-Situ Example	Citation
Checking Understanding	Learners clarify the meaning of each other's contributions	3rd Grade Biology Whole Class Presentation	*A learner presents findings on plant growth to his class. Questions such as "What did you mean by the shade is bigger?" allowed peers to clarify what the plant was bigger than and how bigness was measured.*	(Manz & Allen, 2017)
Making Thinking Visible	Learners provide the reasoning that motivates their contributions	2nd Grade Mathematics Whole Class Discussion	*Learners explain their approach to solving math problems. Rather than simply reciting procedures they followed, they share their reasoning and justifications. This allows peers to engage in shared sense-making.*	(Cobb, Wood, Yackel, & McNeal, 1992)
		9-10 year olds Science Small Group Discussion	*Learners predict which materials will block out the most light. They prompt each other to explain the reasoning behind their predictions (e.g. "Why did you think that?") which allows for richer discussion.*	(Mercer, Dawes, Wegerif, & Sams, 2004)
Building a Local Language	Learners imbue signs and symbols with publicly available meanings	1st-2nd Grade Physics Participatory Simulation	*Learners combine semiotic resources (e.g. gestures, talk, pictures) to convey physics concepts. They work to agree upon shared conventions, such as using multiple arrows to symbolize the size of force.*	(Enyedy, Danish, Delacruz, & Kumar, 2015)
		3rd Grade Science Whole Class Discussion	*A learner evokes geological and planetary time-space frames and a thought experiment to re-define the term "fireball," in a way that plausibly explains what caused the formation of the Earth.*	(Hilppö et al., 2016)
Perspective Taking	Learners try to understand others by seeing from their point of view	6th Grade Probability Pairs Game	*A learner laughs at himself as he discovers why he and his peer's prediction is wrong. His peer shares in both the laughter and ignorance. He repeats his peer's explanation word for word until he too understands.*	(Kazak, Wegerif & Fujita, 2015)

Table 1.12

Building Trust

Sub-Practice	Description	Context	In-Situ Example	Citation
Showing Vulnerability	Learners share personal struggles	4th Grade Science Whole Class Discussion	*A learner, during her class presentations, readily admits when her initial theories are wrong and then she revises them. This helps set a norm that being wrong is an acceptable part of the learning process.*	(Herrenkohl & Mertl, 2010)
Conferring Dignity	Learners tactfully show acceptance and solidarity in the face of vulnerable sharing	3rd Grade Community Activism Project	*Learners share stories of being homeless and fears of their school shutting down. Peers listen and show that these concerns matter. As a team they choose to work with homeless shelters for their group activism project.*	(Sánchez, 2014)
		Various ages Informal Makerspace Group Share	*An 8-year old misses her chance to share her work with the group, and waits awkwardly. When she finally shares, a 10-year old asks the researcher to zoom-in on her work as he says, "Ooh, shooting star. Nice"*	(Vossoughi & Escudé, 2016)
Showing Solidarity	Learners protect and promote their peer's contributions and ability to contribute	6th Grade Robotics Small Group Design Task	*Learners, in response to a domineering groupmate, use playful talk and wordplay to form an exclusive bond which, in turn, allowed them to take charge of building a Lego device for their group.*	(Sullivan & Wilson, 2015)
Showing Commitment	Learners offer unconditional and unwavering help and follow-through	2nd-3rd Grade Literature and History Writing Task	*Learners give advice to a peer who requests help with a current draft. They follow-up with, "Why don't you just start writing and then read us what you did? We, I can tell you how it sounds...before we have to go."*	(Gutiérrez, 1992)
		Various ages Las Redes Informal Tinkering	*A 2nd Grader puts down her current project and helps another youth who is interested in getting started on making Squishy Circuits. The 2nd Grader offers consistent and supportive feedback throughout.*	(DiGiacomo & Gutiérrez, 2015)

Table 1.13

Generating Novel Insights

Sub-Practice	Description	Context	In-Situ Example	Citation
Reframing Fixed Ideas	Learners reformulate the problem and solution space to see new possibilities	4th Grade Science Whole Class Discussion	*Learners question a given explanation about how clouds make rain. They broaden the problem space to include the issue of how clouds, which are lightweight and gaseous, can hold rain which is a heavy liquid.*	(Phillips, Watkins, & Hammer, 2017)
Playing with Ideas	Learners entertain possibilities without settling on any one idea	Kindergarten Science Whole Class Discussion	*Learners studying shadows speculate whether people can see their shadows if they were floating around in space. They play out multiple hypothetical scenarios that help them better understand how shadows work.*	(McDyre, 2017)
		5th Grade Engineering Small Group Design Task	*Learners brainstorm design solutions for a given engineering task. They suspend judgment in order to hear multiple ideas (without fixating on any one of them) and to collaboratively develop ideas together.*	(Jordan & Babrow, 2013)
Moving across Settings	Learners move within or between contexts to learn from others	5th Grade Combinatorics Small Group Task	*Learners who are stuck on a combinatorics problem visit another group to learn from their approach. Seeing this new approach prompted changes in both their problem-solving methods and solutions.*	(Mueller, Yankelewitz, & Maher, 2011)
Making Cross-Connections	Learners directly apply ideas from one context to another context	3rd-4th Grade Science Whole Class Discussion	*Learners studying thermodynamics connect to their prior experiences: "When you go outside your body heat fl-flows out of you but when you put a coat on it acts as a stopper for the body heat and it traps it."*	(Rosebery, Ogonowski, DiSchino, & Warren, 2010)
Taking a Break	Learners rest, making space for fresh perspectives or renewed attention	5th Grade Robotics Small Group Design Task	*A learner becomes frustrated when her programmed robot behaves problematically. She takes a break as her teammates rotate in one by one to troubleshoot. The learner returns with a new approach to try out.*	(Jordan & McDaniel, 2014)

Table 1.14

Building Capacity

Sub-Practice	Description	Context	In-Situ Example	Citation
Mobilizing Resources	Learners introduce, share, circulate, remix, and repurpose resources	4th Grade Literacy Whole Class Discussion	*Learners use stratagems as they argue a position. Learners re-use successful stratagems with increasing frequency and across conversation topics. Stratagems include, "I think [POSITION] because [REASON]."*	(Anderson et al., 2001)
		4th-5th Grade Engineering Small Group Design Task	*Learners bring and share glue guns from their homes to help construct stable towers. The guns are used to make stronger joints (by burning a hole into a straw and inserting a second straw into the hole of the first).*	(Roth, 1996)
Inventing Resources	Learners invent and reinvent resources	1st Grade Literacy Non-Fiction Writing	*A learner effectively invents a prologue by writing 'The Story before the Story' which she uses to draw connections between her story's featured historical figures and to connect their work to her readers' lives.*	(Ghiso, 2013)
		2nd-3rd Grade Topology Whole Group Discussion	*Learners create a map of their wooden block city as an aid to rebuild it. Through their struggles to represent height, they design various representations, reinventing topographical lines along the way.*	(Enyedy, 2005)
Developing Proficiency	Learners gain mastery over tools and techniques	5th Grade Informal Makerspace	*A learner closely studies the 3D printing process. Then, she offers to help the teacher as he performs print jobs. Then she helps answer learners' questions. Finally, she becomes in charge of the 3D printer.*	(Ramey & Stevens, 2018)
		6th Grade Science Research Collaboration	*Learners are taught by moth researchers how to build moth traps. Learners use their newfound familiarity with moth traps to suggest modifications for empirical investigation (e.g. changing the trap's LED color).*	(Stroupe, Caballero, & White, 2018)

Table 1.15

Iterating Progressively

Sub-Practice	Description	Context	In-Situ Example	Citation
Prototyping	Learners create a rough yet usable draft or mock-up of their work	4th Grade Engineering Small Group Design Task	*Learners sketch their initial ideas for a tool that can scoop and separate sand from gravel. They then build a physical model of their sketch. This prompts learners to discuss anticipated issues and potential solutions.*	(McFadden & Roehrig, 2018)
		4th Grade Engineering Small Group Prototyping	*Learners design a prototype for a three story building. They discuss and add contextual features to meet imagined user needs such as parking, flood protection, and moving between floors (e.g. elevator).*	(English & King, 2017)
Generating Feedback	Learners solicit feedback from others who view and playtest their work	4th-5th Grade Small Group Software Design Task	*Learners program educational software for younger learners. They receive feedback by casually visiting other group's projects, by showcasing their own work, and by conducting "usability testing" with 3rd graders.*	(Kafai & Ching, 2001)
Evaluating	Learners assess their own and others' contributions using persuasion as needed	5th Grade Biology Whole Class Discussion	*Learners debate whether orcas are dolphins or whales. They draw on documentary, anatomical, lexical evidence as well as question the credibility of evidence to persuasively judge each position.*	(Engle & Conant, 2002)
		6th Grade Science Whole Class Discussion	*Learners develop theories of sinking and floating. To convince their peers of their theories they consult references, present demonstrations, and revise their theories to account for additional variables.*	(Cornelius & Herrenkohl, 2004)
Revising	Learners modify their work to make improvements	5th Grade Science Small Group Modelling	*Learners build a consensus group model of the process of evaporation by drawing from their individual models. Learners negotiate which parts of their prior models to revise as they build a collective model.*	(Baek & Schwarz, 2015)

Table 1.16

Expanding who Participates

Sub-Practice	Description	Context	In-Situ Example	Citation
Accessing Agentic Opportunities	Learners can freely use materials, share contributions, and document their work	2nd-3rd Grade Anatomy Whole Class Discussion	*A learner jokes about his nickname "bony" to gain entry into a discussion about the human body. Once he has the conversation floor, he makes contributions that forwards the group's understanding of the heart.*	(Gutiérrez, Baguedano-López & Tejeda, 1999)
		4th-5th Grade Mathematics Large Group Discussion	*Learners help remove language as a barrier to participation by working to translate their peers' problem-solving strategies (for a paper-folding task) between Spanish and English.*	(Turner, Dominguez, Maldonado, & Empson, 2013)
Accessing Positive Recognition	Learners and those they identify with are positioned as competent	6th Grade Programming Small Group Project	*A learner is positioned as a novice by his group. In response, he visits and helps other groups program their Scratch projects. As others validate his expertise, he is invited to join another group.*	(Kafai, Fields, & Burke, 2010)
		5th Grade Biology Whole Class Discussion	*Learners recognize aspects of themselves (e.g. Spanish cultural heritage) in a community expert class visitor. They enthusiastically ask questions about the visitors' work, and soon position their own work as scientific.*	(Stromholt & Bell, 2018)
Accessing Supportive Climate	Learners feel welcome and at ease in their learning context	3rd Grade Science Small Group Discussion	*Learners use language brokering and code switching to help a newcomer non-dominant language speaker participate. They move their desks close to each other, slouch into each other, and borrow each other's pens.*	(Gamez & Parker, 2018)
		6th Grade Nutrition Appetizer Preparation	*Learners remake their classroom into a kitchen scene—blending smoothies and prepping appetizers. They walk around to sample food, discuss nutrition, and their cultural history. The setting is inviting.*	(Calabrese Barton & Tan, 2009)

Table 1.17

Expanding Who Benefits

Sub-Practice	Description	Context	In-Situ Example	Citation
Improving Personal Livelihood	Learners use their inquiry work to meet their needs	4th Grade Science Afterschool Program	*A learner participates in a microscope design activity. Afterwards, she repurposes materials from the microscope project and other available items to create a functional purse.*	(Calabrese Barton, 1998)
Deepening Familial Relations	Learners bond with their families	Various ages Family Quest Child-Parent Gameplay	*Learners work with their parents on virtual missions around issues such as bullying. Parents valued the chance to spend "uninterrupted quality time" to play with their children and to discuss social issues them.*	(Siyahhan, Barab & Downton, 2010)
Deepening Interpersonal Relations	Learners bond with their peers or role models	1st Grade Critical Literacy Pair	*Learners create interpretive drawings of Ruby's Wish. A year later, two learners share an updated interpretive drawing of Ruby along with a personal letter to stay in touch with their first-grade teacher.*	(Crafton, Silvers & Brennan, 2009)
Deepening Intergenerational Ties	Learners bond with people of different ages	Kindergarten Multimodal Art Project Pairs	*Learners are partnered with elder-care residents to create multimodal narratives to communicate their personal interests and desires using a variety of artistic mediums.*	(Heydon, 2011)
Deepening Community Relations	Learners bond with their own or other communities	1st Grade Critical Literacy Small Group	*A group of learners raise books for a school impacted by Hurricane Katrina as they investigate why certain communities were disproportionately impacted by the Hurricane.*	(Silvers, Shorey, & Crafton, 2010)
Deepening Bioregion Relations	Learners bond with species, water, and land	Various Ages ISTEAM Camp Clay Project	*Learners make clay creations that display the value of their bioregion. These include an otter-shaped incense burner, a plant-based medicine-bearing cup, and carved designs based on local natural forms.*	(Barajas-López & Bang, 2018)

Table 1.18

Expanding What's Valued

Sub-Practice	Description	Context	In-Situ Example	Citation
Dispelling Settled Ideologies	Learners reveal the history, tensions, bias, and alternatives of a given status quo	1st Grade Literacy Persuasive Writing	*A learner performs a persuasive argument that shows a scene between herself and an older boy who writes her off as, "just a little girl." She gives a response that shows that one's credibility is not tied to one's gender.*	(Ghiso, 2015)
		3rd Grade Literacy Small Group Writing	*Learners research the conspicuous absence of African Americans in local history books. They create an alternative community genealogy that portrays the many contributions of African Americans to their city.*	(Campano, Ghiso & Sánchez, 2013)
Speaking Truth to Power	Learners show others how the status quo implicates them in reproducing harm	4th Grade Science Afterschool Program	*Learners feel disenfranchised by their science teacher. In their afterschool program they request to make a video with their friends to show their teacher what their science capabilities and fun science looks like.*	(Calabrese Barton, 2001)
		6th Grade Science Play and Rap Performances	*Learners write and perform plays and rap songs about science content. Female learners opportunistically use their performances to make visible the ways that they are silenced by male peers during science discussions.*	(Varelas, Becker, Luster, & Wenzel, 2002)
Enacting New Possibilities	Learners take up new ways of knowing, doing, and being	4th Grade Science Small Group Experiments	*Learners perform science in ways that are unique to their personalities and desires including being conscientious, being nurturing, standing up for others, and creating inventions to solve practical problems.*	(Carlone, Scott & Lowder, 2014)
		6th Grade Science Small Group Projects	*Learners invent new forms of science participation. These include rewriting and singing the lyrics of a popular song to make a study aid for bone anatomy, and using a puppet to show how oil spills work.*	(Tan & Calabrese Barton, 2008)

(*enacting new possibilities*). See Table 1.18 for descriptions, examples, and citations of each italicized practice.

Discussion

This literature review draws together and compiles over 250 cases that attest to K-6 learners' capabilities and competencies to leverage authentic inquiry practices to advance their collective inquiry. The thematic analysis of these cases identifies a set of authentic inquiry practices that, when considered together, reveals the holistic nature of the enterprise of authentic inquiry work. This analysis makes clear that authentic inquiry as a collective activity entails far more than mastering general research tools and techniques (such as the scientific method). Rather, it includes research practices such as conducting investigations, negotiating inquiry norms, and interpreting phenomenon; organization practices such as managing investigations, documenting work, and enhancing workflow; motivation practices such as taking interest, engaging feelings, and navigating fragility; collaboration practices such as coordinating joint work, constructing meaning, and building trust; innovation practices such as generating novel insights, building capacity, and iterating progressively; and equity practices such as expanding who gets to participate, who gets to benefit from participation, and what gets to be counted as valued participation.

To reiterate, this literature synthesis does not claim that all young learners can automatically and effortless perform all of the listed practices. Nor does this synthesis claim that this list exhausts all possible practices that can be used to support and sustain authentic inquiry. Rather, this synthesis provides a compilation of research studies and a set of inquiry practices that can move conversations forward about how best to support young learners in performing authentic inquiry.

Implications for Theory

Educational theory offers numerous models for conceptualizing what it means for a learner to be competent. Dominant models locate competency in an individual's recognized status, performance outcome, or fixed traits such as meta-cognition (Hall & Stevens, 1995). This literature synthesis takes a step forward in demonstrating the viability of an alternative model that locates competency in the authentic inquiry practices that learners leverage to advance their collective inquiry.

Viewing learners' moment-to-moment interactions as they support and sustain their work reveals a layer of competency that is overlooked when theorists attend only to a learner's recognized status, performance outcomes, or innate abilities. Furthermore, a model that locates competency in a rich holistic ecology of authentic inquiry practices can help replace individual-level and deficit-based explanations of competency (e.g. some learners are talented and some are not) with system-level and asset-based explanations of competency (e.g. some learning environments constrain generative aspects of inquiry such as collaboration and innovation while others afford it). In addition to demonstrating a viable alternative to dominant models of competency, this literature synthesis also provides a more expansive view of the inquiry process. Inquiry, under this analysis, is a process that gets performed through a rich holistic ecology of authentic inquiry practices. This perspective supports the work of educational researchers who are currently theorizing the epistemic affordances of learners' embodied and relational experiences, while also advocating for an axiological reorientation that re-centers definitions of inquiry around what is meaningful to learners and their communities in the first place (Bang & Vossoughi, 2016; Jaber & Hammer, 2016a; Keifert & Stevens, 2019; Krist & Suárez, 2018).

Implications for Practice

Practitioners seeking to provide young learners with opportunities to engage in authentic inquiry can browse the compilation of articles presented here to see richly documented examples of what this kind of learning looks and sounds like in action. Practitioners can also consider what they can do to make space for a wide range of inquiry practices to co-occur during a facilitated authentic inquiry. For example, practitioners can work to negotiate norms with learners that directly honor the myriad ways that learners can productively contribute to inquiry (Cohen & Lotan, 1995).

Practitioners can also work to transform an aspect of the activity system (i.e. the relationships between subjects, tools, rules, a community, a division of labor, and an object that constitutes a given learning environment) that appears to be unnecessarily constraining learners take up of holistic practices. For example, when young learners participated in a game-based inquiry activity that had a cooperative goal as its object, rather than a competitive goal, the learners were far more likely to take up practices that supported and sustained their inquiry by keeping each other motivated, focused, and working together (Peppler, Danish & Phelps, 2013).

Implications for Policy

At a national curriculum level, policy documents are beginning to recognize the important role that inquiry practices play in advancing learning in content domains such as science and engineering (NRC, 2012; NGSS Lead States, 2013). At an international level, multiple countries are seeking to change education to better prepare learners to address the increasingly complex (i.e. open-ended and interdisciplinary) problems of the 21st century (Voogt & Roblin, 2012). Providing learners with opportunities to engage in authentic inquiry has shown promise in forwarding these national and international agendas (Barron & Darling-Hammond, 2008). Yet, even as inquiry-based learning environments have become more popular, there exist few systematic attempts to document the rich variety of inquiry practices that learners can leverage in these settings to advance their collective inquiry. The current study contributes to these agendas by making visible a vital layer of work that gets performed, but is under-recognized, in facilitated authentic inquiry learning environments.

Directions for Future Research

This literature synthesis adds to an ongoing effort to develop systematic ways of identifying learners' authentic inquiry practices (Jennings & Mills, 2009; Kafai & Peppler, 2011; Takeuchi, 2008). Future research can continue to develop systematic approaches that help make visible additional under-recognized yet generative authentic inquiry practices. More work is certainly needed to identify authentic inquiry practices that happen at larger time scales, in asynchronous interactions, and in interdisciplinary learning environments.

Future research can also use this compilation of authentic inquiry practices to further unpack the complex achievements of young learners within the context of a specific trajectory of authentic inquiry. Research questions that can continue to reveal the work that young learners perform within a context of a specific inquiry include: what range of authentic inquiry practices do young learners simultaneously take up and what is the interplay between these practices? How do young learners re-mediate their learning context in order to make space for the inclusion of more authentic inquiry practices? How do young learners develop and build on a specific authentic inquiry practice over time at different stages of their investigation? Put differently, how is collective inquiry a holistic, contentious, and cumulative achievement and what does this tell us about young learners' competencies as inquirers? Scholars are becoming increasingly aware of the importance of these questions as they try to understand how to provide opportunities for learners to support and sustain their own authentic inquiry work (Calabrese Barton et al., 2013; Carlone et al., 2016; Gresalfi et al., 2009; Herrenkohl & Mertl, 2010; Mercer, 2008). The next two articles in this dissertation take up these questions by examining how young learners enacted a multitude of authentic inquiry practices during a single inquiry trajectory in an afterschool Mancala Club.

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*Indicates studies included in the literature review. For a full listing of the 267 studies examined in this literature synthesis refer to the supplemental reference list.

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Article 2

Authentic Inquiry as a Holistic Achievement in Mancala Club

Abstract

Much of the research on young children's capabilities and competencies as inquirers focuses on cognitive-general or discipline-specific outcomes (Brown, 1992; Metz, 2011), overlooking the learning practices that young learners develop to support and sustain their work as inquirers (Cohen & Ball, 1999; Thomas, 2000). Authentic inquiry learning environments are providing new opportunities for making visible the learning practices learners develop to support and sustain their inquiries. The current study makes visible the wide-ranging learning practices that young learners developed as they worked on an authentic inquiry task within the context of an afterschool game-based learning environment called Mancala Club. The analytic resources of Activity Theory were used to empirically investigate the mediators that facilitators of Mancala Club used to support learners, the ways that learners drew upon and innovated upon these mediators to support their inquiry, and how this work transformed learners' ways of knowing, doing, and being in the process. Findings illustrate the ways that young children within the context of Mancala Club developed the following authentic inquiry practices to support their extended inquiry: Conducting investigations, negotiating inquiry norms, interpreting phenomenon, managing investigations, documenting work, enhancing workflow, taking interest, engaging feelings, navigating fragility, coordinating joint work, constructing meaning, building trust, generating novel insights, building capacity, iterating progressively, expanding who gets to participate, expanding who benefits from participation, and expanding what counts as valued participation. By making visible these learning practices (rather than focusing on cognitive-general or discipline-specific outcomes) this study pushes forward theoretical conceptualizations about young children's competencies and capabilities as inquirers while also providing guidance for practitioners on how to support the development of these manifold authentic inquiry practices in similar informal game-based authentic inquiry learning environments.

Introduction

Historically, educational theorists have framed learners' competencies and capabilities as inquirers in terms of cognitive-general outcomes (such as epistemological reasoning and meta-cognition) or in terms of discipline-specific outcomes (such as using the scientific method or mathematical proof) (Brown, 1992; Metz, 1995, 2011). These cognitive-general and discipline-specific outcomes were typically studied in laboratory settings that focused on isolated and individual one-off tasks (Metz, 2001; Brown, 1992; Rogoff, Topping, Baker-Sennett, & Lacasa, 2002). Young children fared poorly in these settings leading scholars to claim that sophisticated inquiry was beyond their grasp (Driver, Leach, Millar, & Scott, 1996; Karplus, 1977; Lawson, 1979). The rising popularity of authentic inquiry learning environments (Barron & Darling-Hammond, 2008)—where knowledge is made relevant to real-world contexts, learners' own interests, and professional researchers' practices (Shaffer & Resnick, 1999)—has pushed back on this deficit view of young children's inquiry abilities in two ways.

First, by making learning meaningful to young children and supporting them in the process of learning, young children can achieve sophisticated forms of epistemological reasoning previously thought to be outside of their grasp (Metz, 2011). Additionally, a growing number of empirical studies reveal that young learners can make conceptual growth in domains typically thought too advanced for them such as: Complex Systems (Danish, Peppler, Phelps & Washington, 2011), Computational Thinking (Papert, 1980), Discrete Mathematics (Maher & Martino, 1996), Engineering (Watkins, Spencer, & Hammer, 2014), Geometry (Greenstein, 2014), History and Science (Herrenkohl & Cornelius, 2013), Philosophy (Daniel et al., 2005) and the Science of Lunar Phases (Hobson, Trundle, & Saçkes, 2010), Physical Forces (Enyedy, Danish, Delacruz & Kumar, 2012; Herrenkohl & Mertl, 2010), and Thermodynamics (Rosebery, Ogonowski, & Warren, 2010).

Second, scholars conducting research in authentic inquiry learning environments are raising questions that challenge the field to expand its gaze beyond cognitive-general and discipline-specific outcomes as the privileged measure of young children's inquiry competencies and capabilities. Put differently, scholars of authentic inquiry learning environments are increasingly recognizing that authentic inquiry is demanding in ways that cannot be readily measured on achievement tests of cognitive-general or discipline specific outcomes (Hmelo-

Silver, Duncan, & Chinn, 2007). Supporting and sustaining work on an extended inquiry project, for example, is challenging for learners who are still learning to perform research, organize their work, motivate themselves, collaborate well, innovate upon resources, and navigate inequities (Phelps, Dissertation Article 1; see also Barron & Darling-Hammond, 2008; Edelson, Grover, & Pea, 1998; Hmelo-Silver, 2004).

When considering these aspects of learners' authentic inquiry work that are neither cognitive-general nor disciplinary-specific, a number of 'complex' questions emerge (Hmelo-Silver, Duncan, & Chinn, 2007) including: how can facilitators support learners in performing this work, what work do learners do to support and sustain their inquiries, and in what ways do learners grow from performing this work (Engeström, 2011, Herrenkohl & Mertl, 2010; Hmelo-Silver, Duncan, & Chinn, 2007)? As Hmelo-Silver and her colleagues (2007) point out, these complex questions require complex evidence that the educational field does not adequately have. Indeed, only recently are educational researchers beginning to craft novel analytic methods and conceptual frameworks that can provide more complex and holistic pictures of young learners' capabilities and competencies as inquirers. These resources include (a) taxonomies of authentic inquiry practices (Jennings & Mills, 2009; Kafai & Peppler, 2011; Phelps, Dissertation Article 1; Takeuchi, 2008), (b) analyses of how these authentic inquiry practices shift over time and across sites (Vossoughi & Gutiérrez, 2014) at multiple levels including personal shifts, interpersonal shifts, and contextual shifts (Rogoff, 1994), and (c) multi-dimensional models of learning that integrate ways of knowing, doing, and being (Herrenkohl & Mertl, 2010; Packer & Goicoechea, 2000; Rogoff, 1994) and that connect cognitive to emotional and physical work (Carlone et al., 2016; Keifert & Stevens, 2019).

The current study takes up these 'complex questions' and builds on the field's analytic resources to examine closely within the context of an afterschool game-based authentic inquiry learning environment how (a) facilitators supported young learners' research, organization, motivation, collaboration, self-initiation, and critical practices, (b) the work young learners performed to sustain their inquiry by resourcing the facilitators' supports as well as developing their own supports, and (c) learners' ways of knowing, doing, and being became transformed in this process (in relation to the inquiry task, to their peers, and to the broader afterschool learning environment).

This analysis has implications for both theory and practice. Educational researchers studying authentic inquiry learning environments argue that these environments can help learners learn how to learn (Barron & Darling-Hammond, 2008). This study shows this process in action, making visible both how young learners draw on a range of research, organization, motivation, collaboration, innovation, and equity practices that not only transform their inquiry, but also transform the learners themselves. As such, it makes visible young children's wide-ranging inquiry competencies and capabilities that have been overlooked by studies focusing on cognitive-general or discipline-specific outcomes. Additionally, this study shows how in the context of a game-based afterschool club, facilitators can introduce a number of mediators that support learners' research, organization, motivation, collaboration, innovation, and equity practices.

Research Questions

The current study takes up two research questions within the specific context of an afterschool game-based authentic inquiry learning environment for young learners:

1. *What authentic inquiry practices do young learners leverage to advance their collective inquiry on a game-based challenge in Mancala Club?*

2. *How do these enacted authentic inquiry practices, simultaneously, transform young learners' ways of knowing, doing, and being in relation to the game Mancala, to their peers, and to Mancala Club?*

To answer these research questions this study is organized around two overlapping analyses that examine how learning unfolded within a specific authentic inquiry task during the first year of an afterschool learning environment called Mancala Club. The first analysis documents the specific research, organization, motivation, collaboration, innovation, and equity practices that young learners perform to advance their collective inquiry. The second analysis examines how these enacted practices transformed young learners' ways of knowing, doing, and being with specific attention to their transformed participation with the game Mancala, their transformed interactions with their peers, and their transformed engagement with the broader Mancala Club learning environment. These overlapping analyses showcase how the inquiry process is holistic—in terms of the wide-ranging practices learners perform and in terms of how learners become transformed through the process (in ways that go beyond simply learning more discipline-specific content knowledge).

Conceptual Framework

This conceptual framework draws together three bodies of related literature that establish the fundamental concepts examined in this study: authentic inquiry practices, Activity Theory, and combinatorics thinking. First, this section lays out what researchers currently know about learners' authentic inquiry practices. Next, it focuses on why socio-cultural theory is a particularly productive approach to studying how young learners develop and are transformed by authentic inquiry practices. Finally, it reviews the literature on how young children engage with a central aspect of the authentic inquiry task presented here: combinatorics thinking within the context of an existence task.

What is known about elementary-age learners' authentic inquiry practices?

For the purposes of this study, inquiry is defined as authentic inasmuch as the inquiry draws on (a) the complex dynamics of real-world contexts (such as open-ended and interdisciplinary problems), (b) learners' own interests and experiences, and (c) professional researchers' own inquiry practices (Shaffer & Resnick, 1999). An example of an authentic inquiry activity that draws together all three dimensions is the Water Taste Test (Rosebery, Warren, & Conant, 1992). Older learners conducted blind taste tests of water from different water fountains at their school to determine which fountain was most preferred. Surprised by their results (learners preferred water from what they had previously thought was the worst water fountain at their school), learners set out to comparatively analyze each water fountain for chemical and biological differences. In describing this inquiry project, Rosebery, Warren and Conant (1992) note how learners' inquiry work is true to real world activities that are ill-defined, hold multiple solutions, and make use of multiple disciplines, as well as how it is meaningful to the learners and to their larger community, and, finally, how it resembles the practices of professional water chemists who work with water treatment plants.

Typical descriptions of the practices entailed in authentic inquiry, however, have been critiqued for narrowly focusing on the tools and techniques of research (such as the scientific method or mathematical proof) and overlooking the more social and attitudinal aspects of the work (Edelson, 1998; Edelson, Gordin, & Pea, 1999). Lori Takeuchi (2008; 2010) pushes back on this narrow portrait by creating a taxonomy of authentic inquiry practices informed by her ethnographic studies of marine scientists in the field and of middle school learners investigating the kelp forest ecology of Catalina Island. Takeuchi's taxonomy includes a wide range of practices such as: use inscriptions, maintain equipment, connect to personal experience, camaraderie, reason with others, be uncertain, deal with messiness of data, and tinker with tool.

Takeuchi's list of authentic inquiry practices supports the following claims: (a) that inquiry work does not follow a singular method, path or process (National Research Council, 2012), and (b) that inquiry work draws together and transforms learners' ways of knowing, doing, and being simultaneously (Herrenkohl & Mertl, 2010; Packer & Goicoechea, 2000). Both of these claims reveal the holistic dimension of the inquiry process. Building on Takeuchi's work (see also Jennings & Mills, 2009; Kafai & Peppler, 2011) and extending it into the context of elementary-age learners, Phelps (Dissertation Article 1) performed a literature synthesis, in tandem with the current study, to compile together the various authentic inquiry practices that scholars have empirically documented young learners engaging in. This work shows how learners perform heterogeneous practices such as conducting research, organizing their work, motivating themselves, collaborating with peers, innovating upon practices, and promoting equitable learning conditions (Phelps, Dissertation Article 1). Figure 2.1 summarizes this working list of authentic inquiry practices (see Phelps, Dissertation Article 1 for a detailed methodological account of how this working list was generated).

Research

Conducting Investigations

- Standardizing Procedures
- Operationalizing Constructs
- Generating Original Data
- Consulting Reference Materials

Negotiating Inquiry Norms

- Using Socio-epistemic Norms
- Using Evidentiary Standards
- Using Representation Criteria

Interpreting Phenomena

- Explicating Meanings
- Explaining Mechanisms
- Describing Systems
- Building Models
- Substantiating Claims

Organization

Managing Investigations

- Problem-Scoping
- Planning
- Orienting
- Handling Logistics
- Safekeeping

Documenting Work

- Recordkeeping
- Structuring Entries
- Tracking Progress
- Presenting

Enhancing Workflow

- Modularizing
- Streamlining
- Focusing

Motivation

Taking Interest

- Merging Interests
- Taking Excursions
- Taking Ownership
- Taking Affiliation

Engaging Feelings

- Showing Wonder
- Showing Pleasure
- Becoming Engrossed
- Showing Empathy

Navigating Fragility

- Processing Emotions
- Persisting
- Taking Risks
- Negotiating Conflicts

Collaboration

Coordinating Joint Work

- Creating a Shared Vision
- Monitoring Contributions
- Building on Contributions
- Apprenticing Peers

Constructing Meaning

- Checking Understanding
- Making Thinking Visible
- Building a Local Language
- Perspective Taking

Building Trust

- Showing Vulnerability
- Conferring Dignity
- Showing Solidarity
- Showing Commitment

Innovation

Generating Insights

- Reframing Fixed Ideas
- Playing with Ideas
- Moving across Settings
- Making Connections
- Taking a Break

Building Capacity

- Mobilizing Resources
- Inventing Resources
- Developing Proficiency

Iterating Progressively

- Prototyping
- Generating Feedback
- Evaluating
- Revising

Equity

Expanding Who Participates

- Accessing Agentic Opportunities
- Accessing Positive Recognition
- Accessing Supportive Climate

Expanding Who Benefits

- Improving Personal Livelihood
- Deepening Familial Relations
- Deepening Interpersonal Relations
- Deepening Intergenerational Ties
- Deepening Community Relations
- Deepening Bioregion Relations

Expanding What's Valued

- Dispelling Settled Ideologies
- Speaking Truth to Power
- Enacting New Possibilities

Figure 2.1. Authentic Inquiry Practices

The current study uses this synthesis of young learners' authentic inquiry practices as an analytic tool to make visible the wide array of work that learners perform. In doing so, this study takes another step forward in fashioning a holistic account of learners' authentic inquiry practices (Carlone, et al., 2016; Herrenkohl & Mertl, 2010; Packer & Goicoechea, 2000; Takeuchi, 2008; Vossoughi & Gutiérrez, 2014).

Socio-cultural Perspective

This study draws on the conceptual resources of Activity Theory to warrant the following assumptions: (a) young learners are capable and competent, (b) learners' learning and developmental processes can be explained by reference to their evolving use of socio-cultural practices that draw together tools, norms, values, social interactions and so on to navigate and negotiate their collective activity, and (c) that authentic inquiry practices are inherently holistic, bringing together learners' ways of knowing, doing and being (Cole, 1996; Engeström, 2014; Leont'ev, 1981; Herrenkohl & Mertl, 2010; Wertsch, 1991).

Activity Theory envisions learning not as the acquisition of new knowledge, but as the transformation of the individual's relation to a collective goal-directed activity. A productive way to observe the process of learning as such is to focus on the ways in which individuals master and appropriate practices to transform their participation within an activity system. This allows researchers to make visible how learning is more than an epistemological phenomenon, but an ontological phenomenon that simultaneously transforms the learners' ways of knowing, doing, and being (Herrenkohl & Mertl, 2010; Packer & Goicoechea, 2000). What then is a practice?

Scribner and Cole (1978) who use Activity Theory to make sense of the Vai's literacy learning defined practices as "the carrying out of a goal-directed sequence of activities, using particular technologies and applying particular systems of knowledge. It is a usual mode or method of doing something—playing the piano, sewing trousers, writing letters" (457). Scribner and Cole go on to argue that these practices are not simply derived from an individual's cognitive abilities, but rather that the performance of these practices leads to the development of context-specific cognitive skills. The way Vygotsky (1981) puts this in what he calls his general genetic law of cultural development:

> "Any function in the child's cultural development appears twice, or on two planes. First it appears on the social plane, and then on the psychological plane. First it appears between people as an interpsychological category and then within the child as an intrapsychological category. This is equally true with regard to voluntary attention, logical memory, the formation of concepts, and the development of volition." (163)

For these reasons, this study examines young learners' competencies and capabilities as inquirers by investigating the strategies they use to transform their participation in a number of challenging yet generative inquiry practices. As such, this study does not attend to young learners' cognitive abilities nor to pre-determined learning outcomes. Rather, the focus is on the ways that learners transform the practices that allow them to support and sustain their collective inquiry work.

To analyze the emergence and co-development of young learners' authentic inquiry practices in-situ, this study draws on the methodological guidance of Activity Theory. The methodology proposed by Activity Theory is uniquely situated for carrying out this type of investigation. As Vygotsky (1999) remarks,

> "The basic problem is the study of those means and devices that the subject used to organize his behavior in concrete forms most adequate for each given task. In

> directing our attention to the study of specifically these (external and internal) means of behavior, we must conduct a radical review of the methodology of the psychological experiment itself." (59)

To study how young learners develop practices that mediate their activity, Vygotsky and his colleagues created the method of double stimulation. The first stimulus consists of a novel and challenging task that cannot be readily solved by a learner's existing practices. The second stimulus is comprised of the signs and tools and other resources of a mediator-rich learning environment that a young learner can experiment with to fashion a new practice for productively approaching the novel and complex problem (Vygotsky, 1978, p. 74).

For example, in the forbidden color game at Vygotsky's laboratory, young children are given a novel and challenging task: answer color-specific questions (what colors can leaves be?) with the constraints that some colors are not allowed to be said and that no color can be repeated. This novel and challenging task acts as the first stimuli—without assistance young children frequently lose at this game as they forget which color words they have already used and which they were instructed not to say. The second stimuli comes in the form of nine color cards. Children who develop a practice of using these color cards as memory aids to mark their progress (reminding themselves of which colors they have already said and which they are forbidden to say) have a far easier time winning the game than children who do not develop this practice.

Additional studies demonstrate that when young children are given a potentially mediating tool (for example, a compass to use for a map representing task) before they encounter difficulty with a task, they do not readily transform their learning practices (Lehrer & Pritchard, 2002). Conversely, when learners are given a novel and complex task, but are not situated in a mediator-rich learning environment, they also do not readily transform their learning practices (D'Andrade, 1981). Taken together, these examples suggest that an ideal methodology for eliciting the development of authentic inquiry practices requires a challenging and novel task situated within a mediator-rich learning environment. Activity Theory reminds us that mediator-rich learning environments are not settings defined exclusively by the presence of technical and conceptual tools, but are settings that allow learners to engage in collective activity through volition, social interaction, and play (Vygotsky, 1987/1934, p. 50; Vygotsky, 1978/1933, p. 90, 102).

The current study draws on these insights by situating young children within a learning environment that simultaneously acted as (a) an affinity club open to learners' multiple motives for playing with an ancient family of board games called Mancala, (b) an authentic inquiry learning environment in which learners faced novel, complex and collective challenges directly embedded in Mancala, and (c) a mediator-rich learning environment that allowed learners to create new practices as they struggled with challenges. This study focuses on a single collective Mancala challenge, the Ultimate First Turn Challenge, which was novel and complex to young learners because it requires learners to make use of combinatorics—a branch of discrete mathematics that is not typically taught with any sophistication until high school.

What is known about how elementary-age learners use combinatorics to solve existence tasks?

Mancala is a generic name that refers to over hundreds of pit and pebble games played around the world (Russ, 1999) dating back to the ancient civilization of Sumer (Haggerty, 1964). Simple to play, but challenging to master, Mancala has been advocated by educators as a fun, intuitive, and culturally significant means for teaching young learners arithmetic practices (Benner 2004; Haggerty, 1964; Zaslavsky, 1991) and for teaching older learners topics such as game theory and combinatorics (de Voogt, Rougetet & Epstein, 2018). Mancala appreciates worldwide popularity to this day, and can be found in a number of afterschool programs housed in the school district that the learners of this study attended, yet rule variations often differ from school to school. Figure 2.2 uses a flowchart to represent the board layout and rule set that was played at the school the learners in our study attended. The authentic inquiry task embedded within this Mancala rule-set positioned learners to attempt to find a combination of first-turn moves that ensures victory (in other words, a series of moves that scores 25 stones or more on the first-turn). This task is an existence task (Zaslavsky, 2005) because learners must figure out and show whether or not a first-turn game-winning strategy is possible. It is also a task that draws on combinatorics thinking because learners must search through various permutations of possible first-turns in Mancala of which there are hundreds because a first turn in this particular rule-set can generate multiple extra turns.

Papert (1980, p. 21) describes combinatorial thinking as present in tasks "where one has to reason in terms of the set of all possible states of a system." In the research literature, combinatorics tasks for young children include finding all possible combinations of (a) outfits given a set number of shirts and pants (Davis, Maher & Martino, 1992; English, 1993, 2005; Papert, 1980), (b) block arrangements given different colored blocks (Maher & Martino, 1996), and (c) toy gear layouts so that when rotated, two specific gears will turn in the same direction (Metz, 1985). Existence tasks that draw on combinatorics thinking, as the current study does, include showing whether or not its possible to construct a complete circuit (loop) out of a given number of curved and straight toy railroad tracks (Karmiloff-Smith, 1999a, 1999b).

Researchers have found that for elementary-age learners combinatorics problems are novel problems that learners do not readily have systematic procedures for solving (English, 1993; Le Calvez, Giroire & Tisseau, 2008), and for this reason they are difficult problems for learners to solve (Godino, Batanero and Roa, 2005; Mashiach-Eizenberg & Zaslavsky, 2004). Yet, despite the novelty and difficulty of combinatorics problems, they can be solved by elementary-age learners when embedded in contexts that are rich and meaningful to learners (English, 1993; 2005; Maher & Martino, 1996; Maher, Powell, & Uptegrove, 2010). Similarly, in a review of combinatorics-eliciting existence tasks, Brown and Reeve (1987) argue that young children can capably and competently leverage and experiment with resources in their learning environments to focus their attention, monitor their progress, develop increasingly sophisticated problem-solving procedures, and even continue to motivate themselves to correct and perfect their already adequate solutions. Taken together, combinatorics and combinatorics-eliciting existence tasks are novel and difficult challenges for young learners, but within their grasp of solving.

Researchers have also documented how young learners go about solving combinatorics and combinatorics-eliciting existences tasks, articulating a number of stages learners go through. For example, Piaget and Inhelder (1975) present the following three stages of young learner performance on combinatorics tasks: a “non-planning stage,” where learners attempt to make progress through trial and error, a “transitional stage” where learners experiment with different procedures, and finally a “solution stage” where learners develop a systematic way to work through the combinatorics problem. Brown and Reeve (1987) in their review of combinatorics-eliciting existence tasks present a similar series of stages. First, during trial and error learners attempt one solution after another, reconfiguring the entire solution pathway each time. Next, learners begin to consider the system as a whole, using insertion in strategic places to salvage parts of the solution pathway that work, rather than restarting from scratch each time. After finding a solution that works, some learners spontaneously self-initiate additional work, trying to find multiple adequate solution pathways or trying to correct and perfect an otherwise adequate solution pathway (see also Karmiloff-Smith, 1979a, 1979b).

Based on this literature review, combinatorics and combinatorics-eliciting existence tasks appear to be an ideal choice for investigating this study's phenomenon of interest: the spontaneous emergence and development of young learners' authentic inquiry practices over time. Furthermore, because combinatorics tasks originated in the context of games (Abramovich & Pieper, 1996) and hold real-world relevance (Kapur, 1970) the choice of a task using combinatorics seems particularly fitting for an afterschool affinity game club.

Although this task has a correct solution (there either is or is not a game-winning strategy), it still acts as an authentic inquiry task because the complex dynamics of the task position learners to create strategies (from trial and error to systematic procedures) to make progress on the task (Wood, 2013). Furthermore, because this task is much more complex than the combinatorics tasks listed above (such as picking out an outfit) it challenges learners to develop a number of authentic inquiry practices in order to adequately support and sustain their investigation. Further still, because this task is game-embedded, a number of ill-defined problems envelop it such as how to best minimize game-play errors and reduce redundant game-play steps (c.f. Steinkuehler, 2006 on deep play). The analysis that follows the method section focuses on the specific authentic inquiry practices that developed and how these, in turn, transformed learners ways of knowing, doing, and being in relation to Mancala, to their peers, and to the broader club itself.

Figure 2.2. Mancala Round-and-Round Ruleset

Methods

Context

This paper reports on data collected during the first iteration of an afterschool affinity game club called Mancala Club. Mancala Club's first iteration was designed and facilitated by John Benner, Gabe de los Angeles, and David Phelps. We are all learning scientists and game designers who have many experiences facilitating play with elementary age learners in informal learning environments. We are all male, two of us are White and one Native American. In Mancala Club, we also served as coaches, camera operators, and researchers.

The afterschool site was housed within a mid-sized urban Elementary school which receives Title 1 funds and represents a diverse racial student demographic. Each quarter the PTA and Parks Department organizes voluntary afterschool enrichment programs for learners. We offered Mancala Club, at no cost to families, during the spring quarter in 2015 for seven sessions total. Parents signed up their children through enrollment packets.

Twelve elementary age learners participated in the club and consented to be in the study. The group was partially diverse across grade level (17% 2nd grade, 50% 3rd grade, and 33% 4th grade), gender (33.3% female) and race/ethnicity (42% White, 33% African immigrant, 17% African-American, 8% mixed or other).

Mancala Club met weekly across seven sessions for an hour and forty minutes per session. The structure of the club approximately followed the timetable shown in Figure 2.3. This structure was modeled after (a) the school's use of a socio-emotional program called RULER and (b) ethnographic observations of the chess club at the school that learners in the current study attended. Specifically, the RULER program implements various tools to support learners in identifying and openly discussing their feelings (Nathanson, Rivers, Flynn, & Brackett, 2016). The coaches built two of these tools into the structure of the club: The Mood Meter and the Club Charter. In the

Mood Meter tool learners map how they feel across two spectrums: pleasantness and energy levels. Through the Charter tool learners discuss how they want to feel in the club, what behavior expectations will help to achieve the desired feelings, and what strategies they can draw on to meet these expectations. Furthermore, the coaches organized the flow of activity in a way that resembles the rhythm of the same school's Chess Club which includes beginning Club time together by eating a snack in the cafeteria.

Time	**Activity**
2:50-3:00	Snack
3:00-3:15	Outdoor Exercise
3:15-3:30	Arrival Meeting: Mood Meter, Club Charter, Preview Challenges, Share Mancala Experiences
3:30-4:20	Free Choice of Mancala Stations: Achievement Station (Ultimate First Turn Challenge), Competition Station (Bot Challenge), Exploration Station (Design a Variant Challenge), Social Station (Friendly Play)
4:20-4:30	Clean-up, Debrief, and revisit the Mood Meter

Figure 2.3. Mancala Club Schedule

This structure also allowed the club designers to meet multiple needs and interests of learners—physical needs for food and movement, safety needs for clear expectations and behavioral norms, autonomy needs for agency and free choice, and self-actualization needs for becoming more central participants in the affinity culture of Mancala Club. It also allowed the designers to meet the needs of the research study—to observe learners freely engaging in extended inquiry over multiple sessions of activity and at different challenge stations. This study focuses on how learners interacted with the design of one particular station challenge: the Ultimate First Turn Challenge.

Study Design

Following the principles of Design Based Research (Cobb et al., 2003), the current study simultaneously creates a learning environment based on conjectures from learning theory and tests these conjectures by placing learners within the learning design. As learners interact with the learning environment in unforeseen ways, new conjectures emerge about how to best support learning and make it visible, and the learning environment is continually refined in response. Design Based Research (DBR) itself has been continually refined over time and it has been taken in a number of novel directions including Community Design Based Research (CDBR), Design Based Implementation Research (DBiR), and Participatory Design Research (PDR). Mancala Club, which has now been iterated over a dozen times follows two specific DBR variants: Multi-tiered Design Experiments (Lesh, Kelly, & Yoon, 2008) and formative intervention (Engeström, 2011).

Initially, Mancala Club was designed to scaffold and make visible young learners' engineering, mathematical modeling and computational practices as learners solve novel and complex challenges. Critical to the design of this study was the decision to not assume or pre-specify which engineering, mathematical modeling and computational practices learners would draw on and develop. As such this intervention was not designed to enact a uniform and linear trajectory of pre-sequenced discipline-specific practices (i.e. a learning progression). Instead, the study was designed in a way that allowed learners to move laterally across challenges, pursuing them in whatever depth or combination suited their interests. This decision was fitting given that the study occurred in an afterschool game-based affinity space. Through these decisions, researchers, coaches and elementary-aged children became co-learners, and hence the study was both multi-tiered (learning at multiple levels) and formative (what will be learned is not pre-specified ahead of time). Although the study was not initially designed to make visible and analyze the holistic breadth of young learners' authentic inquiry practices, nor the holistic transformations that learners underwent through their inquiry, the openness of this study design along with the nature of the collected data (see below), supported a fine-grained analysis of the holistic dimension of young learners' inquiry process.

Facilitators' Tools, Talk, and Task

Prior to designing and facilitating this Mancala Club, Coach John had experience creating a Mancala Club in another afterschool environments. He drew on this experience in several productive ways that supported learners in developing various authentic inquiry practices. Coach John's contributions are worth detailing here because they show how the tools, the talk, and the task worked to create a mediator-rich learning environment (Sohmer, Michaels, & O'Connor, 2009). This account shows that young learners' own work was not performed in a vacuum (Vossoughi, Hooper, & Escudé, 2016) but drew on and innovated upon a number of mediators introduced by the Mancala Coaches.

First, based on his prior experience in facilitating afterschool Mancala Clubs, Coach John suggested populating the learning environment with a number of tools that he had good reason to believe would support young learners' inquiries with Mancala. These tools included the Club Charter (described above) for learners to regulate their emotions, pre-cut wood and wood glue for learners to create their own take-home Mancala boards, stones for learners to take-home to play Mancala with, stenographer notepads for learners to document their work in, and a notation system to allow learners to translate their Mancala moves into an algorithm-based language.

Second, Coach John took time during arrival meetings to introduce the various tools to the club in a straightforward and structured way that respected and made opportunities for learners to share their prior knowledge and expertise. For example, in presenting the notation system to learners, Coach John asked learners who had participated in Chess Club to describe what notation is to the rest of the club. Then he showed learners how to designate a letter of the alphabet (A-F) to each hole on the Mancala board moving from right to left from the goal (see Figure 2.4). These letters represent the possible inputs (where players choose to begin their move). As players gain extra turns (by landing in their goal) and make additional decisions, then additional inputs are written down forming a string of letters (i.e. an algorithm). Next, Coach John showed players how to count the number of stones in their goal at the very end of their turn and how to record this number (the output) at the end of the recorded string of letters. Then, Coach John had learners demonstrate a game while collectively practicing how to notate that game. Coach John ended the lesson by asking learners how Mancala notation compared to Chess notation. To make the notation system clear to the readers, Figure 2.4 maps the notation system onto the Mancala Round-and-Round Ruleset flowchart.

Third, Coach John, along with the other coaches, responded opportunistically in the moment (Wendell, Watkins, & Johnson, 2016) to make salient contradictions in the learners' activity and to suggest additional mediators for learners to take up to explore and resolve these contradictions. Examples directly relevant to this study include: In response to a stone-dropping error being made, Coach John asks learners if there is a way they can use notation to backtrack and resolve the error. On two different occasions, in response to learners using notation in innovative ways Coach John comments that learners may find a better way to do notation than Coach John's own way. In response to Renata discovering an 18-stone solution to the Ultimate First Turn Challenge after self-studying at home, coaches positioned her to facilitate the Ultimate First Turn Challenge station for the day to share her study strategies. In another example, when Renata has difficulty keeping the learners at her station working at the same pace, Coach John

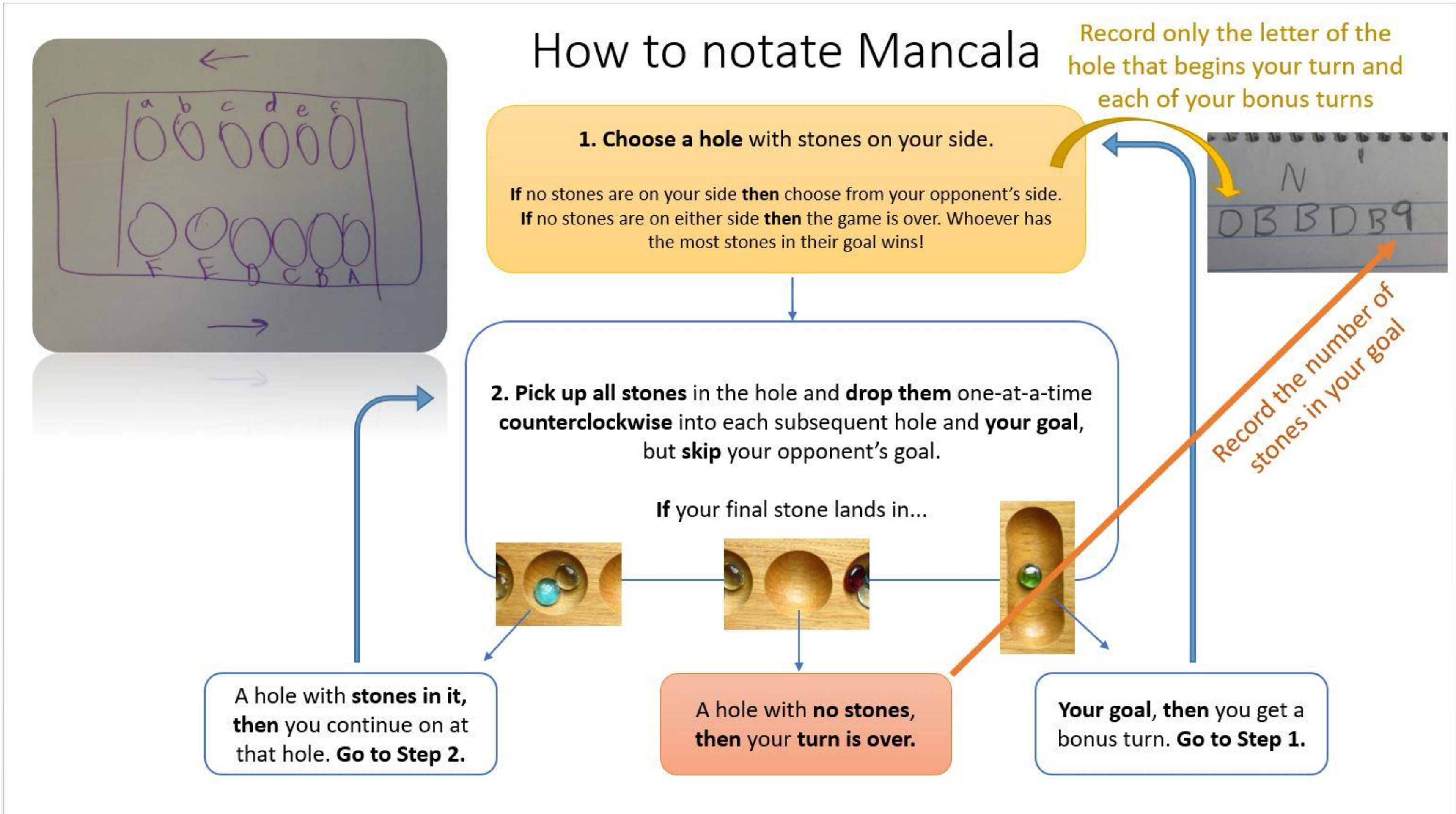

Figure 2.4. Mancala Club's Default Notation for Round-and-Round Ruleset

offers poster board to Renata and lets her figure out how to best use it. These examples show how Coach John worked to support learners in-situ while also respecting and honoring their agency.

Lastly, Coach John, was able to share exciting moments from his previous Mancala Club experiences to pique learners' interest in the Ultimate First Turn Challenge (See Figure 2.5). An abbreviated account of Coach John's introduction of the task through dramatic storytelling at an arrival meeting is presented below:

Figure 2.5. Coach John's Dramatic Storytelling

Coach John: "I've been playing Mancala for a lot of years and I thought I was pretty good at it... but this one kid, this kid Andrew, Andrew made me look like a Mancala amateur. He was so into this game he practiced like real chess masters practiced. I just played it for fun and thought I was good at it. He had this whole system for playing turns, and we played with the rules just like this (motions to Mancala Club rule-set)... he found a system, a set of moves he could make on his very first turn, if he went first, that would let him get over twenty stones...before I even got a chance to move...so we wrote down the moves that he made, and then we experimented with different points, and his strategy, no matter how many different ways we experimented his strategy was still better. But guess what. The notebook that I had that had that strategy in it was lost."

Learners: "Noooo."

Coach John: “I know. But whatever. We got boards. We got stones. We got notebooks.”

Learner: “What was the strategy?”

Coach John: “Well I don’t know that’s the thing, we’ve got to figure it out. But what’s going to be kind of fun, if you do a good job with notation, and you write down your moves then you can remember what you did and then you can look at the end of your first move and see was that a good first turn, was that a good strategy?”

Through the situated tools, talk, and task that Coach John introduced, Mancala Club became a mediator-rich authentic inquiry learning environment. A visual summary of these mediators and the ways in which they appeared (in hindsight) to support young learners’ authentic inquiry practices during the Ultimate First Turn challenge are presented in Figure 2.6. Of course, learners did not always interact with the mediators in a straightforward or expected way. Rather, learners innovated upon these mediators, repurposed them, combined them, and developed their own mediators to perform their inquiry work.

Data Collection

All 7 sessions of Mancala Club (including arrival meetings, free choice stations, and debriefs) were videotaped for later analysis using three cameras situated at different stations. This produced approximately 21 hours of film footage. The current study utilizes video and audio data taken during the Ultimate First Turn Challenge which spanned 5 club sessions (day 2-6), resulting in approximately 4 hours of time-on-task video.

Additionally, coaches took ethnographic field notes of interactions, and audio-recorded semi-structured debriefs immediately after the end of each Club session. A third data source consists of photo documentation of learners’ products and artifacts during each session. These products include learners’ notebooks, learners’ contributions to wall charts, and learners’ designed Mancala bots. The claims in this paper will be made by triangulating these three data sources.

Analytic Procedure

Conversation and Interaction analysis (Hall, 2001; Jordan & Henderson, 1995) along with Grounded Theory (Glaser & Strauss, 1967; Charmaz, 2008) are used to examine the authentic inquiry practices that young learners leveraged to advance their collective inquiry on the Ultimate First Turn Challenge. Following the conversation and interaction analytic methods detailed by Hall (2001), and by Jordan and Henderson (1995), video tapes of all sessions were content logged to chronicle and summarize, at a high-level, the various activities that were enacted during Mancala Club. A second pass identified 'hot spots' relevant to the phenomenon of interest.

The Ultimate First Turn Challenge was chosen for extended analysis due to the rich and visible nature of the interactions between learners and the number of artifacts learners designed as they took on authentic inquiry practices. Hot Spots within the Ultimate First Turn Challenge were transcribed for verbal markers (such as pauses, overlaps and intonations) and non-verbal markers (such as gestures and spatial body-position). The analysis progressed iteratively through multiple viewings of the entire 4 hours of time-on-task video. Simultaneously, identified practices were continually reviewed and refined in a dialectic conversation with a literature synthesis of young children's authentic inquiry practices in facilitated inquiry-based learning environments (see Phelps, Dissertation Article 1 for a full accounting of this process).

These iterations and the discoveries they led to can be broken down in the following way: The initial viewings (iteration 0) primarily focused on the various strategies young learners developed to create inquiry norms and hold each other accountable to them, to streamline their workflow, to troubleshoot problems, and to motivate each other. During the first major iteration (iteration 1), analysis of the entire data set, revisited each of these codes and attended to additional codes such as the work learners performed to conduct investigations, to record their findings, to coordinate joint work, to construct collective meaning, to build trust, to mobilize resources, to negotiate rules, and to problem-pose.

The next major iteration (iteration 2) revisited each of these categories while also attending to the research practice of sense-making, the motivation practices of taking interest, taking ownership, and taking satisfaction, and the self-initiation practices of sharing resources, innovating upon resources, innovating with resources, moving across settings, moving within settings. Additionally, this iteration made salient the contentious nature of these inquiry practices as it attended to how learners worked to transform their learning opportunities by re-mediating power, re-mediating affect, and re-mediating social positioning. This noticing forms the basis of Article 3 in this dissertation which led to additional viewings of a ~50 minute chunk of data. These repeated viewings made salient additional critical practices that became reformulated as equity practices. The third iteration (iteration 3) deliberately reviewed each of the identified practices in the previous iterations to continue to refine and in some cases substantively redevelop the terminology used to describe each such as reformulating self-initiation practices into innovation practices.

To help make young learners' authentic inquiry practices visible throughout these iterations different approaches involving different modalities were taken including: (a) reading only the transcripts to notice patterns in who talks, when, and with what words, (b) watching the video without audio to more closely follow the flow of gesture and body movement, (c) listening only to the audio to notice tone, intonation, and speech rhythm, (d) watching the video on half speed to notice subtle shifts in gesture and body position, (e) watching sections of the video while re-playing learners' Mancala moves to better notice when learners make 'expert' moves as well as stone-dropping mistakes, (f) watching particularly rich episodes of the data collectively with research groups in the University setting to notice and keep in check my own biases and perspectives, and

(g) placing video screenshots, learner's artifacts, and dialogue snippets side-by-side to notice how a single practice can be expressed through multiple modalities (these compilations form the basis of Figures 2.7-2.12).

Qualifiers

Certainly, additional steps and exploration can be taken to extend and refine the working list of authentic inquiry practices used here. Several qualifiers are important to keep in mind. First, these categories are not mutually exclusive. They are interrelated, overlapping, and even co-constitutive. Research practices, for example, can be collaborative. Organization practices can be innovative, and so on.

Second, these categories are not exhaustive. These categories are not offered as a complete set of practices within young children's grasp. Rather, these categories reflect the idiosyncratic agendas of various researchers contributing work to this topic. They also reflect the specific contexts of the learning environments that researchers study authentic inquiry practices in. These contexts tend to be designed and facilitated environments that lend themselves to co-located and synchronous interactions that are analyzable at a moment-to-moment level. Other contexts such as online networks or massively multiplayer videogames or learning across multi-year multi-sites are underrepresented here.

Finally, these categories are not unambiguous. Different researchers use different terms, and certain terms can have multiple meanings. With these qualifiers in mind, the categories presented here are intended to provide a holistic yet straightforward compilation of empirical research in the field, that when synthesized together make visible next steps for research and practice in the field.

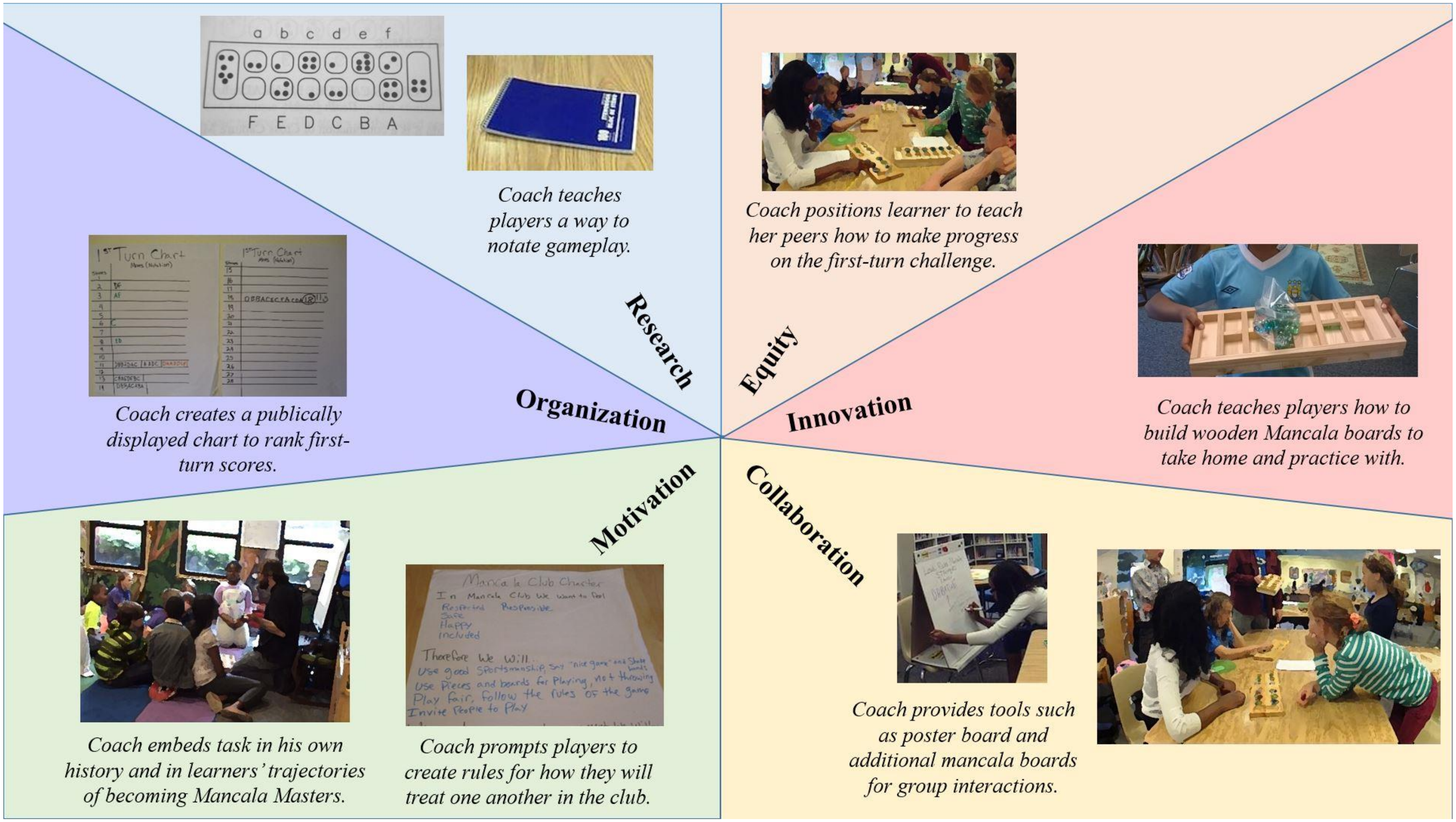

Figure 2.6 Summary of Mediators Introduced by Coaches

Analysis 1 – Learners' Authentic Inquiry Practices

Research Practices

Learners supported and sustained their inquiry work through several research practices including conducting investigations, negotiating inquiry norms, and interpreting phenomena. As expected (based on previous research on combinatorics tasks) learners conducted investigations by using a trial and error approach. Also as expected, learners coupled trial and error with an insertion strategy. Rather than trying out completely different combinations every single time, learners kept constant the beginning segments of their permutations that successfully extended their turns, while varying the moves of their ending segment until finding one that led to an extra turn. Eventually, learners guided their insertion strategy by principled decision-making that appeared to make use of tacit yet productive rules for exploiting various features of this given Mancala rule-set. These principled but tacit rules include maximizing extra turns, maximizing stones scored per turn, and minimizing dead-ends.

In addition, learners negotiated inquiry norms around (a) socio-epistemic issues of how to treat one another in relation to the inquiry process, and (b) evidentiary standards for what counts as a valid solution. Learners navigated norms around whether it was valuable to make mistakes, valuable to explore multiple solution paths, and valuable to collectively pool and share the solutions discovered. Learners also held one another accountable to the evidentiary standards of research verification by valuing rigorous note-taking and a peer review process.

In an example that made evidentiary standards salient for the group, several learners approach Renata claiming that a peer in the club found a way to score 21 stones of the first move. Renata responds, "That's what everybody says but nobody saw him, nobody made notation, so nobody has any proof." Without a documented record the offered solution does not become legitimized. Renata continues with an alternative explanation that makes salient the socio-political dimension of scientific rigor, "plus, if you know, that's [student], his best friend, who wants to get him to be popular." Renata, shortly thereafter, spontaneously enacts a peer review process. The peer review process involves Renata asking her peers to show her their notes and to provide a live demonstration of their notation so that she can check for errors. Once she verifies their work she adds their solution to a poster board. Lydia jumps into the process as well, finding an error in Dalton's algorithm when she peer-reviews it.

In addition to conducting investigations, and negotiating inquiry norms, learners begin to see the board state, and how to exploit it, in more sophisticated ways. In other words, as they became more familiar with Mancala, learners noticed a number of form-function relations including: (a) starting on holes that end in one's goal to maximize extra turns, (b) starting on holes that end in large stone holes on the opponent's side and bringing those stones onto one's own side, (c) starting on holes with a large pile of stones to minimize dead-ends, or (d) mixing and matching the above strategies to perform combo moves. The epistemic fluency that comes with a greater appreciation of form-function relations is expected (but perhaps not so quickly with young learners) given previous research on analog games such as dominoes (Nasir, 2005) and spades (Schademan, 2011). See Figure 2.7 for a visual display of what these research practices look and sound like in action.

Organization Practices

Learners supported and sustained their inquiry work through several organization practices including managing their investigations, documenting their work, and streamlining their workflow. Similar to previous studies on combinatorics and combinatorics-eliciting tasks, learners did not make explicit plans for how to structure their investigations. The coaches, however, supported Renata in co-constructing an in-situ plan for how to structure her lesson for teaching her peers her solution-generation strategies for the Ultimate First Turn Challenge. The coaches also suggested materials—such as poster paper—for Renata to use, which she took up to write out the instructions for her group as well as to record their solutions.

Learners also used their notebooks to record down their solution paths, creating headings and using lines to distinguish between their experimenting and their gameplay. In previous studies of combinatorics tasks, young learners track their progress by creating branching tree diagrams or an equivalent structure to visually organize the various solution paths that had been attempted (Davis, Maher, & Martino, 1992). Lydia took up a different approach in Mancala Club. Rather than visually branching out various solution paths, Lydia crossed out and erased dead-ends directly from her algorithms. Keeping the beginning of the algorithm constant, she then wrote in new potential turn-extending letters. This organization style allowed her to expediently make use of the insertion technique as part of her trial and error strategy.

Learners devised additional ways to streamline their workflow processes. These additional techniques—tracing, reversing, and creating a save point—all allowed learners to quickly cycle through insertion strategies without reverting the board back to its initial start state. Eliminating the need to reset the board saved learners from having to undergo a number of otherwise repetitive steps and it minimized a number of potential errors that can occur when learners re-play their moves (as detailed in Figure 2.9 on navigating fragility).

The tracing strategy was made salient during session 3 when a coach asked Renata how she made progress on the Ultimate First Turn Challenge so quickly. Renata turned her board to the coach and demonstrated the tracing technique. After scoring an extra turn, Renata would choose a hole, count the stones in it, use her palm and fingers to simulate picking up stones from that hole, pretend to drop them one at a time around the board until her last stone drops, and then she would simulate picking up all the stones from that hole and continuing her turn until she either reached a dead-end or an extra turn. If a dead-end was reached she would know not to pick the hole that her simulation started with and would begin simulating a new possibility starting from a different hole. This strategy kept the board-state intact and she could remain in mid-progress without having to reset the board after reaching a dead-end. As she explained this strategy in her own words: “I would just trace my moves and see where it would go.”

Lydia, who employed the tracing strategy Renata used, had developed by session 5 (and attempted on session 4) a way to take a turn and then revert it back if she reached a dead-end. To do this she would pick up stones one-at-a-time, moving in a clockwise direction starting from the hole she ended in and working back to the empty hole she began in. By dumping the stones back into the empty hole the boardstate was reverted a turn, and Lydia could continue to test out permutations without a reset. In another example, Lydia is supported by a coach to modify her notation to include a diagram of a Mancala board that shows a specific board state (i.e. the number of stones that are in each hole at the beginning of a certain decision point). By tying this board state to her algorithm, Lydia effectively creates a save point. Instead of resetting the board back to the beginning after a dead-end, Lydia can reset the board to her most recent save point by referring to her drawn diagram of a specific board state. As Lydia explains this new tool-convention to Mancala Club during a debrief meeting, “But instead of like having to restart every time we made a mistake we like we found a point where everything was correct, like there was no mistake,” and “I drew down the board, and instead of drawing the amount of stones I wrote down the number, there were 12 in the goal, and 0 there, then 10, so the number of stones so that we could just go back to that if we messed up." See Figure 2.8 for a visual display of what these organization practices look and sound like in action.

Motivation Practices

Learners supported and sustained their inquiry work through several motivation practices including taking interest, engaging feelings, and navigating fragility. Studies of informal game-based learning environments demonstrate that learners have a high intrinsic motivation that supports their interest in becoming better at a given game both within and outside of the learning environment (Steinkuehler & Duncan, 2008). In Mancala Club four learners pursued their interest in the Ultimate First Turn Challenge by independently studying first move strategies outside of the club. Furthermore several learners pursued this challenge across multiple days of the club (choosing to work on it instead of engaging in other activities). Additionally, learners took ownership of their strategies and solutions individually as evidenced by learners attributing credit to other learners' strategies and by asking others not to copy down their work without asking. Taking ownership also occurred at a collective level when peers or facilitators positioned others with opportunities to share their strategies and solutions with one another. Further still, learners took interest by merging their Ultimate First Turn Challenge inquiry with other club activities, such as using their high scoring solutions to defeat Coach John's Mancala Bots in competitive play.

Furthermore, learners strengthened their motivation by taking joy in their discoveries, being lighthearted in their camaraderie, expressing positive pride in their achievements, and expressing wonder and empathy during Coach John's story about how a young kid beat him at Mancala on the very first turn. For example, Lydia jumps up and down with joy at her work area after making a discovery, claiming that "oh my God, I found another way to get eleven besides yours. It's a lot shorter." Another sign of learners taking satisfaction in the process of working on the Ultimate First Turn Challenge can be seen in the ways that learners engaged in playful banter and teasing. For example, learners poke fun at Renata when she accidentally calls "B" a number rather than a letter. In another example, learners and coaches engage in playful banter together over using Mancala algorithms to spell out puns such as "BAD." Lastly, learners expressed satisfaction through showing pride in their achievements such as when Neha reviews a mistake she made in her notation to discover that she scored even more stones than she had realizing, exclaiming, "I'm awesome!"

Learners did appear demotivated at times while working on the challenge due in part to the necessity of the challenge (working through all the various permutations is a time-consuming and focus-demanding task) and the contingencies of the challenge (set-backs due to stone-dropping, notation-writing, or memory errors). A single mistake could undermine the entire process and lead to a full board reset. Learners devised a number of techniques to help reduce the most frequent errors including: set-up errors, stone-dropping errors, and notation errors. Each technique is described below.

Set-up errors occur when a board starts with fewer or with more than 4 stones in any given hole. It can be difficult from a glance to precisely tell how many stones are in a hole. One technique learners used to reduce set-up errors involved setting up the board, then aligning one's body (by pulling the board in close and leaning over it) to take a bird's eye perspective of the board while using one's fingers to count the number of stones in each board.

Stone-dropping errors occur when stones are dropped into a wrong hole, or two are accidentally dropped into the same hole, or the stone lands in the right hole but bounces out of it. Learners typically pick up stones from a hole by clenching their fist around the stones. Then they hover their fist over the next hole, palm facing down, and slightly open up their fingers allowing for a stone to be released and drop into the hole. In place of this technique, Renata leaves all the stones in the starting hole, and picks them up one-at-a-time as she distributes them into the subsequent holes. Similarly, Neha developed a palm face-up technique. She scoops the stones out of a hole with one hand, and then uses her other hand to pick stones one-at-a-time from her face-up palm and then distributes them into subsequent holes.

Before creating the palm face-up technique, Neha used a system of hums that corresponded to and seemed to regulate the tempo at which she moved stones around the board. The hum beats were evenly spaced in time, with short hums marking the act of dropping a stone in a hole, and an elongated hum marking the final stone that lands in a hole. For example, if Neha picks up 5 stones from a hole she will make 5 hums as she systematically moves her hand over each subsequent hole dropping a stone one at a time, to the beat of her humming, with the final stone drop receiving an elongated hum as her palm opens back up ready to grab a new batch of stones.

Notation errors occur when the hole that was used to start a turn is written down incorrectly. To minimize notation errors, Clay mapped the alphabetical sequence (each hole's assigned A-F value) directly onto his board (by using a marker). Other learners developed counting techniques—using their fingers or a pencil to rhythmically tap out each hole (starting with A) until reaching the selected hole which they then would immediately write down in their notebooks. This technique prevented learners from simply guesstimating where in the alphabetical sequence a given hole was. See Figure 2.9 for a visual display of what these motivation practices look and sound like in action.

Collaboration Practices

Learners supported and sustained their inquiry work through several collaboration practices including coordinating joint work, constructing meaning, and building trust. Previous research reveals that combinatorics and combinatorics-eliciting tasks lend themselves well to both individual work and group work. During the Ultimate First Turn Challenge learners engaged in both individual and group work. As previously mentioned group work was supported when the coaches directly positioned Renata (who had discovered an 18-stone strategy in self-study) to facilitate the Ultimate First Turn Challenge station for a single session. Renata helped her peers coordinate their joint work in a number of ways. She established a shared goal for the group—to modify an 11-stone solution in order to find an 18-stone solution. Renata also developed a strategy to actively monitor her peers' work as she walked them through the 11-stone solution. After presenting each move of the 11-stone solution, Renata had the group pause and call out the number of stones in their goal so that she could make sure that "everyone's on the right track." Along the way Renata provided just-in time instruction to a learner in the group who was unfamiliar with the rules of Mancala.

When learners appeared to have different understandings of the rule-set, of the notation system, and of Renata's instructions for her designed activity, learners worked to construct meaning. For example, in response to Neha not understanding how to play Mancala, Renata builds a local language or rich semiotic ecosystem (Enyedy, 2005) of verbal instructions and bodily gestures to convey the rules of the game. To convey the 'round-and-round' aspect of this Mancala rule set Renata places a finger in the air and spins it around. To convey that a player can only start on their own side of the board, Renata places both hands over the opponent's side to visually block the opponent's holes as starting options. In this way Renata worked to create a language that Neha could understand. In another example, Renata and Clay work to make meaning across their two different notation systems. Although they did not ultimately resolve their discrepancy, they both worked to translate their languages into a visual and enacted form by taking turns using a Mancala board to perform their interpretation of a specific notation algorithm. The examples of teaching another learner Mancala and of trying to reconcile differences in understanding by building and performing a language also reveal the perspective-taking work that learners engaged in.

Additionally learners worked to build trust. When facilitators positioned Renata as The Ultimate First Turn station leader, Renata and her peers did not appear to trust one another in the beginning. This was evidenced by Renata hiding her solution notebook from her peers, and by a peer teasing that they were going to copy down Renata's solution against her wishes. Trust appeared to emerge over time for this group of four learners, however, as Renata continually made herself present and available to her peers, checking-in on their progress and working closely with those who requested assistance.

This commitment was most salient when Neha becomes exasperated and resigned after writing down her notation incorrectly. Renata confers dignity to Neha by moving towards her and kneeling at her side. Once at Neha's level, Renata attempts to calm Neha down, to persuade her not to erase her notation, and to walk her through each step of the written algorithm to examine the mistake. As Renata works patiently with Neha, they discover that Neha's 'mistakenly' notated algorithm generates 5 more stones than Neha had realized, at which point Neha becomes ecstatic.

Trust also formed as learners showed solidarity to their group. Renata for example, stopped Clay from copying Dalton's newly discovered 14-solution. She asks Dalton if he would want to share his solution with others. Neha, in turn, came to respect Renata's wishes by protecting Renata's notebook from Clay who had grabbed it to copy down the 18-stone solution. See Figure 2.10 for a visual display of what these collaboration practices look and sound like in action.

Innovation Practices

Learners supported and sustained their inquiry work through several innovation practices including generating novel insights, building capacity, and iterating progressively. To generate novel insights learners circulated between different tables to see each other's approaches to making progress on the Ultimate First Turn Strategy. Some learners give each other hints, of where to start in the permutation, which leads their peers to new discoveries. Other learners withhold their solutions, inviting their peers to rediscover a permutation for themselves. Still, other learners actively ignore these hints to entertain different starting sequences for their algorithms, which also leads to new discoveries. This is especially salient when contrasting the work of Renata and Lydia. Renata instructs Lydia to begin her permutation with hole D, because as she explains it immediately leads to an extra turn. Lydia, eschewing this fixation on D, explores alternative starting points and through this process discovers that hole A is a promising starting point because it leads to two stones being scored and an extra turn, compared to D which only scores one stone.

To visualize this difference in permutations, Lydia modifies the Club notation system to include data on how many stones are scored at each decision point, not simply how many stones are scored at the end of a turn in total. This new tool-convention allows Lydia to compare the efficiency of various decision points for maximizing stones scored. In short, Lydia is able to be more deliberate in her investigations of the Ultimate First Turn Challenge. Sharing this innovation and its value with the club during a debrief meeting, Coach John remarks "We may end up doing a better way of doing Mancala notation than what I thought was the best way." Lydia, as previously mentioned, developed and shared another innovative tool-convention with Mancala Club: the notation save state diagram that helps to prevent full resets. By transforming the tool-conventions of Mancala Club, Lydia is helping to build capacity, and, in turn, to support and sustain the collective inquiry of the club.

Learners also built up their own capacity by practicing the Ultimate First Turn Challenge outside of the Club. As previously mentioned, four learners used the wooden mancala boards they built to engage in self-study at their homes. As Renata explained, “I just go home, stay in my room, study and see what moves I can do.” Renata also recorded her at-home self-study results in her own notebook. By mobilizing this notebook—bringing it from her home to Mancala Club—she was able to help apprentice her peers to take up the Ultimate First Turn Challenge. Taken together, learners built capacity through engaging in deliberate practice, designing new tool-conventions to support their deliberate practice, and then sharing their work with their peers in Mancala Club.

In addition to building capacity, learners also developed practices to help iterate on their algorithms progressively. Renata intentionally sets her peers up to iterate upon their solutions when she teaches them how to perform an 11-stone solution and then challenges them to build on that solution in order to discover an 18-stone solution. As previously mentioned Renata also imitates a peer-review process to verify solutions. These reviews generate feedback and evaluations that lead peers to re-examine and refine their work. In addition to iterating upon their solutions, learners also iterated upon their tool conventions. For example, as previously mentioned Lydia and a coach worked together to modify notation to include a save state. Before reaching this point, their design work went through several quick successive iterations that included setting up an extra mancala board to act as a save point, then diagramming out the save point (as Lydia realized she does not have access to two Mancala boards at home), then using an arrow to link the diagrammed save state to the notation algorithm, then realizing that the save state, itself, can be progressively updated. As Lydia explains this final insight, “I can erase the numbers that I have here” and “we can change them to what we have (motioning towards her tangible board) like if we want to do it here (points to the final letter in the notation sequence)." See Figure 2.11 for a visual display of what these innovation practices look and sound like in action.

Equity Practices

Learners supported and sustained their inquiry work through several equity practices including expanding who gets to participate, expanding who gets to benefit from participation, and expanding what gets counted as valuable participation. In an effort to build community in Mancala Club, coach John hosted a Mancala Mixer during session 4, pairing together learners who had yet to play together. This was a rare instance in which learners did not have agency over their activity choice, and unsurprisingly several learners resisted this activity. When two learners were picked up early—leaving Neha and Lydia mid-game—Neha and Lydia advocated to be allowed to continue with their Ultimate First Turn experiments rather than being reassigned to play each other in the Mancala Mixer. The coaches found their request agreeable, and in this way, Neha and Lydia were able to successfully re-mediate the power relations that determined who had access to what activities at what time.

Peers also gave each other opportunities to take agency and to be positioned as an authority in relation to their work on the Ultimate First Turn Challenge. This occurred during the first session when Clay scores 15 stones on his first-turn against a coach, and a peer excitedly claims that Clay has "almost found the big special move." This early positioning of Clay as someone who is already competent at this challenge (even before the challenge or notation were formally introduced) may explain why, during the second session, Clay becomes the first learner to dutifully take up the challenge. This positive positioning also became salient in the third session when, during a debrief meeting, learners used their opportunity to ask Coaches questions to instead turn to their peers and ask them about their strategies and advice. By addressing each other directly peers re-mediated the debrief session effectively granting themselves more agency (they are now able to ask each other questions) and positioning each other with more authority (it is their peer's advice that they are interested in.

Additional examples of positive peer-to-peer positioning occurred during session 3 when coaches positioned Renata as a station facilitator. Although contentious at first, Renata re-mediated peers agency by prompting them to participate in increasingly open-ended tasks. She also enhanced their authority by publicly celebrating the various contributions each learner made—from good strategies to Lydia's modified notation system. Examples from session 3 are further detailed in Article 3. Taken together, these examples show how young learners were able to expand their participation in the club by being able to access agentic opportunities and positive recognition.

Learners also worked to expand who gets to benefit from their participation in the club. They used their built wooden Mancala boards to play games with their families and with their friends in out-of-school settings. Learners also brought their families into Mancala Club—siblings, parents, and grandparents. Family members taught club members new ways to play Mancala—a grandmother taught a version she had learned growing up as a child in Africa, and a father taught a variant that he himself designed and thought would be particularly appealing to the age group of the club. Through these experiences learners developed mixed-age, intergenerational, and familial bonds.

As expected, learners also developed bonds between themselves. Renata, Neha and Lydia formed a bond after working closely together on the Ultimate First Turn Challenge in session 3. This bond is evidenced when they self-selected to pursue activities together or went out of their way to join each other. For example, Neha and Lydia choose to play a cooperative variant of

Mancala called Play-to-Tie together. Although Play-to-Tie is a two-player game, Renata joins them at the table and is able to participate by openly strategizing with Neha and Lydia about the game as they play it. On the last day of the club, they clearly enjoy each other's company as they play 4-Player Mancala together. These examples show that learners are able to derive benefits for themselves from challenges such as the Ultimate First Turn that go beyond researcher-defined discipline-specific learning outcomes such as combinatorics thinking.

In addition to expanding who gets to participate and the benefits they derive from participating, learners also worked to expand new valued ways of participating. They did this by enacting and publicly showcasing new ways of knowing, doing, and being in Mancala Club. Episodes in which learners themselves shifted from devaluing to valuing a practice were particularly salient. For example, Renata initially attempts to make Lydia work through the same solution path Renata herself had discovered. Yet, after Lydia tries out different solution paths and finds one that yields the same score as Renata's path, Renata comes to champion Lydia's work during a debrief meeting, "[Lydia] found another way to get eleven without doing the same things I did, she did something completely different." Similarly, Neha makes a mistake which she tries to erase, but as Renata helps her to work through the mistake Neha comes to collectively celebrate her mistake during a debrief meeting, "I thought it was eight, but I did it wrong." By publicly retelling the stories of the multiple solution paths and of the re-examination of the mistake, learners helped to establish new possible ways of knowing, doing, and being in Mancala Club. These examples, of course, also portray the transformations learners themselves underwent during this inquiry, which is the subject of the next analysis. See Figure 2.12 for a visual display of what these equity practices look and sound like in action.

Research Practices

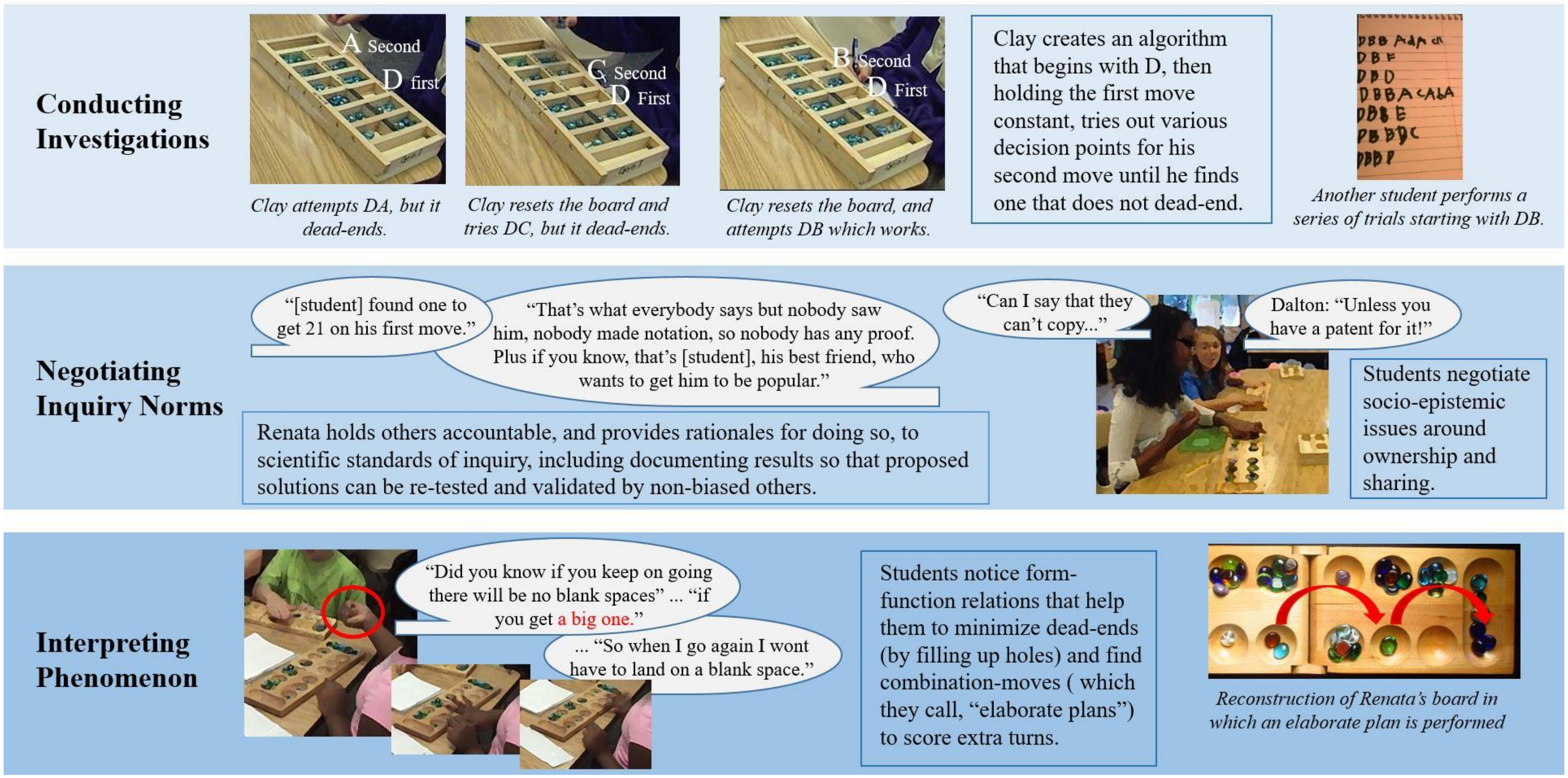

Figure 2.7. Learners' Research Practices

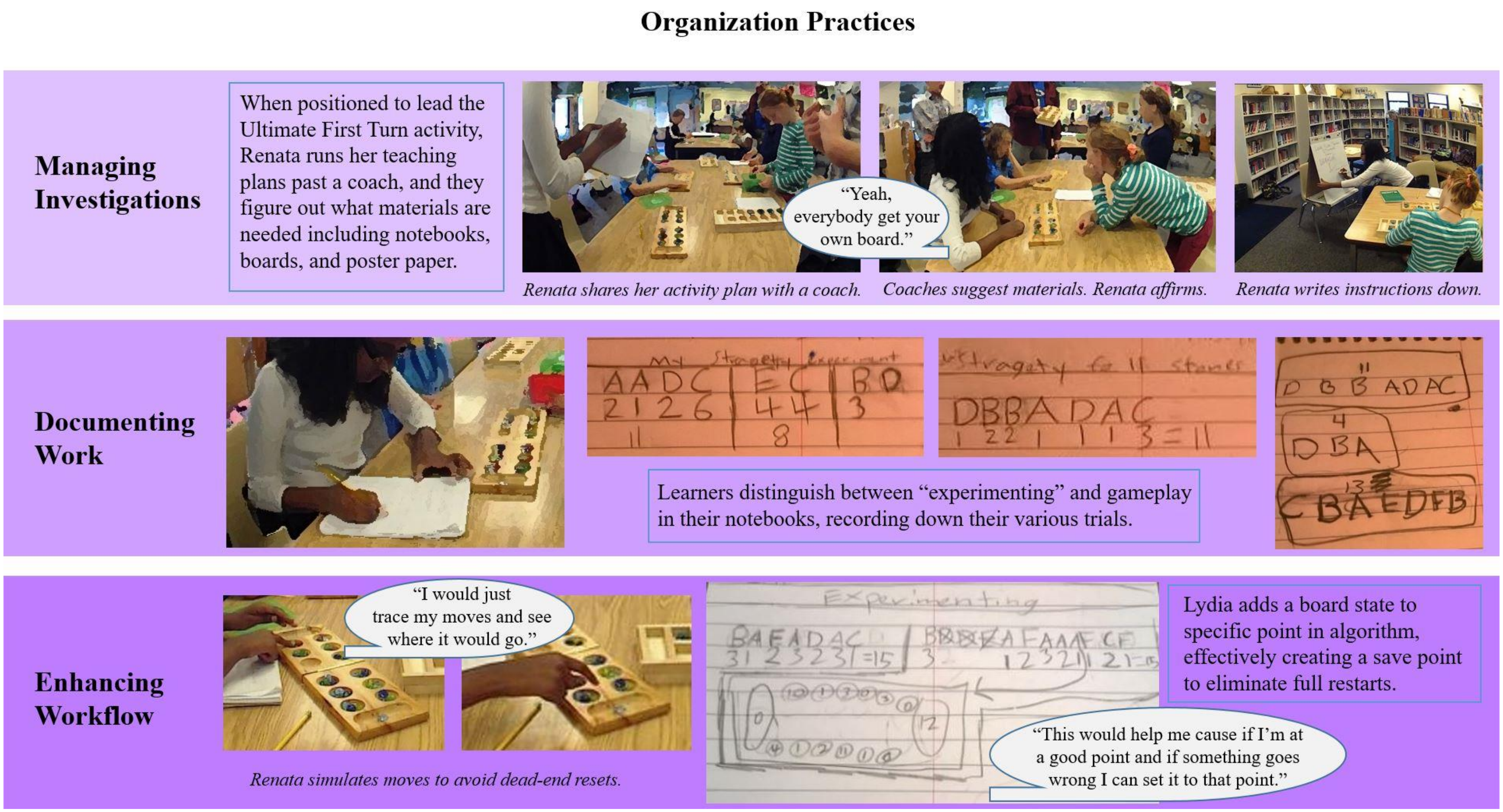

Figure 2.8. Learners' Organization Practices

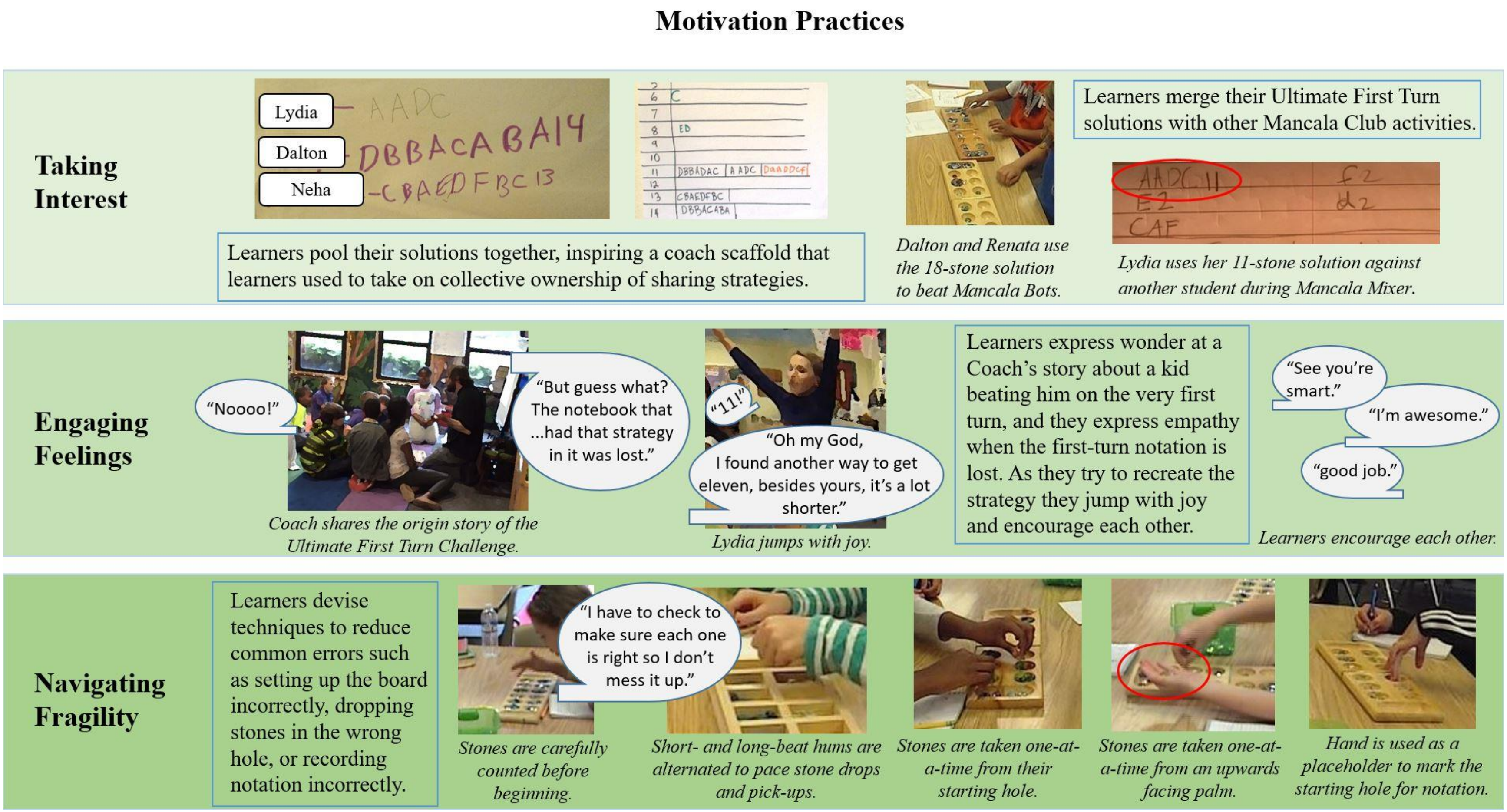

Figure 2.9. Learners' Motivation Practices

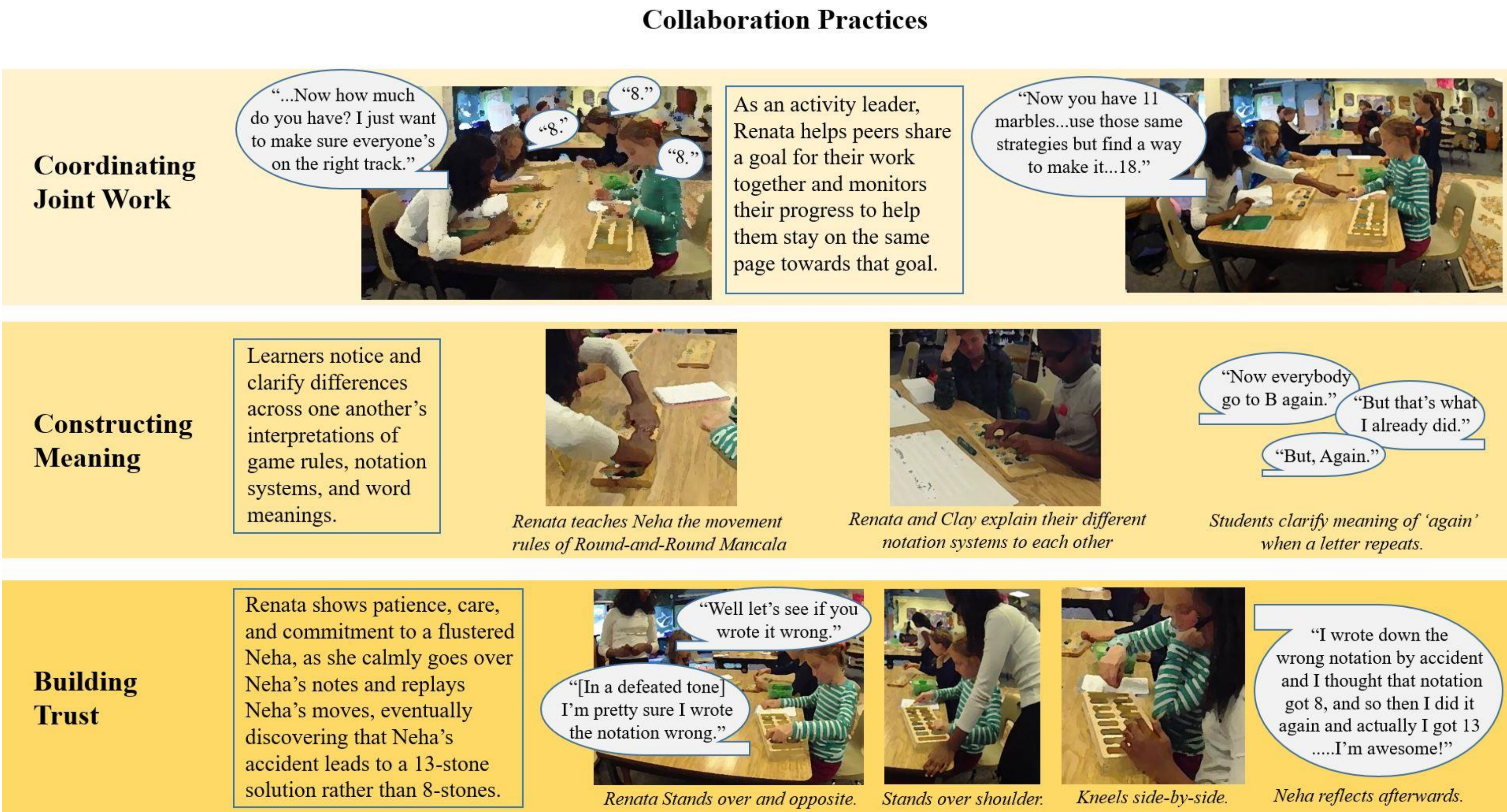

Figure 2.10. Learners' Collaboration Practices

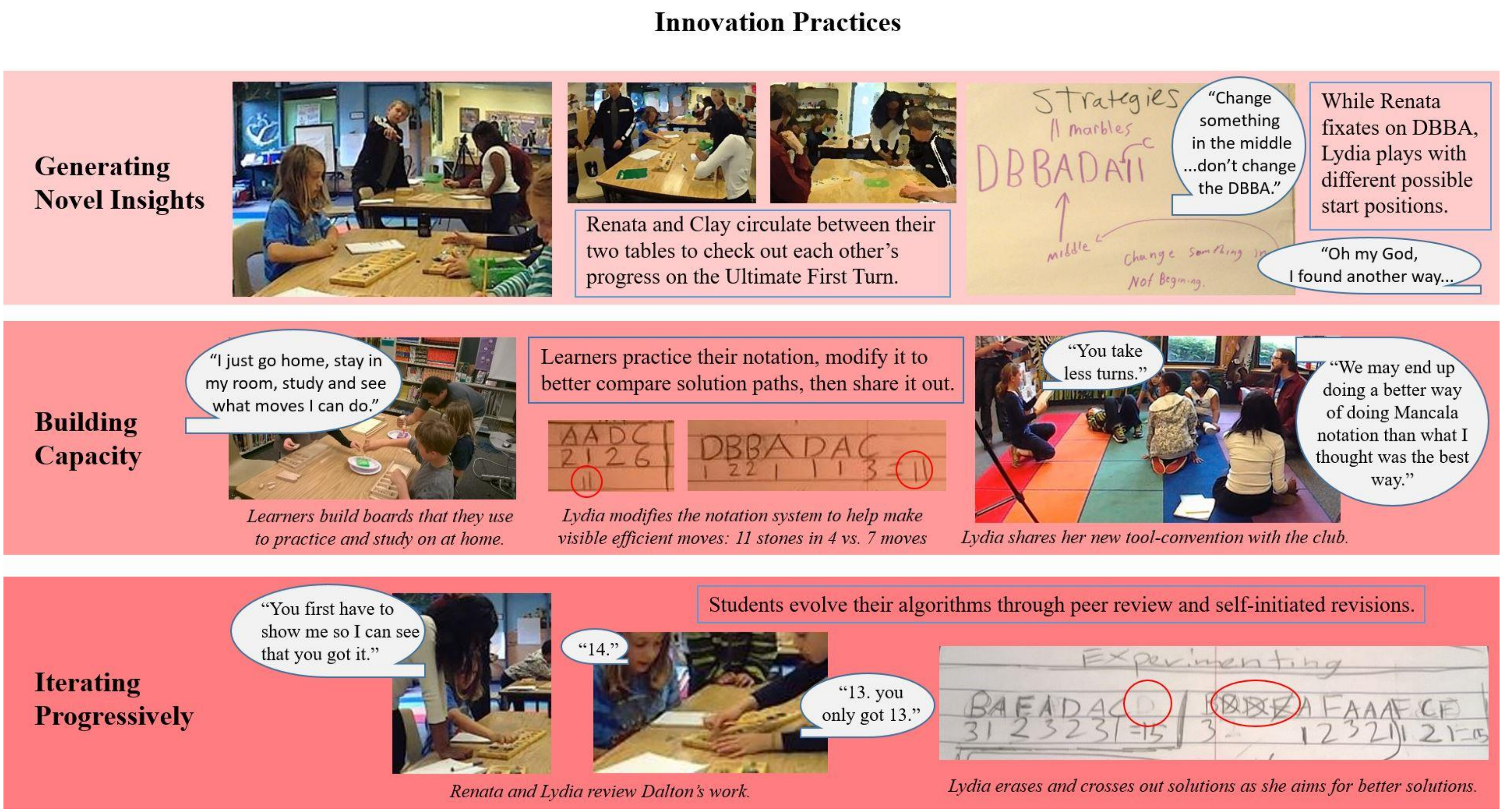

Figure 2.11. Learners' Innovation Practices

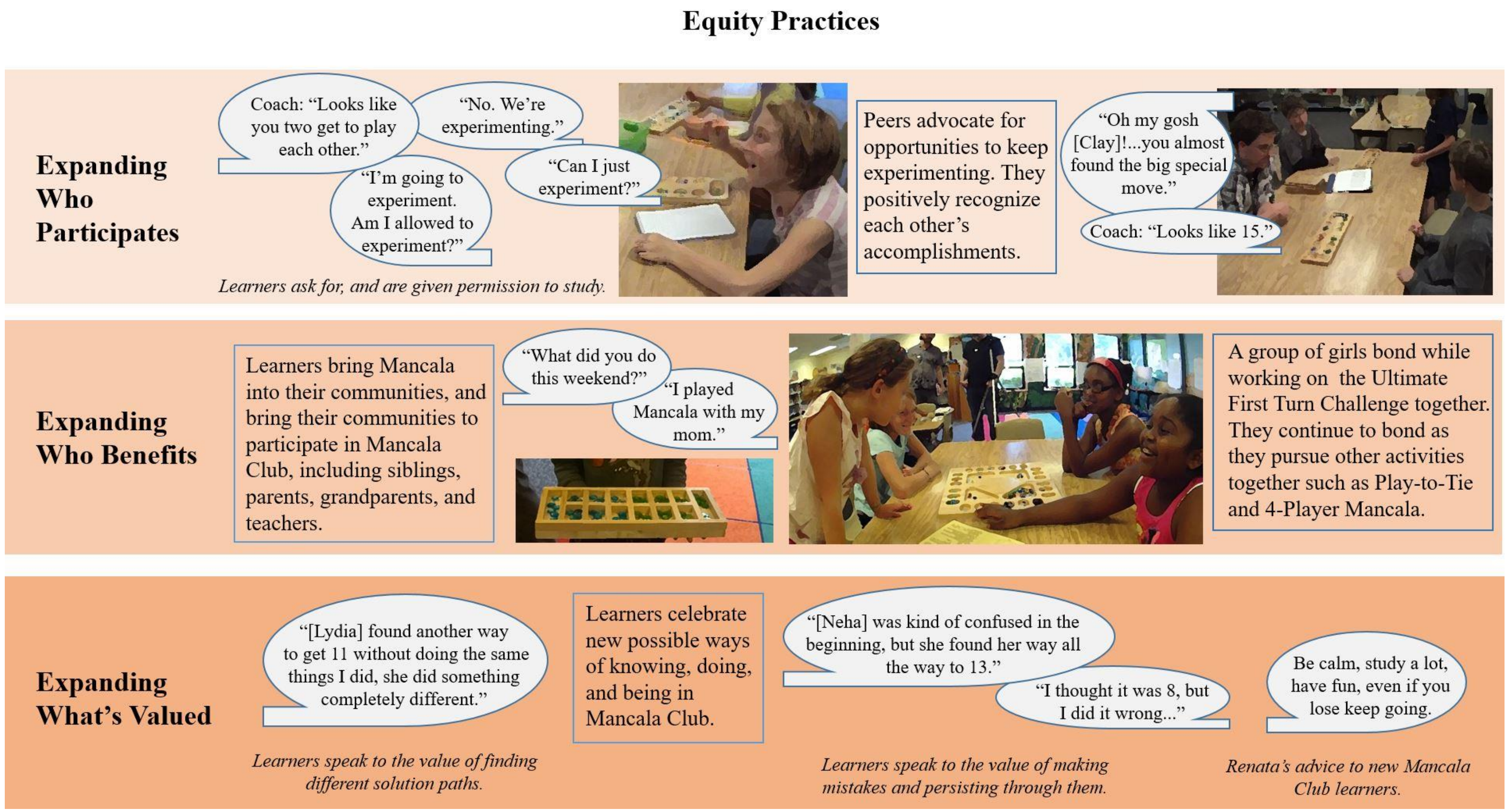

Figure 2.12. Learners' Equity Practices

Analysis 2 – Learners' Transformed Ways of Knowing, Doing, and Being

Through engaging in wide-ranging authentic inquiry practices during the Ultimate First Turn Challenge young learners came to transform their ways of knowing, doing, and being in relation to Mancala, to their peers, and to the Club-at-large. Figure 2.13 summarizes these findings.

First, learners transformed their ways of knowing, doing, and being in relation to the particular Mancala rule-set used in this study. The transformation of learners' ways of knowing is evidenced through learners' shifts in form-function relations in their Mancala gameplay. As detailed in Figure 2.6 learners developed an understanding of how to manipulate different aspects of the Round-and-Round rule-set to achieve different advantageous functions such as maximizing extra turns, maximizing stone scores within a single turn, and minimizing dead ends. Learners also enacted expert recognized combination moves referred to as walking-the-stones.

Learners also transformed their ways of doing in relation to their Mancala gameplay. They learned how to simulate one full turn ahead as well as how to physically undo the last turn taken. They also experimented with using their bodies and inscriptions in novel ways to reduce errors made while playing Mancala (such as Neha dropping her stones to the rhythm of her humming). Learners also transformed their ways of being in relation to Mancala by taking on the practices of expert Mancala players (which Coach John had told them about). These expert practices include engaging in solitaire study, experimenting with different move combinations and documenting the resulting scores, and developing game-winning strategies. As such learners moved beyond their initial novice status in relation to this Mancala rule-set.

Second, learners transformed their ways of knowing, doing, and being in relation to their peers. Learners' peers came to be known by their practices, achievements and contributions. Clay and Renata, for example, were recognized early on for their first-turn multi-digit scoring strategies.

Perhaps because Renata wrote down her strategy (whereas Clay did not) and shared it with the whole group, recognition of Renata's achievement persisted over time. As shown in Figure 2.10 peers also transformed their ways of doing in relation to each other: they coordinated joint work, constructed a locally situated language, and came to give and accept critical feedback in a respectful way. This transformation may be due to what Sengupta-Irving (2014) calls workship relations—where peers form bonds during small group collective problem-solving work. Peers also transformed their ways of being in relation to one another. This occurred through shifts in power, affect, spatial orientation, and social positioning (See Dissertation Article 3 for an extended analysis).

In terms of social positioning, Lydia, Neha, and Dalton—while working under the guidance Renata on the Ultimate First Turn Challenge—were initially positioned with minimal levels of agency and authority through which they simply watched Renata demonstrate her solution to the challenge. Over time, Renata shifted the activity structure in ways that allowed her peers to use their own materials, take up their own investigations, make novel discoveries, and share these with their peers. These moves positioned Renata's peers with increasing levels of agency and authority which constituted shifts in how peers related to one another.

Third, learners transformed their ways of knowing, doing, and being in relation to the Club-at-large. In other words, learners work on the Ultimate First Turn Challenge appeared to impact Mancala Club as a whole. For example, when learners were asked towards the end of the seven club sessions what advice they would give to beginning Mancala players who are new to Mancala Club, Renata gave an answer that indexed practices (e.g. studying) that she had taken up during the Ultimate First Turn Challenge. Her answer, which Coach John turned into a list format for a Club Poster, was: Be calm, study a lot, have fun, even if you lose keep going. Although, learners' evolving understanding of what it takes to be successful in Mancala Club was not studied in detail, Renata's advice suggests that learners can transform their ways of knowing in relation to the broader learning environment itself. Evidence that learners' ways of doing in relation to Mancala Club transformed can be seen in how individual learners including Renata, Lydia, and Dalton resourced their Ultimate First Turn solutions to make progress on other Club activities such as the Mancala Mixer and on other Club challenges such as Mancala Bots (See Figure 2.9).

Learners also transformed their ways of being in relation to Mancala Club. While debriefing learners' work on the Ultimate First Turn Challenge, coaches and learners negotiated norms around solution and strategy sharing in which the following norm became explicitly thematized: learners in Mancala Club work together as a collective team, not as individual competitors. This norm applied to all the activities of Mancala Club, and helped to spark a novel activity called Play-to-tie, a cooperative Mancala variant.

The authentic inquiry practices that learners developed during the Ultimate First Turn Challenge did more than functionally support and sustain learners' extended inquiries. Rather, the inquiry work that learners performed, profoundly worked on themselves (Packer & Goioechea, 2000), transforming their ways of knowing, doing, and being in relation to the game of Mancala, to their peers, and to Mancala Club as a whole.

	In Relation to Mancala	In Relation to Peers	In Relation to the Club-at-large
Transformations in **Ways of Knowing**	**Learners understand more sophisticated form-function relations in Mancala.** -Maximizing extra turns. -Maximizing stones. -Minimizing dead ends. -Mix and match combination moves. -Walking-the-stone pattern move.	**Peers become known by their achievements and contributions.** -Clay's early 15-stone solution. -Renata's 18-stone solution. -Renata's study practice. -Neha's reframed mistake. -Lydia's notation modification.	**Learners understand what it takes to be successful in this setting.** -Renata's response to what advice she would give to beginners in the Club: Be calm, study a lot, have fun, even if you lose keep going.
Transformations in **Ways of Doing**	**Learners develop new techniques and tool-conventions to study Mancala.** -Streamlining by simulating turns forward, playing a turn backwards, and creating a save point. -Reducing errors by using their bodies and inscriptions in novel ways. -Modifying notation system.	**Peers develop workship relations.** -Coordinating their work by eliciting participation and working at the same pace. -Co-constructing a local language to communicate clearly. -Giving and accepting critical feedback in a respectful way.	**Learners use their new Mancala strategies to make progress on other Mancala Club activities.** -Lydia uses her first-turn strategy during the Mancala Mixer. -Dalton and Renata use the 18-stone strategy to defeat Mancala Bots. -Renata explores new ways to play Mancala.
Transformations in **Ways of Being**	**Learners take up coach-specified practices of expert Mancala Players.** -Engaging in solitaire study. -Trying out move combinations and documenting their work. -Developing game-winning strategies.	**Peers social positioning shifts**. -Increasing levels of authority. -Increasing levels of agency. -More symmetrical power relations.	**Learners shift from treating club members as individual competitors to team members.** -Sharing strategies and solutions with group rather than keeping them secret. -Being committed to helping each other grow.

Figure 2.13. Transformations in Learners' Ways of Knowing, Doing, and Being

Discussion

The first analysis reveals the wide-ranging authentic inquiry practices that young learners leveraged to advance their collective inquiry together on the Ultimate First Turn Challenge in Mancala Club. These young learners have shown that a holistic ecology of inquiry practices—that includes conducting research, organizing their workload, motivating each other, collaborating together, innovating upon practices, and promoting equitable learning conditions—is a vital feature of the inquiry process.

The second analysis reveals the variety of ways that learners' inquiry work transformed their ways of knowing, doing, and being in relation to this rule-set of Mancala, to their peers, and to the broader Mancala Club. The vast amount of work that learners engaged in during the course of pursuing their inquiry, and the ways in which this work transformed learners themselves holds important implications for theory, practice and policy.

Implications for Theory

By making visible the wide-ranging and holistic work that young learners' perform during extended inquiry activities this study pushes theory forward in its appreciation of the capabilities and competencies of young learners. In other words, this study demonstrates that the work that young learners perform is greatly underestimated when analyzed from the standpoint of theories that define inquiry learning in terms of cognitive-general or discipline-specific outcomes. The layer of work revealed in this study shows how young learners simultaneously developed research, organization, motivation, collaboration, innovation, and equity practices to support and sustain their inquiry. Specifically, learners created strategies to engage in the following practices: conducting investigations, negotiating inquiry norms, interpreting phenomenon, managing investigations, documenting work, enhancing workflow, taking interest, engaging feelings, navigating fragility, coordinating joint work, constructing meaning, building trust, generating novel insights, building capacity, iterating progressively, expanding who gets to participate, expanding who gets to benefit from participation, and expanding what gets counted as valued participation.

This study also shows the holistic consequences that this layer of inquiry work holds for learners who become transformed in their relations to the object of their inquiry, to their peers, and to the broader Mancala Club setting. These transformations make a case that authentic inquiry leads not just to epistemic shifts in what learners learn but also to ontological shifts in who learners are and the relationships they form.

Implications for Practice

This study implicates the work of learning environment designers as well. Although a considerable amount of research has investigated how to scaffold learners' research practices and to a lesser extent organization and collaboration practices (Thomas, 2000), very little research has investigated how to support learners' motivation, innovation, or equity practices in authentic inquiry settings. Further still, there is little guidance in the research literature for designers who want to support a multitude of these practices simultaneously. The design challenge for practitioners, then, is to create multidimensional supports or a variety of supports that promote the development of a holistic range of authentic inquiry practices. In Mancala Club's Ultimate First Turn Challenge, a variety of supports included: Notation system and notebooks to support learners in conducting investigations, publicly displayed charts to support learners' collective organization practices, dramatic storytelling to support learners in taking interest in the challenge, station groups to support joint work, a make-your-own-Mancala-board activity to support learners taking initiative across settings, and the positioning of Renata as a station leader to support transforming learning opportunities (see Figure 2.6).

Yet, perhaps just as important as furnishing the learning environment with a series of intentionally designed facilitator supports, is to position learners as capable and competent at identifying and developing their own supports, and then to create a public space where learners can share these supports out to the rest of the group. For example, Coach John publicly praised learners' modification of the notation system and their reframing of mistakes, and he gave learners the floor to share the stories of their designs and discoveries with the whole club. In this way, learners are invited to be co-designers and furthermore they are rewarded for being co-designers by having their contributions meaningfully recognized.

Implications for Policy

The current study shows the importance of taking a multi-sited sensibility (Vossoughi & Gutiérrez, 2014) to curriculum reform. In Mancala Club authentic inquiry takes off when young learners are given the tools of inquiry (and encouraged to design their own), and are able to freely use these tools to support their inquiry over time and across settings (their home, at Mancala Club), coming back once a week to a consistent and structured space to share their discoveries and learn from one another. In other words, curriculum reform should honor and recognize that young children's authentic inquiries are not tied to any one formal or informal learning environment (or to any one curriculum for that matter), but that inquiries—if they are authentic—will travel and grow with the child.

To inform policy about how to best prepare learners to handle the complex problems of the 21st century, more empirical research is needed on how young children develop authentic inquiry practices over time, across settings, and with different mediational tools. Herrenkohl and Polman (2018) offer one vision for this research agenda:

> "We expect productive research to result from shifting our focus in learning sciences to people who *employ* knowledge and other tools in *hybrid settings* to solve complex problems that involve purposeful collaboration and managing competing values and goals."

In the meantime educational policy should support the design, implementation, and research of hybrid settings where young children are supported in developing authentic inquiry practices.

Limitations

The central claim of this study is that young children support and sustain their authentic inquiry work through a holistic range of inquiry practices. Further, through enacting wide-ranging inquiry practices, young learners transform their ways of knowing, doing, and being in relation to their task, their peers, and the learning environment. This claim is substantiated through a close analysis of an intact data set of a specific play-based authentic inquiry task in a particular afterschool affinity game club with 2nd-4th graders. There are several moves that could have further contextualized the collective inquiry process in this study, and thus provided more insight into the central claim made.

Learners, for example, do not enter into learning environments in a vacuum. Rather, they bring with them rich histories, potential pre-existing relationships with their peers, as well as interests and expectations. Collecting data on these pre-existing dynamics can help contextualize the unfolding process of inquiry in Mancala Club as well as further humanize the learners. Scholars are increasingly showing the value of interviewing parents, teachers, and the participants themselves to more adequately understand where learners are coming from and what they bring with them (Carlone, Scott & Lowder, 2014; Dutro, Kazemi, & Balf, 2006; Herrenkohl & Mertl, 2010; Jaber & Hammer, 2016; Tan & Calabrese Barton, 2008). In the context of this study, for example, when Renata holds her peers accountable to disciplinary standards of evidence, she appeals to a shared history "Plus if you know, that's [student], his best friend, who wants to get him to be popular." Understanding this shared history could help to unpack these interactions, revealing how the enactment of authentic inquiry practices are implicated in the shared histories of the learners.

Such interactions can also be meaningfully unpacked by attending more explicitly to the role that race, gender, language, socio-economic status, and other social issues play in shaping and constraining who gets to enact which authentic inquiry practices and to what end. Scholars have shown how such dynamics can greatly impact the collective inquiry process (Bang, Warren, Rosebery, & Medin, 2012; Esmonde & Langer-Osuna, 2013; Leander 2002a, 2002b; Nasir, Rosebery, Warren, & Lee, 2006; Warren & Rosebery, 2011). In the context of this study, for instance, Clay plays an antagonistic role to Renata when he rebuffs her offers for help yet tries to copy from her notebook without her permission. Neha shows solidarity to Renata by grabbing Renata's notebook out of Clay's hands. Looking closely at issues of gender and race in these interactions can help to further meaningfully unpack them.

Additionally, it would be valuable to understand how the learners themselves made sense of their interactions. Do they experience their collective inquiry as a conglomeration of research, organization, motivation, collaboration, innovation, and equity practices? Would they agree with the characterizations of how their ways of knowing, doing, and being transformed over time? Do they see their work as holistic, and if so, in what ways? Scholars are designing exit-ticket surveys that allow learners to report out their experiences. These include the Experience Sampling and

Reflection Form and the Student Inquiry Engagement Instrument (see Anyichie & Butler, 2018, for an example of each in action). Scholars are also innovating debrief activities that allow learners to visually display whether they perceive their inquiry practices as unified (integrating experiences of the head, heart, and hands) or not (Carlone et al., 2016).

Taken together, expanding the data collection and analytic techniques of this study to portray the historical, intersectional, and experiential dynamics of the collective inquiry process would have added more depth and clarity to the central claim of this study. Yet, even if the dynamics that constituted young learners' inquiry work are not fully elucidated, the central claim, as evidenced by the analysis above, still holds: learners supported and sustained their inquiry work through forming a robust holistic ecology of inquiry practices. Furthermore, this intricate web of practices transformed the learners as well.

Future Directions

By foregrounding the holistic nature of the collective inquiry process, several other important features of the inquiry process were backgrounded. These features include the ways in which collective inquiry is not only holistic, but also contentious and cumulative (Calabrese Barton et al., 2013). Analyzing contentious moments as well as cases where learners return to a previous inquiry can provide a more realistic account of how the inquiry process unfolds at both a moment-to-moment level and across larger time-scales. It can also help to locate young learners' competency in the work they perform to re-mediate their learning environment in the face of contention, as well as re-situate inquiry practices in new ways when revisiting an initial inquiry.

The importance of the cumulative dimension of the inquiry process became salient during the second iteration of Mancala Club (not reported here) when Neha returns a year later and revisits the Ultimate First Turn Challenge to discover a 22-stone solution. An analysis of this work can show how she drew on inquiry practices that she developed during her first Mancala Club, as well as took up additional inquiry practices that were well-suited to her newfound role as a returning Mancala Club member amongst newer learners. The contentious dimension of the inquiry process forms the focus of Article 3, which presents an analysis of an approximately 50 minute episode of the Ultimate First Turn Challenge. During this session a group of four learners continually re-mediate relations of power, affect, social positioning, and spatial orientation in response to a series of contentious moments that otherwise constrained their agency and limited their ability to enact a wide-range of authentic inquiry practices.

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Article 3

Authentic Inquiry as a Contentious Accomplishment in Mancala Club

Abstract

Authentic inquiry learning environments have been heralded as equitable alternatives to traditional learning environments for engaging learners in collective and meaningful inquiry work. Yet, scholars are increasingly making visible the ways that power dynamics and social interactions within these contexts work to constrain, undermine, and de-legitimize young learners' attempts to perform authentic inquiry practices (Esmonde, 2009). Drawing on the theoretic resources of Activity Theory and Critical theory this study investigates three interrelated dimensions of equity that are relevant to participation in authentic inquiry practices: equity as the expansion of who gets to participate, equity as the expansion of who gets to benefit from participation, and equity as the expansion of what counts as valued participation in the first place. Using conversation and interaction analysis, the current empirical study analyzes the work that a group of four 3rd and 4th graders performed to expand equitable interactions within an authentic inquiry learning environment called Mancala Club. Findings indicate that young learners can productively expand equitable interactions through specific moves that worked to re-configure and interrupt relations of power, affect, spatial orientation and social positioning that had, at the beginning of their cooperative work together, severely limited the opportunities for each learner to engage in authentic inquiry practices. The results attest to the capabilities and competencies of young learners as critical inquirers who can work together to build relational equity and productively engage in authentic inquiry practices. The results also support practitioners in becoming more attuned to how the dynamic interactions between power, affect, spatial orientation and social positioning work to expand or restrict equitable moment-to-moment interactions in authentic inquiry learning environments.

Introduction

Learning environments are increasingly being designed to position learners to engage in authentic inquiry (Barron & Darling-Hammond, 2008). Authentic inquiry learning includes learning that is authentic to the complexities of real-world problems, to learners' own experiences, and to professional researchers' actual inquiry practices (Shaffer & Resnick, 1999). By making learning relevant to real-world contexts, learners' own interests, and to professional practices, proponents of authentic inquiry learning environments argue that learners will be able to make better use of what they learn and, thus, avoid the problem of inert knowledge (Brown & Campione, 1996; Scardamalia & Bereiter, 2006; Bielaczyc & Collins, 2006).

Scholars working with an Activity Theory lens have provided a more holistic account of the work that learners perform in authentic inquiry learning environments. Learners do not simply accumulate more meaningful knowledge in these environments. Rather, learners (a) transform their ways of knowing, doing, and being (Herrenkohl & Mertl, 2010) in ways that are cognitively, emotionally, and physically integrated (Carlone et al., 2016), and (b) develop novel ways to conduct their research, organize their work, motivate themselves, collaborate with others, become innovative, and pursue equitable participation (Dissertation Article 2). These holistic visions help us to better understand the wide-ranging work that is involved in authentic inquiry, and the ways in which this work transforms the learner.

Additionally, Socio-Cultural theorists pursuing a more critical direction have taken up equity issues including examining who gets to participate in authentic inquiry, who gets to benefit from this participation, as well as what counts as authentic inquiry in the first place (Birmingham et al., 2017). Scholars working on this front have demonstrated how authentic inquiry learning environments can play forward problematic issues of power and privilege that delegitimize the participation of certain learners among culturally and/or racially heterogeneous learners (Bang, Warren, Rosebery & Medin, 2012; Engle, Langer-Osuna, McKinney de Royston, 2014; Esmonde, 2009; Langer-Osuna, 2016; Sengupta-Irving, 2014). This can take place even when the learning environment is directly designed and normed to be cooperative (Bianchini, 1997; Cohen, Lotan, Scarloss, & Arellano, 1999). Learners whose contributions are delegitimized tend to contribute little, take up fewer inquiry practices, and, as a result, learn less than their 'high status' peers (Cohen, Lotan, & Leechor, 1989; Leechor, 1988; Lohan, Cohen, & Holthuis, 1994).

Yet, this research also shows that traditional power asymmetries of whose contributions 'count' can be productively interrupted by facilitators who work to legitimize a range of ways to contribute to the collective inquiry (Boaler, 2006) or who 'assign competence' to learners who have otherwise been positioned as 'low status' (Cohen & Lotan, 1995). Additionally, learners themselves can interrupt power asymmetries by drawing on areas they are competent at (or 'high status' in) and productively using these to hold the floor while offering contributions to the collective inquiry (Esmonde & Langer-Osuna, 2013; Stromholt & Bell, 2018).

The current study extends both these strands of research by examining how a small group of culturally and racially heterogeneous young learners continuously re-configured their informal authentic inquiry learning environment, called Mancala Club, to allow for more equitable participation amongst themselves during a 50 minute period. Initially, one learner, Renata, was positioned as high status by the Mancala Club coaches and was tasked to help support her peers on an authentic inquiry task (which she had previously made significant progress on). At the beginning of the task, Renata positions her peers with minimal agency and authority. Yet, over time Renata's peers successfully negotiate and gain increasing levels of agency and authority until more symmetrical power relations emerged.

Each qualitative shift in social positioning co-developed along with qualitative shifts in power, affect, spatial orientation and the collective activity structure of the authentic inquiry task. Additionally, each qualitative shift afforded Renata and her peers' unique opportunities to take up authentic inquiry practices that were generative for their collective inquiry. By tracing the moment-to-moment shifts along each of these dimensions, this study makes visible the work that young learners are capable of performing, even in the face of contention and conflict, to interrupt power asymmetries within their authentic inquiry learning environments. As such, this study contributes to our holistic understanding of young children's capabilities and competencies as inquirers and to our critical understanding of authentic inquiry environments as sites that can reproduce as well as interrupt inequitable participation.

Research Questions

The current study takes up two research questions within the specific context of an afterschool game-based authentic inquiry learning environment for young learners:

1. *How do young learners in a small peer group working on a novel and complex challenge reconfigure relations of power, affect, spatial orientation, and social positioning to equitably expand who gets to participate, who gets to benefit from participation, and what counts as valued participation?*
2. *What does this tell us about the capabilities and competencies of young children?*

To answer these research questions this study is organized around an analysis of the moment-to-moment interactions that unfolded within a specific collective inquiry task during the first year of an afterschool learning environment called Mancala Club. A conceptual framework is provided to unpack three equity oriented projects that exist at the intersection of Activity Theory and Critical Theory. Additionally, the conceptual framework links these equity oriented projects to the existing research base of what is known about (a) relations of power, (b) relations of affect, (c) relations of spatial orientation, (d) relations of social positioning, (e) participation frames, and (f) shifts in activity systems.

Conceptual Framework

To answer these research questions this study draws together three interrelated equity-oriented projects that exist at the intersection of Activity Theory and Critical Theory. These equity-oriented projects examine the reproduction and interruption of inequitable participation during learning activities. Inherent to learning activities are relations of power, affect, spatial orientation and social positioning. This conceptual framework examines relevant dimensions of each of these terms while focusing on recent research that reveals how teachers and peers actively reorganize relations of power, affect, spatial orientation or social positioning to create more equitable participation. Further, this conceptual framework demonstrates how each of these situative factors can be made visible, in-situ, by analytically attending to shifts across participation frames and activity systems that organize collective inquiry. Lastly, this conceptual framework discusses the holistic range of authentic inquiry practices that can emerge when learners are positioned with responsibility and agency for their learning.

Activity Theory

The current study draws on Activity Theory which conceptualizes collective activity as the central unit of analysis for explaining the process of learning. Engeström (2014) models collective activity as a set of relations between subjects, mediating artifacts, objects, division of labor, community, and rules (shown in Figure 3.1 below). Attending to these co-constitutive relationships and how they shift over time will illuminate the ways in which learners go about the work of transforming their learning environments to support and sustain their collective activity.

The conceptual resources of Activity Theory allow us to position (a) young students as capable and competent learners, (b) learning as the co-transformation of collective activity along with a learner's ways of knowing, doing, and being, and (c) collective activity as situated in a myriad of relations including culture, history, and power. The following section elaborates upon each of these points.

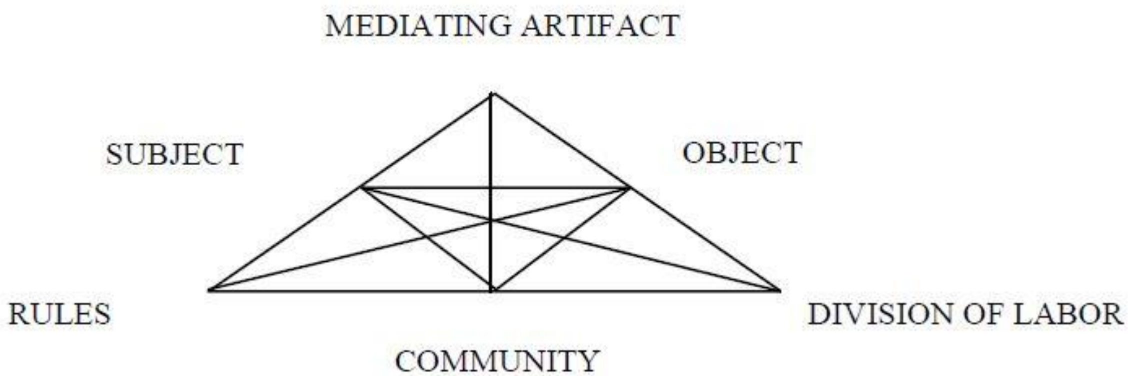

Figure 3.1. Engeström's Activity Theory Model

First, Activity Theory pushes back on traditional conceptions of competence as a measure of a leaner's unassisted and individual ability. In contrast, Activity Theory envisions competence as a range of potentiality that includes what a learner can accomplish alone as well as what a learner can accomplish through the assistance of resources and social interactions (see Vygotsky, 1978 on the Zone-of-Proximal-Development). In other words, Activity Theory allows us to see what achievements are within a learner's grasp.

Secondly, Activity Theory examines how the process of learning unfolds within collective goal-directed activity (see Engeström, 2014 on Activity Systems). Such collective goal-directed activity is comprised of a number of processes that resource specific tools and social interactions to achieve particular outcomes. Learning is not located within an individual's mind. Rather, it is located within the learners' mastery, appropriation, and transformation of these practices which, in turn, transform a learner's relationship to the object of their goal-directed collective activity (see

Wertsch, 1998, on mediation). Simultaneously, Activity Theory assumes that learners' changing practices do not simply mark increases in understanding (such as domain content knowledge or cognitive abilities). Rather, learners' ways of knowing, doing, and being co-develop as learners transform their relationship to the object of their goal-directed collective activity (see Herrenkohl & Mertl, 2010; also Packer & Goicoechea, 2000, on ontology).

Finally, Activity Theory assumes that collective activity is situated and constituted by a number of relational forces including cultural relations, social relations, historical relations, institutional relations, power relations as so on (Wertsch, 1998). These relations play a substantive role in shaping which practices within a given collective activity are valued and legitimatized and which practices are not (Wertsch, 1998). This valuation and legitimization, in turn, impacts who gets to participate in activities and who gets to benefit from participation. Activity Theory offers many more conceptual resources than these, but each of these is particularly relevant to the context of this study. Specifically, this study makes visible the capabilities and competencies that young learners develop as they work to reconfigure the situative dimensions of their collective activity—such as relations of power, affect, spatial orientation, and social positioning—in ways that make each others' participation more equitable.

Critical Theory

Critical theory attunes educational researchers to the ways in which learning environments are sites that reproduce power and privilege in ways detrimental to equity, but at the same time can become sites where learners interrupt inequities (Giroux & McLaren, 1989; Green, 2017). This paper takes up a call by numerous scholars who are actively moving socio-cultural theories of learning in this critical direction with implications for theory (see edited volume of *Power and Privilege in the Learning Sciences* by Esmonde and Booker, 2016; Bang & Vossoughi, 2016), analysis (González, Moll, & Amanti, 2005; Gutiérrez, 2008; Gutiérrez, Baquedano-López,, & Tejeda, 1999; Hand, Penuel, & Gutiérrez, 2012; Lee, 2001) and practice (See Bang, Warren, Rosebery & Medin, 2012; Carlone et al., 2015; Cornelius & Herrenkohl, 2004; Engle et al., 2014; Esmonde, 2009; Gresalfi, Martin, Hand & Greeno, 2009; Gutiérrez, Rymes, & Larson, 1995; Herrenkohl & Mertl, 2010; Langer-Osuna, 2016; Leander, 2002; Roth, 2007; Roth & Walshaw, 2015; Taylor & Hall, 2013).

Equity-Oriented Projects

A number of interrelated equity-oriented projects are being pursued at the intersection of Activity Theory and Critical Theory. Three of these projects, relevant to the analysis of this study, include expanding who gets to participate in learning environments, who gets to benefit from this participation, and what counts as valued participation in the first place (see Birmingham et al., 2017 for a similar discussion on consequential learning).

The first of these interrelated equity-oriented projects attends to how opportunities for participation are shaped by normative hierarchies that work across race, class, gender, sexuality, language, and migrant status (Collins, 2000; Esmonde & Booker, 2016; Warren & Rosebery, 2011). These hierarchies influence who has access to the means (tools, norms, discourses) of authentic investigation, who has access to the conversational floor to discuss the investigation, and who has access to positive interactions while working on or discussing the investigation.

Specifically, studies have shown that female students (Sadker, Sadker & Zittleman, 2009), students of color (McAfee, 2014), and immigrant students (Planas & Gorgorió, 2004) have limited access to participation in cognitively demanding learning opportunities than their White male counterparts. Furthermore, even in situations where diverse groups of learners are performing authentic investigations together, learners may be treated as deficit or ‘low status’ based on factors such as their race, class, and gender which, in turn, limits their opportunities (Bianchini, 1997; Cohen, Lotan, Scarloss, & Arellano, 1999; Langer-Osuna, 2016) and their willingness (Cohen, Lotan, & Leechor, 1989; Lotan, Cohen, & Holthuis, 1994) to access the conversational floor. Hierarchies that position learners as 'low status' also impact how positively learners are treated by their teachers and others. For example, when African American, Latin@, and Native American students make contributions to the conversational floor, their contributions are more readily perceived by their teachers and peers as lower-achieving, disruptive and threatening and as such they may receive discouragement or even punishment from their teachers (Bang, Warren, Rosebery, & Medin, 2012; Downey, & Pribesh, 2004; Lewis, 2003; Neal, McCray, Webb-Johnson, & Bridgest, 2003; Skiba, Michael, Nardo, & Petersonm, 2002). All of these factors limit who has access to participation.

Yet, there is more to equity than access alone. Critical theorists and Activity theorists question who benefits from increased access to participation in authentic investigations (Bang & Vossoughi, 2014; Gutiérrez & Dixon-Román, 2010). For example, who benefits when access means that learners have to leave behind their culture and language to engage in learning activities whose end result is to achieve the academic outcomes of White middle-class students (Gutiérrez & Dixon-Román, 2010). Such assimilationist trajectories of participation work to maintain the status quo and further the ends of institutionalized racism, classism, and sexism. This can be more detrimental than beneficial to learners, especially, for learners who define excellence not just as doing well in school, but also as maintaining cultural values, developing critical attitudes, and strengthening their community ties (Hilliard, 2003; Valdés, 1996).

Research finds that marginalized learners are capable of transforming the normative discourses and structures of their learning environments to suit their own purposes (Dixon-Román, 2009), to reflect their own identities (Stromholt & Bell, 2018), and to benefit their communities (Birmingham et al., 2017; Calabrese Barton, 1999, 2001). If the designed learning environments are not set up to support these efforts, however, then learners will have additional cognitive and emotional work to perform (McGee & Martin, 2011; Stinson, 2008), and any successes will be tentative and fragile (Gutiérrez, Rymes, & Larson, 1995).

Fortunately, a number of learning environments are being designed that invite learners to critically investigate issues relevant to their communities and society-at-large such as the politics and ideologies of how places get named, boundaries get drawn, and access gets stratified (Bang et al., 2014; Gordon, Elwood, & Mitchell, 2016; Taylor & Hall, 2013), the ways in which oppression and domination manifest in housing data, credit card data, and the distribution of world wealth (Frankenstein, 2005; Gutstein, 2003; Gutstein & Peterson, 2005), the under-recognized pollution and water contamination of local sites (Bouillion & Gomez, 2001; Calabrese Barton, 1998; Stromholt & Bell, 2018), the socio-economic problematics of urban renewal projects (Comber et al., 2008), and the negative impact of standardized testing (Campano, Ghiso, & Sánchez, 2013). Affinity spaces also offer participation opportunities where learners can freely work to pursue their own goals (Barron, Gomez, Martin, & Pinkard, 2014; Peppler & Kafai, 2007; Vossoughi, Hooper, & Escudé, 2016) work to the benefit of their collective affinity group (Kafai, Quintero, & Feldon, 2010; Steinkuehler & Duncan, 2008; Nasir & Cooks, 2009; Nasir & Hand, 2008), and work to challenge the status quo (Birmingham et al., 2017; Kirshner, 2008, 2009; Kirshner & Geil, 2010).

A third interrelated equity-oriented project advocates not just for expanding who gets to participate and who gets to benefit from participation, but also challenges what counts as valued participation in the first place. Historically, not all ways of knowing, doing, and being that are productive for inquiry are equally valued. Rather, the ways of knowing, doing, and being that are typical of White middle-class European-American people are valued—in ways that have become so legitimized, normalized, and canonized that they constitute the settled expectations (Harris, 1993) of what it means to learn in classroom settings.

In broad strokes, the settled expectations of knowing privilege context-independent and hypothetico-deductive meaning-making (such as classifying fixed traits of objects or discovering underlying laws that render these objects' behavior predictable) (Bang, Warren, Rosebery, & Medin, 2012; Bang et al., 2014; Warren & Rosebery, 2011). The settled expectations of doing involve the expedient and exclusive use of one's mind to manipulate symbols and apply formal procedures to solve precise, domain-specific, and well-defined problems (Brown, Collins, & Duguid, 1989). The settled expectations of being center on the initiation-response-evaluation structure (Mehan, 1979), whereby teachers initiate a question or problem, students respond, and the teacher evaluates whether the students' response fits the settled expectations or not. If not, students' ways of being are negatively positioned as "disruptive," "inattentive," or "incompetent" which in turn makes students feel as if they do not belong in school or have a future academic trajectory (Lee, Spencer, & Harpalani, 2003; Martin, 2009; Nasir et al., 2006).

Advocates of this equity-oriented project work to desettle these expectations by designing learning environments that support epistemological heterogeneity (Bang, Warren, Rosebery, & Medin, 2012; Bang et al., 2014; Bang & Vossoughi, 2014), robust repertoires of practice (Gutiérrez & Rogoff, 2003), and for legitimate peripheral participation such as apprenticeship, student-led inquiry, or learning by observing and pitching in (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Rogoff, 2014). All of these supports work to expand the valued ways of knowing, doing, and being that co-constitute what counts as valued inquiry. Nasir and colleagues (2006) have documented a number of designed learning environments that have taken up this work including the Cultural Modeling Project (Lee, 1993, 1995, 2007), Chèche Konnen (Warren & Rosebery, 2004), and the Algebra Project (Moses & Cobb, 2001). Scholars working on this front have expanded the field's understanding of what counts as valued participation in science (Aikenhead, 1996; Bang, Warren, Rosebery, & Medin, 2012; Bricker & Bell, 2014; Lee, 1999; Sohmer & Michaels, 2005; Takeuchi, 2008; Warren, Ogonowski, & Pothier, 2005), in math (Civil, 2002; Frankenstein & Powell, 1994; Goldman & Booker, 2009; Gutiérrez & Dixon-Román, 2010; Moll & González, 2014; Nasir & Hand, 2008; Saxe, 1991; Taylor, 2009), in literacy (Ball, 1995; Dyson & Smitherman, 2009; Gallego & Hollingsworth, 2000; Gee, 1990; Lee, 2007, 2008), in creativity (Vossoughi, Hooper, & Escudé, 2016), and in authentic inquiry more generally (Phelps, Dissertation Article 1).

Taken together these three equity-oriented projects work to shift who has access to learning opportunities, who gets to benefit from this access, and whose ways of participation get to be valued and legitimized. The current study analyzes the equity work that a small group of 3rd and 4th graders themselves performed when one of their peers was positioned as their leader. This analysis shows how these learners expanded opportunities for each other to more deeply participate in authentic inquiry while simultaneously expanding who benefited from their group work as well as what counted as valued participation within their group.

Specifically, these authentic inquiry practices include the work learners do to access the means of investigation, the conversational floor, and positive relational interactions, to pursue their own goals as well as to benefit their affinity community, and to expand what counts as valued ways of knowing, doing, and being. This study finds that in order to make these equity moves, learners worked to re-mediate relations of power, affect, spatial orientation, social positioning, and activity systems. These moves have individually been reported previously in the research literature, although not typically with learners this young and not in ways that display their interrelatedness. The following sections of this conceptual framework detail the relevant work by scholars who attend to relations of power (Carspecken, 1996; Gutiérrez, Rymes, & Larson, 1995), affect (Battey & Neal, 2018; Boaler, 2008; Flores, 2016), spatial orientation (Kendon, 1990), and social positioning (Engle, 2012; Gresalfi & Cobb, 2006).

Re-mediating Power

Carspecken (1996) drawing on the work of Max Weber identifies a number of moves individuals make to shift power relations. These include making bids to increase the legitimacy of one's position through physical coercion, appeals to cultural norms of acquiescence to higher positions, appeals to the fear of sanctions or desire of rewards, or appeals to personal charisma. A number of scholars are documenting how learners use these and similar moves to shift their own standing during group work in authentic inquiry learning environments (Bang, Warren, Rosebery, & Medin, 2012; Cohen & Lotan, 1999; Cornelius & Herrenkohl, 2004; Engel, Langer-Osuna, & Royston, 2014; Lampert, Rittenhouse & Crumbaugh, 1996). For example, Cornelius and Herrenkohl (2004) explicitly tracked how fifth graders attempted to bolster the legitimacy of their theories during an authentic science investigation by appealing to partisanship, to authoritative discourse, and to the ownership of ideas. Moreover, scholars are documenting the moves that learners (who are given privileged positions) make to interrupt these power relations and to open up space for their otherwise silenced peers to gain access to the conversational floor (Herrenkohl & Mertl, 2010; Vossoughi, 2014).

Re-mediating Affect

Flores (2016) in her assessments of how adults learn new skills, creates a typology of phenomenologically experienced moods that are unproductive for learning along with their productive counterpart moods. Unproductive moods that make learners less willing to learn include: confusion, resignation, frustration, arrogance, impatience, boredom, fear (of making mistakes), overwhelm, insecurity, and distrust. Productive moods that increase a learner's willingness to learn include: wonder, perplexity, serenity, patience, ambition, resolution, confidence and trust. By drawing on the phenomenological skill-based model of learning (Dreyfus & Dreyfus, 1980), Flores is able to document which moods tend to co-occur at which stages of the learning process (from beginner to master). For example, beginners who struggle with their willingness to learn tend to do so because they experience confusion, frustration, impatience, and insecurity, whereas masters may be unwilling to learn due to becoming arrogant and resigned. When learners of varying expertise work together they may have to navigate a variety of these unproductive moods.

Unproductive moods can be exacerbated when students experience negative relational interactions during their inquiry work, as African-American, Latin@, and Native American students disproportionately do (Bang, Warren, Rosebery, & Medin, 2012; Downey, & Pribesh, 2004; Lewis, 2003; Neal, McCray, Webb-Johnson, & Bridgest, 2003; Skiba, Michael, Nardo & Peterson, 2002). A number of scholars are documenting the interactional moves that teachers use to create a positive atmosphere (See Battey & Neal, 2018, for an overview of this literature). These moves include: praising learners for positive behaviors (Neal, McCray, Webb-Johnson, & Bridgest, 2003), framing demanding inquiry as something everyone can successfully do (Boaler, 2006; Turner, Dominguez, Maldonado, & Empson, 2013), taking up and acknowledging the value of learner contributions (Boaler, 2006; Empson, 2003), attending to learners' language, culture and everyday experiences (Civil, 2007; González, Andrade, Civil, & Moll, 2011; Moschkovich, 2002), and setting an emotional tone that shows that set-backs and mistakes are natural and expected (Hand, Penuel, & Gutiérrez, 2012; Herrenkohl & Guerra, 1998; Nasir, 2008; Nasir & Hand, 2008). Scholars are also revealing the ways that learners themselves enact positive relations with their peers such as showing a commitment to helping each other learn, showing respect to each other, taking responsibility for when things go wrong, and learning effective methods of peer communication and support (Boaler, 2006; 2008). Scholars suggest that building an atmosphere of positive affect through peer support is itself a skill-to-be learned that is rare to find in classrooms (Boaler, 2008) and that is challenging to enact in practice for peers who are not attuned to each other's zone-of-proximal-development (Esmonde, 2009; Gijlers & de Jong, 2005). As such, building positive affect may follow the same phenomenological trajectory outlined by Flores (2006) that is itself vulnerable to unproductive moods such as frustration, confusion, impatience, and insecurity.

Re-mediating Spatial Orientation

Kendon (1990) identifies a number of physical orientations within group interactions that work to privilege and exclude certain individuals or to set different tones of interaction. For example, an F-formation creates a space in which individuals in a group have equal and direct access to the materials between them. Yet, this shared spatial privilege can be primed to be competitive (an H-formation where individuals interact directly opposite of one another) or cooperative (an L- or I- formation where individuals interact side-by-side) (see also Ciolek & Kendon, 1980). Individuals can also restrict access to an otherwise shared space by positioning themselves away from a group or positioning materials closer to themselves.

Scholars in education have begun to examine the implications of spatial orientation for equity. Leander (2002a) for example reports on how a group of learners, during a classroom literacy discussion, positioned the "Black community" as a single group that is prone to act out of anger. Learners in this group resourced spatial configurations—such as grouping themselves together and refusing to enter the interactional space of their African-American peer, Latanya—to further position themselves against and to actively agitate Latanya. Such spatial configurations worked to reduce Latanya's access to the conversational floor and to positive relational interactions, as well as to redirect the inquiry so that it dehumanized rather than benefitted her. In a related study, Leander (2002b) analyzes how a female student, Chelle, was silenced by a group of males during a classroom literacy discussion on women's rights. Leander finds that when Chelle argues that women do not have equal rights, the group of males uses both communicative resources (such as overlapping speech, increasing tempo and volume, minimizing and ridiculing Chelle's contributions) and spatial resources (such as when the males publicly talk about Chelle, but actively facing away from her to maintain a focal position in an interaction space that does not include her). Similar to the Latanya episode, these moves work to restrict Chelle's access to the conversational floor and to positive relational interactions, as well as to benefit the male's privileged position in society at the expense of Chelle herself.

Ma and Munter (2014) examine the intersection of spatial orientation and learning opportunities in skateboard parks. When novice skaters, for example, practice tricks on a flat plane (away from the ramps that risk catching too much speed or getting in someone's way), more experienced skaters resting alongside a fence facing the flat plane will share advice and encouragement. In another instance, when skaters' skating habits revealed they had different perceptions of what kind of skating the park was for (catching air to do tricks versus making laps around the whole course), a group of experienced skaters 'snaked' the other skater (grouping themselves together and following the other around the park wherever he went, cutting him off) until he left. Although this skater may have learned more about the other group's norms of this skate park, he certainly was not subject to positive relational interactions nor was his way of doing valued.

Examining a science inquiry interaction amongst a group of upper elementary age learners, Engle, Langer-Osuna, and McKinney de Royston (2014) show how spatial privileging (defined in terms of who is able to visually and physically access and attend to the space of interaction) works alongside other factors to influence whose scientific ideas gain traction on the conversational floor. They examine how factors such as gaze, bodily alignment, and proximity can shift and change during interactions in ways that privileges some learners while marginalizing others.

Re-mediating Social Positioning

Engle (2012) in her work on authentic inquiry learning environments has traced the trajectory of how learners shift from being positioned with intellectual agency, to authorship, to contributorship, and finally to a local authority during authentic inquiries. Gresalfi and Cobb (2006) examine social positioning along the dimension of agency, differentiating between disciplinary agency (whereby learners follow given procedures) and conceptual agency (whereby learners actively choose methods and develop relations between concepts and principles). Authority, they argue, cannot be fully realized unless learners are also given adequate agency.

Yet, as discussed earlier, normative hierarchies work to delegitimize which groups of learners are perceived to be and socially positioned to be competent and agentic in authentic inquiry learning environments (Bang, Warren, Rosebery & Medin, 2012; Engle, Langer-Osuna, McKinney de Royston, 2014; Esmonde, 2009; Langer-Osuna, 2016; Sengupta-Irving, 2014). These normative hierarchies manifest even in learning environments that are directly designed and normed to be cooperative as learners pick up on their teacher’s cues of who is ‘low’ and ‘high’ status (Langer-Osuna, 2016), and as learners themselves play forward deficit frames that differentiate learners into ‘low’ and ‘high’ status along racial, socio-economic, gendered, and other lines (Bianchini, 1997; Cohen, Lotan, Scarloss, & Arellano, 1999).

Teachers, however, can make interactional moves to counter these relational asymmetries (DiGiacomo & Gutiérrez, 2016) by ‘assigning competence’ to learners who have otherwise been positioned as ‘low status’ (Cohen & Lotan, 1995), or by positioning themselves as genuine learners alongside their learners so that they share authority and agency in an investigation (DiGiacomo & Gutiérrez, 2016; Gutiérrez & Vossoughi, 2010; Kafai, Desai, Peppler, Chiu, & Moya, 2008; Rahm, Miller, Hartley, & Moore, 2003). Specific ways that teachers make these moves include validating learners’ sense-making, inviting learners to share and elaborate upon their sense-making to other learners, and inviting peers to take up each other’s contributions by calling attention to what is important about them (Turner, Dominguez, Maldonado, & Empson, 2013). Researchers are increasingly finding that learners themselves can enact these interactional moves. For example, learners who are deemed to be ‘low status’ can resourcefully draw on areas that they are recognized as competent in and productively use these to hold the conversational floor while offering contributions to the collective inquiry (Esmonde & Langer-Osuna, 2013; Stromholt & Bell, 2018). Likewise, learners can advocate for their expertise to be recognized by seeking solidarity and support from their peers (Kafai, Fields, & Burke, 2010).

Participation Frames

Participation frames act as a heuristic for understanding how activity gets organized at an interactional and intersubjective level (Goffman, 1981, 1986; see also Lakoff, 1987 on frames). That is, participants within an activity make meaning of their actions and their expectations for how others will act based on the frames they use to make sense of the activity. In short, participation frames act as frames of reference that guide interactions. In educational settings, researchers have studied how learners take up frames such as the doing school frame (Pope, 2001) also referred to as the completing the worksheet frame (Hammer, 1994; Hammer, Elby, Scherr, & Redish, 2005), the productive disciplinary engagement frame (Engle & Conant, 2002; Hand, Penuel, & Gutiérrez, 2013), and a coaching frame (Hand, Penuel, & Gutiérrez, 2013).

Participants' frames can clash (Kelly & Green, 1998) or even become laminated on top of one another (Goffman, 1981; Hand, Penuel, & Gutiérrez, 2013) if participants in an activity are attempting to draw on different frames to guide their interactions together. The analysis of this study shows that a complicated relationship (that includes clashes and lamination) occurs between the doing school frame and the coaching frame. These two frames are elaborated upon next.

In the doing school frame (and its equivalent filling out the worksheet frame) participants are divided into teacher and students. Teachers are expected to lead the activity and manage students' behaviors while students are expected to be quiet, still, and focused as they follow the teachers' instructions for how to go about finding correct answers (Hammer, 1994; Hammer et al., 2005; Jiménez-Aleixandre, Rodríquez, & Duschl, 2000; Pope, 2001). This organizing frame overlaps with what Haberman (1991) calls the pedagogy of poverty, found in many traditional classrooms.

By contrast, in the coaching frame, participants are divided into coaches and players. Coaches are expected to help players analyze their gameplay and make non-judgmental suggestions for improvement (not just for individual players but also for the team collectively) while players are expected to make mistakes, to actively grow from their mistakes and to celebrate their successes (Hand, Penuel, & Gutiérrez, 2013; Nasir, 2008; Nasir & Hand, 2008). This organizing frame is found in many team sports, and is also typical of sports commentary in which the moves of players are announced, retold, and analyzed by commentators (Hoyle, 1993).

One way to get at the contrast between these two frames is to ask what does each one sound like in practice. Typically, the doing school frame sounds one-sided: a teacher giving directives and students quietly following along, or it sounds like students being chastised by the teacher for not quietly following along. The content of the talk is formal and impersonal focused on whether an answer is correct or not. By contrast the coaching framework sounds multi-voiced rather than one-sided and the talk focuses on action-verbs as participants recount stories and mistakes in a non-judgmental way, looking to collectively improve their work together.

This study contends that frames act in specific ways to organize the intersubjective expectations and norms around relations of power, affect, spatial orientation, and social positioning (see also Engel, Langer-Osuna, & Royston, 2014; Hand, Penuel, & Gutiérrez, 2013). That is, the doing school frame and the coaching frame are expected to enact social interactions with differing arrangements of power, affect, spatial orientation, and social positioning.

Shifts in Activity System

One way to render the dynamics of power, affect, social positioning, and spatial orientation visible is to examine how they play out across contrasting activity systems. For example, scholars have studied how a shift in the tools of the activity such as giving pairs of learners a blank representation template or a storyboard representation template impact how collaboratively those learners work together (Danish & Saleh, 2014). Scholars have also examined how shifting the object of the activity such as playing a game with a competitive win condition or a cooperative win condition can afford greater collaboration that is marked by more positive affect and active engagement from more learners (Peppler, Danish, & Phelps, 2013).

Additionally, scholars have analyzed how a shift in the division of labor such as the use of an audience question-asking role impacts the co-development of other inquiry practices such as taking the perspective of others and giving and receiving critical feedback (Herrenkohl & Guerra, 1998). Scholars have also investigated the authentic inquiry practices of the same group of learners across different activity system configurations within the same curriculum (Esmonde, 2009; Herrenkohl & Mertl, 2010; Cornelius & Herrenkohl, 2004), or across the same designed activity system configuration before and after a given curriculum (Danish & Phelps, 2011). These studies reveal that how learners take up authentic inquiry practices is greatly impacted by a number of situative dynamics such as power, affect, social positioning, and spatial orientation. Furthermore, they reveal that these situative dynamics are sensitive to changes in the activity systems.

More research is needed on this front to better understand how the interplay of these dynamics provide differential opportunities for learners to engage in and benefit from authentic inquiry practices, as well as to understand the potential ways these dynamics unfold across different activity systems within the same authentic inquiry learning environment. The current study follows and contributes to this line of work. What is unique about this study, however, is the role that the 3rd and 4th graders themselves played in transforming the activity system, as well as the ways they reconfigured relations of power, affect, social positioning, and spatial orientation at each qualitatively distinct shift in the activity system.

Authentic Inquiry Practices

This study draws on Shaffer and Resnick's (1999) multi-dimensional conceptualization of authentic inquiry as learning that is authentic to (a) the complexities of real-world contexts, (b)

Research

Conducting Investigations

- Standardizing Procedures
- Operationalizing Constructs
- Generating Original Data
- Consulting Reference Materials

Negotiating Inquiry Norms

- Using Socio-epistemic Norms
- Using Evidentiary Standards
- Using Representation Criteria

Interpreting Phenomena

- Explicating Meanings
- Explaining Mechanisms
- Describing Systems
- Building Models
- Substantiating Claims

Organization

Managing Investigations

- Problem-Scoping
- Planning
- Orienting
- Handling Logistics
- Safekeeping

Documenting Work

- Recordkeeping
- Structuring Entries
- Tracking Progress
- Presenting

Enhancing Workflow

- Modularizing
- Streamlining
- Focusing

Motivation

Taking Interest

- Merging Interests
- Taking Excursions
- Taking Ownership
- Taking Affiliation

Engaging Feelings

- Showing Wonder
- Showing Pleasure
- Becoming Engrossed
- Showing Empathy

Navigating Fragility

- Processing Emotions
- Persisting
- Taking Risks
- Negotiating Conflicts

Collaboration

Coordinating Joint Work

- Creating a Shared Vision
- Monitoring Contributions
- Building on Contributions
- Apprenticing Peers

Constructing Meaning

- Checking Understanding
- Making Thinking Visible
- Building a Local Language
- Perspective Taking

Building Trust

- Showing Vulnerability
- Conferring Dignity
- Showing Solidarity
- Showing Commitment

Innovation

Generating Insights

- Reframing Fixed Ideas
- Playing with Ideas
- Moving across Settings
- Making Connections
- Taking a Break

Building Capacity

- Mobilizing Resources
- Inventing Resources
- Developing Proficiency

Iterating Progressively

- Prototyping
- Generating Feedback
- Evaluating
- Revising

Equity

Expanding Who Participates

- Accessing Agentic Opportunities
- Accessing Positive Recognition
- Accessing Supportive Climate

Expanding Who Benefits

- Improving Personal Livelihood
- Deepening Familial Relations
- Deepening Interpersonal Relations
- Deepening Intergenerational Ties
- Deepening Community Relations
- Deepening Bioregion Relations

Expanding What's Valued

- Dispelling Settled Ideologies
- Speaking Truth to Power
- Enacting New Possibilities

Figure 3.2. Authentic Inquiry Practices

learners' own interests and volition, and (c) professional researchers' own inquiry practices. Authentic inquiry learning environments tend to engage learners in extended inquiry through problem-based learning, project-based learning, or design-based learning (Barron & Darling-Hammond, 2008). The first two dissertation articles argue that young learners' authentic inquiry practices in such learning environments, including the one studied here, are much more extensive than the typical portrayal of inquiry practices as the mastering of the research tools and techniques of scientists. Figure 3.2 features a working list of a wide range of specific moment-to-moment practices that appear generative for young learner's collective inquiry process. These practices go beyond mastering the tools and techniques of researchers to include the ways that learners' organize their work, motivate themselves, collaborate with others, resourcefully innovate, and pursue equitable participation. The current study shows how shifts in relations of power, affect, spatial orientation, social positioning, frames, and activity structures can constrain and afford which learners leverage which practices and to what ends.

Methods

To answer the question of how young learners reconfigure relations of power, affect, spatial orientation and social positioning to open up space for new inquiry practices to emerge and become legitimized, this study draws on the design, participants, and data collection strategies described in the second article in this dissertation. The major difference is that this analysis zooms in on one particular session of the Mancala Ultimate First Turn Challenge (session 3), and focuses on the shifting relations of power, affect, spatial orientation, and social positioning as an authority-positioned peer devises strategies to help her fellow peers learn.

Participants and Research Site

Mancala Club's first iteration was designed and facilitated by John Benner, Gabe de los Angeles, and David Phelps. We are all learning scientists and game designers who have many experiences facilitating play-based inquiry with elementary age learners in informal learning environments. We are all male, two of us are White and one Native American. In Mancala Club, we also served as coaches, camera operators, and researchers.

Mancala Club is an afterschool affinity space that invites elementary age learners to learn about and play the world's oldest family of board games: Mancala. Housed in a mid-sized urban Elementary School that receives Title 1 funds, Mancala Club was offered at no cost to families during the spring quarter of the 2014-2015 school year. During the spring of 2014-2015, 12 elementary age learners consistently participated in the club and consented to be in the study. The group was partially diverse across grade level (17% 2nd grade, 50% 3rd grade, and 33% 4th grade), gender (33.3% female) race (42% White, 33% African immigrant, 17% African-American, 8% mixed or other), and familiarity with Mancala (no familiarity, some familiarity, and inter-generational familiarity through parents and grandparents who played Mancala). The group of peers featured in this analysis includes Renata (female, African immigrant, no previous familiarity with Mancala), Lydia (female, White, intergenerational familiarity with mancala), Neha (female, Mixed or other, no familiarity with Mancala), and Dalton (male, White, some familiarity with Mancala).

Mancala Club Structure and Task

Mancala club lasts an hour and forty minutes one day a week for seven weeks and consists of the activities and time scheduled listed in Figure 3.3. This schedule allows learners to eat, exercise, and to connect with each other before freely choosing a Mancala-related activity to pursue. The Ultimate First Turn Challenge was one of many choices that learners could voluntarily take up.

Time	Activity
2:50-3:00	Snack
3:00-3:15	Outdoor Exercise
3:15-3:30	Arrival Meeting: Mood Meter, Club Charter, Preview Challenges, Share Mancala Experiences
3:30-4:20	Free Choice of Mancala Stations: Achievement Station (Ultimate First Turn Challenge), Competition Station (Bot Challenge), Exploration Station (Design a Variant Challenge), Social Station (Friendly Play)
4:20-4:30	Clean-up, Debrief, and revisit the Mood Meter

Figure 3.3. Mancala Club Schedule

The challenge was introduced during the arrival meeting of session 2 when Coach John shared the story of how a young learner discovered a game-winning first-turn move that he then used to defeat John. John's story also models how this young learner and John worked together to use a notation system to carefully record the game-winning combination of moves. The true story ends when Coach John reveals that the notebook with the game-winning move was lost. John presents this story as an invitation for learners to use their notebooks and a notation system to rediscover and re-record the game-winning combination of moves.

The Ultimate First Turn Challenge is an authentic inquiry task that reflects the complexities of real-world problems, the interests of learners, and the need to engage in the practices of professional inquirers. Working through potentially hundreds of permutations to discover a game-winning combination of moves on the first-turn is both complex and novel for young children (who typically are not taught combinatorial thinking until high school or later). In Mancala Club, the challenge is also presented as an open-ended activity in which learners take responsibility for how they approach and manage their collective inquiry. Furthermore, the Ultimate First Turn Challenge is an activity that learners voluntarily took up. It is directly embedded within the gameplay of Mancala and seemingly fits within the trajectories of learners as aspiring Mancala masters. Further still, learners are provided with supports and materials that they can use to engage in professional inquiry practices such as notating their gameplay to document their work. Learners are also encouraged to innovate their own supports and materials to help them progress on the task.

Only one learner, Clay, takes up this specific challenge during session 2. Yet, during the week in between session 2 and 3, Renata takes up the challenge at her home using her own Mancala board that she constructed as a club activity during session 1. She shares her notebook of first-turn move combinations that score up to 18 stones on the first turn (25 are needed to guarantee a win). Upon seeing the notebook and Renata's enthusiasm, the coaches invite Renata to be the station leader for the Ultimate First Turn Challenge for session 3. Renata takes up the invitation and three other learners voluntarily choose to spend the entirety of their activity time with Renata, while Clay continue to work on the Ultimate First Turn Challenge on his own at a different table. After session 3, Neha and Lydia continue to work on the Ultimate First Turn Challenge during additional club Sessions while some learners work on the challenge at their homes. Lydia pursues the challenge into session 6, while Neha returns the following year to the second iteration of Mancala Club to continue making progress on the Ultimate First Turn Challenge. Within this timeline of events, the current study features session 3 of the first year of Mancala Club, to make visible the consequential shifts in young learners' collective activity.

Study Design

Mancala Club was designed as a learning environment to leverage young learners' love of play and game mastery to engage them in sophisticated STEM practices typically not taught until high school (such as discrete mathematics, computer science, and engineering). It follows the principles of Design Based Research (Cobb et al., 2003) which embeds a series of conjectures about how learners learn within a designed learning environment. These conjectures are put to the test as researchers observe how the inquiry process actually unfolds within the designed learning environment.

Researchers can, through week-to-week and in-the-moment iterations, modify the learning environment as needed based on more nuanced conjectures that emerge from the context-specific nature of how learners take up Mancala Club. In retrospect, many of the supports that researchers designed to support learners in performing mathematics, computer science, and engineering work, also served to help learners productively engage with research, organization, motivation, collaboration, innovation, and equity practices (see Phelps, Dissertation Article 2, for a fuller survey of these practices). Although the current study focuses primarily on peer-to-peer interactions, it is important to contextualize these interactions within a specific set of mediating supports that were iteratively designed throughout this study (See Figure 3.4 for a visual summary of these researcher-designed mediators).

Data Collection and Analytic Procedure

Conversation and interaction analysis of this session covers 50 minutes of video (including segments of overlapping video to capture different angles of learners' interactions) along with the artifacts learners produced during this time (their notebook entries and their use of a poster board). The work learners performed on the Ultimate First Turn Challenge in its entirety (in and beyond session 3) were analyzed in accordance with the principles of Conversation and Interaction Analysis (Hall, 2001; Jordan & Henderson, 1995). Multiple viewings of the video allowed for researchers to create content logs and identify hot spots of particularly rich interactions. The analysis progressed iteratively and was enhanced by different modal approaches to the data including writing and reading transcripts, watching video without audio, listening to the audio without video, watching the video on half speed, and watching the video while replaying the

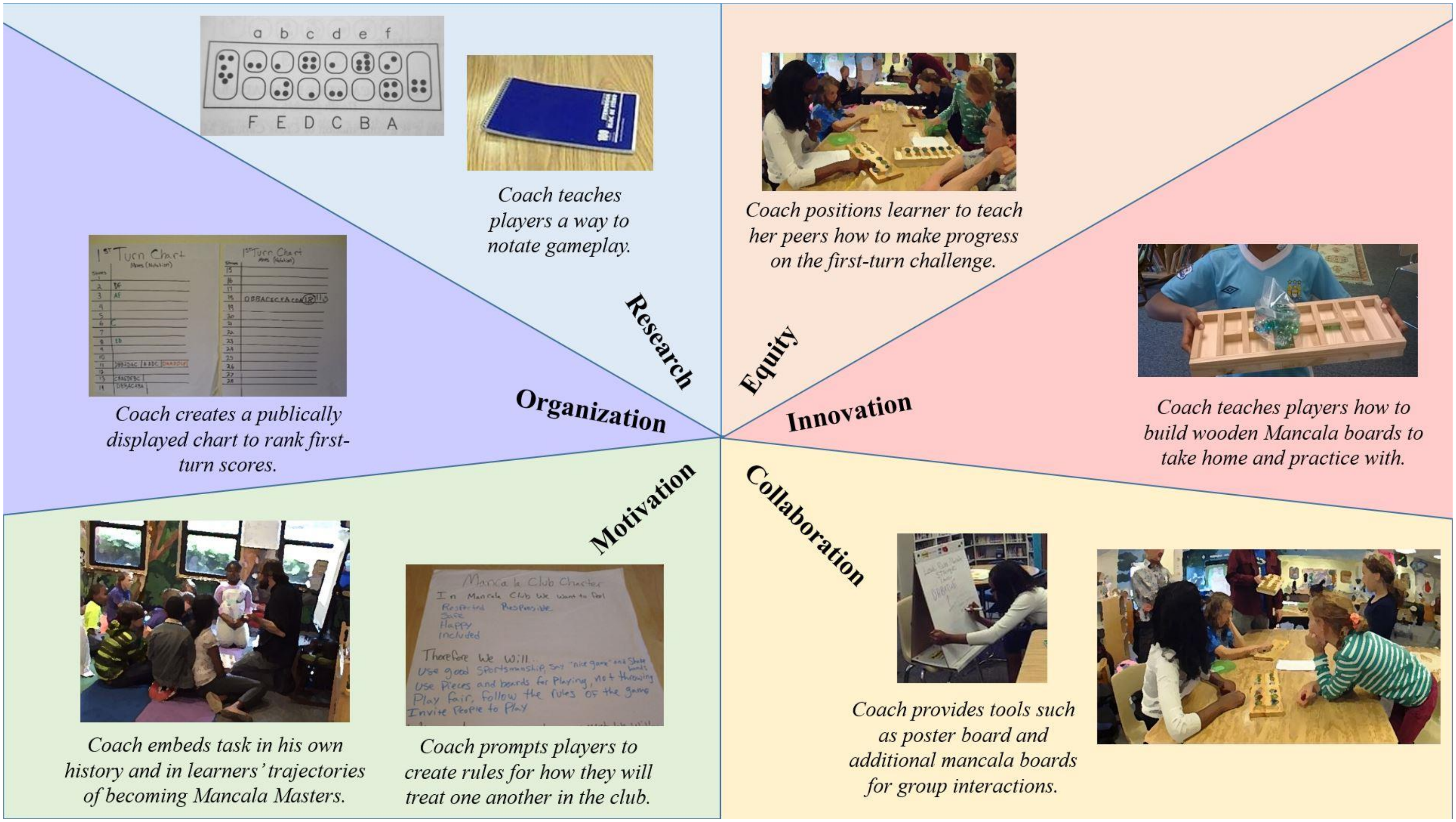

Figure 3.4 Summary of Mediators Introduced by Coaches

learners' Mancala moves with a Mancala board. These different modalities allowed for close attention to the different modalities at work in learners' own interactions including gestures, body positions, tone, intonation, and speech rhythm. Afterwards, the approximately 50-minute segment featured in this study was watched an additional three times to map out shifts in relations of power, affect, and social positioning. Codes to mark shifts in power, affect, and social positioning were developed using a grounded theory approach (Glaser & Strauss, 1967; Charmaz, 2008) that attended both to the data itself and to existent codes in the research literature which are detailed in the conceptual framework above. This back-and-forth dialogue between the video data and the research literature has been productively used by studies grounded in Activity Theory to showcase the holistic and often unrecognized work that young learners perform when engaged in inquiry (Packer & Goicoechea, 2000).

By focusing on this particular session, this paper presents an in-depth analysis of a number of complex and consequential dynamics. These dynamics include (a) the ways in which coaches' positioning of Renata as a station facilitator provided her with two contrasting social positions—expert Mancala Player and emerging Teacher—that readily conflicted with each other, (b) the ways in which the resolution of these conflicts re-configured the activity structure of the lesson, (c) the ways in which the shifting activity structures co-developed with shifts in the matrix of power, affect, social positioning, and spatial orientation that (d) complicated the ways in which Renata and her peers were able to access and make use of various authentic inquiry practices. Ultimately, these dynamics transformed the trajectory of each of the learners in this analysis as well as of Mancala Club itself which at the time was still struggling to resolve the contradiction between the practices of competitive gameplay that prize individual performance and the practices of a community-of-inquiry that champions collective performance.

Analysis

A timeline of key moments has been created to accompany this analysis. The scope of the timeline is the beginning and end of a single Mancala Club session in which Renata is positioned by the coaches as facilitator of the Ultimate First Turn Challenge station. Including a whole group debrief this session lasts approximately 50 minutes. The timeline is organized around five distinct 'phases' of this session that are marked by qualitative shifts in the activity structure of Renata's group. These phases in chronological order are: passive demonstration (~8mins), hands-on demonstration (~10mins), independent problem-solving (~8mins), small group share-out (~14mins), and whole-group debrief (~9mins). By organizing the timeline of key moments in this way, the analysis makes visible how relations of power, affect, spatial orientation, and social positioning became re-configured across each activity structure, as well as the ways these dynamics expanded or restricted equity in terms of who gets to participate (in the means of investigations, in the conversational floor, and in positive interactions), who benefits from participation, and what counts as valued ways of participation.

Passive Demonstration

Upon noticing that Renata had brought in a notebook from home that had a first-turn strategy for scoring 18 stones, the Mancala coaches invited Renata to lead the Ultimate First Turn Station. She was not obligated to take this role, but she readily agreed. The coaches expected that Renata would take on the role of a fellow coach, following the pedagogical norms of Mancala Club: sharing process strategies and insights and encouraging her peers to put these to use in their own investigations of the challenge. The coaches also expected Renata's peers to engage the activity from a coaching frame as well: being open to Renata's suggestions, trying out new practices, and being non-judgmental as they make and learn from their mistakes along the way. Yet, as evidenced in the first phase of the activity, Renata appears to take on 'a doing school' frame which creates tension with Renata's peers who seem to be acting out of the 'coaching' frame. Renata's use of the doing school frame is understandable given that when placed in new situations (such as being positioned to be a station leader) learners resource frames that they are familiar with even if these clash with the frames of their local context (Kelly & Green, 1998).

Renata begins by demonstrating her 18-stone strategy using a Mancala board that she places in front of herself. She refers to her personal notebook (that she brought from her home) as the other learners gather around the table and watch. The demonstration, however, does not run smoothly. Renata continuously makes stone-dropping mistakes as she moves the stones to recreate her 18-stone strategy. Renata's peers lean over the table and attempt to help her correct her mistakes by pointing out where they think the stones need to be moved to. As this happens Renata moves her personal notebook to her chest, out of view of her peers. Ultimately she resets the board and restarts the demonstration. One peer leaves and another takes her place (Neha). Renata continues to make stone-dropping errors and her peers continue to try to help her correct, but in doing so, Neha accidentally knocks another stone out of place, to which Renata exclaims she is confused and with a tone of anger calls out Neha, and then asks her peers to stop touching the board.

Renata continues to have difficulty demonstrating her strategy error-free as Renata's peers continue to touch the board. Approximately 7 minutes into the demonstration, Neha places her hands on both ends of the board and slides it closer to the middle of her and Renata. Renata moves the board back and in a frustrated tone directed at the coaches she exclaims "Neha's making me restart all over again because she keeps touching the board." The coaches suggest that everyone uses their own boards to follow along with Renata to which Renata readily agrees: "Yeah everybody get your own board." This moment marks the shift in activity from a passive demonstration to a hands-on demonstration (See Figure 3.5 for a visual summary of these interactions).

Already in this scene, relations of power, affect, spatial orientation, and social positioning, are unfolding in consequential ways for Renata and her peers. Here, for example, power operates to restrict Renata's peers' physical and visual access to the tools of the demonstration including the Mancala board and Renata's personal notebook. Renata's peers resisted this power dynamic by, at times, ignoring her directive and touching the board as most evident when Neha moves the board closer to herself. Renata and her peers displayed negative affect as well. The learner who leaves early on may have been bored or dissatisfied with the lesson, while Renata herself grows increasingly confused and frustrated at her peers, which is most evident when she chastises Neha and blames her for having to restart the demonstration. The spatial orientation that emerged during this scene consisted of Renata and her peers situating themselves into different 'quadrants' of a rectangular table. In order to increase their access to Renata's quadrant where the sole Mancala board in use resided, Renata's peers kneeled on their chairs or stood up and leaned across the table. Only Renata appeared to have the privilege to sit comfortably as she facilitated her demonstration. In this phase Renata's peers were positioned as beginners with minimal agency and authority.

These dynamics, in turn, give rise to a strikingly inequitable learning situation. First, these dynamics worked to reduce Renata's peers' access to meaningful participation: Renata controls the means of the investigation, the conversational floor, and sets a negative emotional tone despite her peers' efforts to help her correct mistakes. Similarly, Renata's peers, the affinity club at large, and perhaps even Renata herself do not appear to benefit from this demonstration. Indeed, during this nearly 8 minute phase the demonstration is never successfully completed, and even if it was successfully completed it is not clear who stands to benefit from it. Lastly, this lesson sends the message that the ‘valued’ forms of participation are to be quiet, to be still, to not make mistakes, and to observe with only one’s mind. The forms of participation that Renata’s peers enact outside of this—helping to correct mistakes and attempting to more evenly distribute the visual access to the board—were rebuffed. All of these moves by Renata fall directly within the purview of the ‘doing school’ frame, which clashes here with her peer’s local ‘coaching’ frame.

Hands-on Demonstration

As learners grab Mancala boards, stones, and their notebooks to transition to the hands-on version of Renata’s demonstration, a new conflict immediately arises. In the small break that occurs during this transition, Renata fans her face with a lid to the tray of stones as if to cool herself down. Neha, returning to the table with her notebook, teases Renata that she is going to copy Renata’s 18-stone solution. Renata responds “Noooo, guys please don’t copy this down.” Renata, speaking a bit exasperated, attempts to get the coaches’ attention asking them if she can make a rule that her peers cannot copy her strategy down. Dalton remarks “Unless you have a patent for it!” Renata’s bid here to increase her power to give directives (Langer-Osuna, 2016), again falls in line with the ‘doing school’ frame, which continues to clash with how her peers are engaging in the activity.

The coaches do not grant Renata the ability to forbid her peers from taking notes. Instead Renata and a coach work together to reframe the activity (See Figure 3.6). The coach offers, “teach them how they can discover like on their own what you did,” to which Renata responds, referring to her personal notebook, that she has an 11-stone solution that shares the same beginning as the 18-stone solution and that she can teach them that one as a starting point for her peers to work off of. Although Renata and her peers appear satisfied with this new plan—to simultaneously work through an 11-stone solution—several new challenges emerge from this plan.

The hands-on demonstration reveals to Renata that Neha struggles to follow along using the ruleset and notation (which she had not fully learned due to missing the first session of Mancala Club). This leads to a little bit of overwhelm from Neha, "wait, you're going too fast" and to a little bit of frustration from Renata who slows down to help Neha. Yet, as Neha requests help from Renata and Renata takes the time to help her, their facial expressions appear to soften. At one point, Renata instructs the group to start the next sequence of their turn from "number B." Neha points out that B is not a number and the entire group erupts into laughter including Renata. Neha teases Renata by pointing out that the camera has captured her number B statement, at which point Neha, Renata, and Dalton look at the camera and continue to laugh. By joking with Renata in this way, and by making light of her verbal mistake, the groups' affect appears to soften further and they begin to smile as they work.

Soon afterwards, however, Renata realizes that her peers are all working at different paces and are confusing themselves as well as Renata as to where in her 11-stone sequence they are. This uncertainty makes it difficult for the learners to successfully complete their demonstrations, and Renata grows increasingly frustrated throwing her hands to her face and exclaiming "Oh my God!" Picking up on this groups' struggle to coordinate their joint work, the coaches suggest that Renata uses a publicly displayed poster board to help her peers all be on the same page. Renata readily agrees.

Keeping the poster board at her side, facing towards herself and her peers, Renata paces her peers by (a) writing out a letter of her algorithm, (b) performing the corresponding move on her Mancala board simultaneously with her peers, and (c) checking to make sure each peer has the same number of stones in their goal. She repeats this process for each sequential letter of her algorithm. The number of mistakes that happen during this approach are dramatically reduced and when one does occur (Renata forgets to write down the letter C on the poster board), Neha points out this mistake in a friendly way. Renata acknowledges Neha's help and corrects the mistake by adding in the letter C. Neither learner appears upset or agitated. Neha continues to enact a coaching frame by treating Renata's mistakes as natural and expected. Through these interactions Renata's peers are able to successfully complete their hands-on demonstrations before Renata transitions them to independent work.

During this phase relations of power continue to be contested. This is partly due to how Renata's 18-stone solution has become vulnerable to being copied by others now that her peers have ready access to their notebooks. Power becomes manifested in the following ways: Renata makes a plea to her peers to not copy down her solution and then makes a bid to the coaches to prohibit her peers from copying down her solution (a bid to increase her directive agency; see Langer-Osuna, 2016). Renata's peers resist Renata in the following ways: Neha teases Renata that she's going to copy down her game-winning strategy in her notebook while Dalton points out that Renata does not have a patent for her solution. The coaches do not grant Renata this additional directive agency, and so Renata makes a bid to, instead, transform the very structure of the lesson (which Renata confirms was meant to keep her 18-stone solution a secret).

Likewise, affect continues to manifest itself in unproductive learning moods. Renata is visibly and audibly upset with her peers as they tease her about copying down her strategy and as they do not readily coordinate a joint working pace. Interestingly, these antagonistic moments appear to act as catalysts for transformation within the collective activity as Renata seeks ways to innovate upon her lesson. By the end of this phase, as the coordinated joint work comes together, Neha successfully helps Renata correct a notation mistake in a non-antagonistic spirit.

The spatial orientation of the peer group shifted as well. Rather than peers leaning over Renata's quadrant of the table and negotiating access to the location of the board, learners remained in their various quadrants content to work with their own materials, and not Renata's. Furthermore, this hands-on demonstration positioned Renata's peers with disciplinary agency (Pickering, 1995; Gresalfi & Cobb, 2006) as they are able to follow along in the experiment with access to their own materials.

At this point more equitable arrangements are beginning to emerge. Renata's peers now have access to the means of investigation, but Renata maintains control over the conversational floor. Renata also maintains control over the outcome of the hands-on demonstration, which she uses to her benefit—to keep her 18-stone solution a secret which directly aligns with her personal goals. It is unclear whether learning an 11-stone solution aligns with her peers' goals. What is clearer, however, is that a number of valued ways of participating are taking shape. Renata and her peers engage in the following authentic inquiry practices in this phase: negotiating inquiry norms (around knowledge ownership and mistake making), engaging feelings (playfully teasing Renata and sharing a laugh together), coordinating joint work (as Renata elicits participation and monitors the work of the group), constructing collective meaning (as Renata teaches Neha the Mancala basics), and iterating progressively (as Renata revises her lesson plan to keep her 18-stone solution a secret, and revises her approach to help pace her peers).

Independent Work

Renata initiates the independent work phase by instructing the group to reset their boards and use the same strategies to reach 18 stones instead of 11. After answering clarifying questions she leaves the table saying, “if you get somewhere, tell me.” Renata’s peers get started right away resetting their boards and trying out various permutations. Renata periodically comes back to check in on the group and offer her assistance, “does anybody need help?” Neha repeatedly flags Renata down to receive assistance with the basic rules of the game. Lydia also flags Renata down to share a new discovery, “Oh my God! This is awesome. I’ve already gotten five without so many letters.” Lydia has found an algorithm that uses fewer turns to reach a score of 5 stones. As Renata notices that Lydia is experimenting with different beginning permutations (instead of the specific sequence of moves Renata taught using the notation to start from hole D, then hole B, then B again, then hole A), Renata reminds the group to “change something in the middle...don’t change the DBBA.” Lydia, however, continues to find alternative permutations valuable and shares these with Renata, “I found another way to get eleven besides yours.” Shortly thereafter Renata initiates the next phase of this lesson—a small group share-out.

Dramatic transformations in power, affect, spatial orientation, and social positioning occur during this phase. In terms of power, Lydia does not follow Renata’s directives to use the same beginning moves in her solution path. Noticing this, Renata appears to push back by reminding the group to start their solutions with the same solution path used in Renata’s demonstration. Renata then clarifies this directive on the poster board. Yet, Lydia continues to ignore this directive, pursuing her own interest in developing and testing out a modification to the notation system that allows her to compare different solution paths to Renata’s solution path. Specifically, Lydia’s independent work here leads her to transform the notation system to make visible the number of times stones move around the board based on the initial starting hole chosen. She accomplishes this by tallying the score after each decision point in addition to recording the total number of stones scored at the end of a turn (See Figure 3.7).

Lydia appears to be expressing the productive learning moods of curiosity and wonder. This is coupled with an elated affect as evidenced when Lydia at one point jumps up and down with excitement. These interactions are complicated—Renata's directives to control her peers' investigation paths stem from a 'doing school' frame, but Renata's peers are able to successfully work outside of this frame. These frames have shifted from directly clashing to somehow co-existing, allowing for a more positive affect to take shape as learners perform their work and make discoveries.

The spatial orientation of the group shifts as well. Renata's peers work mostly quietly within their own quadrants, and during the few times that they turn their attention to Renata they do so by bringing her into their own quadrant in a one-on-one formation. Renata's quadrant remains relatively unoccupied throughout this phase—it no longer holds a commanding presence of each peer's attention.

As previously mentioned, Lydia uses her self-directed work to modify the notation system in a way that allows her to track how many stones are scored during each decision point of the solution path. This allows her to notice patterns and make comparisons across various solutions. Through this work Lydia is socially positioning herself to have conceptual agency (Pickering 1995; Gresalfi & Cobb, 2006).

These shifting dynamics allow for a number of equity moves to unfold. First, by innovating upon the notation system Lydia increases her access to the means of investigations as well as expanding the object of investigation (what are alternative solution paths that require fewer turns). Furthermore, by physically leaving the table and by allowing her peers to flag her down as they need help, Renata leaves the conversation floor much more open to her peers. They can choose to talk to each other in Renata's absence or choose to start a specific one-on-one conversation with

Renata if they need help or, in Lydia's case, want to share a discovery. Additionally, antagonistic relational interactions are being replaced by more easy-going interactions. Second, by experimenting with alternative solution paths and innovating upon the notation system, Lydia is presumably pursuing her own personal goals (that lie outside the range of Renata's intended outcome of the inquiry). In this way, who benefits from this inquiry is beginning to expand. Lastly, Lydia's work is expanding what counts as valued ways of doing including building capacity (by inventing new resources), interpreting phenomenon (by using her new notation system to more fully describe system relations within her Mancala gameplay), taking interest (by taking ownership over her work), and engaging feelings (by jumping up and down and showing satisfaction in her work).

Small Group Share-out

During small group share-out Renata writes each peers' name on the poster board, and then asks each peer to demonstrate their solution to her for verification purposes before writing the solution up on the board. This phase is punctuated by a number of incidents that do not seem to go as planned. First, when Renata writes Lydia's name on the board she uses Lydia's nickname which Lydia objects to because it's a personal nickname. Second as Renata peer-reviews Dalton's work, Lydia leans over the table to review it as well pointing out a mistake in the total score count. Third, Neha claims that she messed up her notation and needs an eraser. Renata tries to calm Neha down, but Neha says, "I know I messed up!" Renata crosses over to Neha's side and kneels down to work through the notation with Neha. They figure out that Neha did indeed write down her notation differently than she had intended, but by playing out the incorrect notation (rather than erasing it) they discovered that it led to Neha scoring 5 more stones than her initial way. This interaction marks a turning point in which Renata begins to engage in a 'coaching' frame, supporting and encouraging her peers through their mistakes in order to enhance their learning.

Simultaneously, Clay visits the table and Renata offers him a lesson (she is still the station leader). Clay says no and instead grabs Renata's personal notebook (which Renata left in her quadrant when she crossed over to help Neha) and says he's going to copy down her strategy. Renata says "you can only write it down if you've learned the lesson," and then Neha leans over the table to try to pry the notebook out of Clay's hands. Eventually, Clay sets the notebook down and begins to copy the solutions that Renata has written up on the poster board, to which Renata also rejects, "Wait, I'm not sure. You can't copy it down cause I'm not sure [Dalton] wants to share it." Renata then asks Dalton if he would like to share his 14-stone strategy. At the end of this phase, Renata reports out the progress of each learner to coach David and reframes Neha's mistake as a positive moment. Neha jumps in, clearly elated, recounting how her mistake turned out and concluding that she is "awesome" (See Figure 3.8).

During this phase, the dynamics of power, affect, spatial orientation, and social positioning become inverted, in some respects, to how they were manifested in the passive demonstration phase. The most dramatic moment around relations of power come into play when Clay grabs Renata's notebook and tries to copy down her 18-stone solution. Neha, who half an hour earlier had teased Renata about stealing her solution as well, now intervenes to grab Renata's notebook out of Clay's hands, thereby protecting Renata's solution. Renata, likewise uses her power to show respect for Dalton's authority by stopping Clay from copying down Dalton's solution without Dalton's permission. Furthermore, Renata offered Clay a lesson and to share her notebook only after he receives the lesson. These moments reveal that Renata is not against copying per se.

Rather, she is for knowledge ownership and for autonomy of choice (to share that knowledge or not).

Renata displays a great deal of positive affect during the small group share-out, patiently working with her peers as they attempt to demonstrate their solutions. Neha becomes visibly frustrated and upset after making a mistake and grabs her pencil to erase her notation. Renata works to calm her down, kneeling side-by-side with Neha (a spatial arrangement that signals cooperation; see Kendon, 1990) and working at her level encouraging her through the upset until they learn that Neha's only mistake is that her notation scores more stones than she realizes. This immediately cheers Neha up. The way in which Renata works with her peers flips the spatial orientation from the passive demonstration phase. Now, Renata is the one leaning over her peers' boards and notebooks at their own quadrants as she watches them perform their solutions and touches their boards).

This move allows Renata to maintain her status as expert and facilitator as she continues to issue directives and position herself as having the final say in whether her peers' solutions are correctly performed and ready to be publicly recorded. At the same time, this move also positions Renata's peers as having increased authority (Engle, 2012). Peers are given credit for their work as authorship is attributed to them. Lydia extends her social positioning, further, by jumping in to verify Dalton's solution as well—ultimately providing the last word on his solution by finding a mistake the others had missed.

These varied interactions have expansive implications for equity. Renata gives Dalton the conversational floor as well as autonomy over whether he wants to share his strategy or not. Renata also acknowledges each peer's work by name on the poster board (which acts as an artifact that supplements the conversational floor). Renata shows respect and patience when working with her peers, especially Neha, which creates a positive emotional atmosphere where before there was antagonism. All of which helps to expand who gets to participate. This small-group share out phase further reveals the ways that Renata's peers are benefitting from their investigations finding 13-stone and 14-stone solutions by using Renata's strategies (as evidence that this work was of benefit to Renata's peers, Dissertation Article 2 shows how these learners went on to use these solutions as well as Renata's 18-solutions for their own purposes in the context of other challenges). In this phase we also see a broad expansion of what counts as valued participation. Valued ways of doing that are emerging include negotiating inquiry norms (around the value of mistakes and around the evidentiary standards of the peer review process), documenting work (presenting and reporting findings), building trust (Renata showing commitment and conferring dignity to Neha by joining her by her side and working non-judgmentally through her mistake; and Neha showing solidarity with Renata by trying to stop Clay from copying Renata's notebook). This increasing group solidarity marks a new valued way of being that had not been present earlier. Simultaneously, Renata appears to transform her way of being as well, to take up a 'coaching' role in helping her peers work through their mistakes, giving them the conversational floor, and respecting their autonomy.

Whole Group Debrief

As part of the schedule of Mancala Club, the coaches call all the learners to the carpet for a group meeting to debrief the day's activities and to advertise what is happening the next week. On the way to the debrief, Renata shares Neha's story of the mistake with Coach John, to which Coach John responds to Neha, "A mistake got you a bigger number, wow, that's really exciting." Renata's recounting of Neha's mistake further transitions her into a coaching frame, in which coaches actively share stories of their learners' work.

Yet, as the group sits down and John advertises next week's Mancala mixer activity, a previous conflict resurfaces: Renata says quite firmly, "People, do not notate me!" Coach John directly addresses this issue by framing Mancala Club as a collective team, "So here's the cool thing about this club, alright, we're the only people doing Mancala notation in the whole school right...any strategies that you learn and you share with your friend it's like sharing with the team, right?" After a little back and forth with learners to clarify this team approach, Coach John turns the groups attention to Neha, "Like you made a really cool mistake today, sometimes like mistakes turn out really really cool...Neha tell us the story of what happened with your mistake." Neha takes the floor to share her story.

A few minutes later, another peer raises his hand to ask Renata a question about her studying practices. Renata takes the floor to share her approach, "I just go home, stay in my room, study and see what moves I can do." The coaches use this opportunity to ask if others use this approach and then the coaches connect this approach to what expert Mancala players do. Shortly after, Renata raises her hand to call attention to Lydia's alternative 11-stone solution (another coach frame move). The coaches prompt Lydia to take the floor to share her strategies and her modified notation system and why these were productive for her. She takes the floor as her peers turn towards her. After Lydia explains her notation system to the group, referencing her notebook throughout, coach John remarks, "We may end up doing a better way of doing Mancala notation than what I thought was the best way" (See Figure 3.9).

Relations of power, affect, spatial orientation, and social positioning interact in dynamic ways here. Renata again attempts to use directive power to restrict others from accessing her solutions even when she publicly uses them during gameplay. The coaches do not grant Renata this directive power; instead they work to shift norms around what it means to be a collective team.

Mancala Club as a sense of a collective team begins to emerge soon after. The affect transforms into a productive mood of curiosity and even celebration—Coach John celebrates Neha's mistake by asking her to retell the story, another learner voices his curiosity about Renata's study habits, and Renata expresses her curiosity about Lydia's alternative solution and notation system. This curiosity takes on a collective nature as Neha's mistake, Renata's study habits, and Lydia's alternative solutions and tool-conventions become objects of group discussions that are peer-led.

The spatial orientation shifts as well—from learners sitting as if row by row facing Coach John, to learners turning their questions, their bodies, and their gaze to their peers. The social positioning develops through these moves as well—Neha, Renata and Lydia are becoming contributors to the practices of Mancala Club. Coach John affirms each of their contributions—celebrating Neha's mistake, linking Renata's study habits to expert Mancala players, and claiming that Lydia may have discovered an even better notation system than John had initially devised. Through these shifts some of the classic hallmarks of a teamwork or a "coaching" framework begin to emerge (Hand, Penuel, & Gutiérrez, 2013) such as the awareness that mistakes are natural, expected, and opportunities for learning, as well as the positioning of individual's strategies, practices, and innovations as objects of collective discussion and analysis.

This coaching framing is more typical to team sports than it is to the traditional classroom and it has been shown to hold greater promise for equitable interactions (Hand, Penuel, & Gutiérrez, 2013). This is evidenced in the following ways during the debrief: as learners take turns, for example, sharing their discoveries and practices they are able to take the conversational floor and enjoy positive relational interactions (a mistake, for example, is not framed as a deficit but as a resource). Furthermore, by sharing their discoveries, their study habits, and their innovations learners are expanding who benefits from their work: the collective group of Mancala Club as a whole (peers, for example, can take on Renata's study habits, or take on Lydia's new notation system). Additionally, the interactions during this debrief have helped to clarify that learning from peers' personal stories and advice is a valued way of knowing, that sharing and innovating upon resources is a valued way of doing, and that relating to peers as teammates is a valued way of being.

Figure 3.10 contrasts the configurations of power, affect, spatial orientation, and social positioning across each activity structure as well as the various authentic inquiry practices that were taken up in each activity structure. When contrasting the activity structures side-by-side it becomes apparent that the passive and hands-on demonstrations were marked by power struggles between Renata and her peers. During the independent work phase, Lydia pursues an unscripted space and in the share-out phases Renata respects and legitimizes Lydia's (and the rest of her peers') original work. This seems to be the turning point in which peers shift towards greater group solidarity.

Affect follows a similar course as well. The demonstration phases were marked by frequent frustration and confusion with peers responding in antagonistic ways to one another, whereas the later phases gave way to excitement and joy over discovery and sharing. When there was an episode of negative affect in the later phase (over Neha's mistakes) Renata did not respond antagonistically but worked to support Neha through it. Spatial orientation also appeared to shift from more hierarchical arrangements—peers attending to Renata's quadrant during the demonstration phases—to more egalitarian arrangements in the share-out phases with Renata and peers working side-by-side and then sitting side-by-side on the carpet with attention frequently turned to them as they each shared their stories. Social positioning also followed a progressive trajectory from Renata's peers having minimal authority and agency during the passive demonstration phase to having more agency and/or authority with each shift of the activity structure.

Additionally, Figure 3.10 demonstrates how different activity structures—and configurations of power, affect, spatial orientation, and social positioning therein—afforded and constrained Renata and her peers' take up of different authentic inquiry practices. During the passive demonstration phase Renata's peers did not take up any authentic inquiry practices except for their attempts to transform their learning opportunities (which manifested itself in the power struggles described above). The hands-on demonstration allowed peers to conduct investigations (although pre-given ones), and peers co-constructed with Renata practices around negotiating norms, coordinating joint work which entailed building a local language and taking others' perspectives (as Renata tried to explain the rules of the games to Neha who was unfamiliar with Mancala). In the face of set-backs and frustration Renata and peers also generated solutions and continued to make bids to transform their learning opportunities.

Independent work allowed for Renata to elicit participation from her peers (by creating a new task), and to move freely within the learning environment circulating to other groups or working one-on-one with individuals. Renata's one-on-one assistance allowed for more perspective taking and building a local language together. For Renata's peers independent work allowed them to try their hand at conducting their own investigations and iterating progressively upon these. For Lydia especially, her independent work in transforming the notation system to make visible the relationship between decision points, movement around the board, and stone scores allowed her to develop epistemic fluency, innovate upon resources, and as a result use new appropriate methods to inform her investigations. It also allowed her to take satisfaction in the activity, jumping with joy at the discoveries made possible due to her new notation system. Many

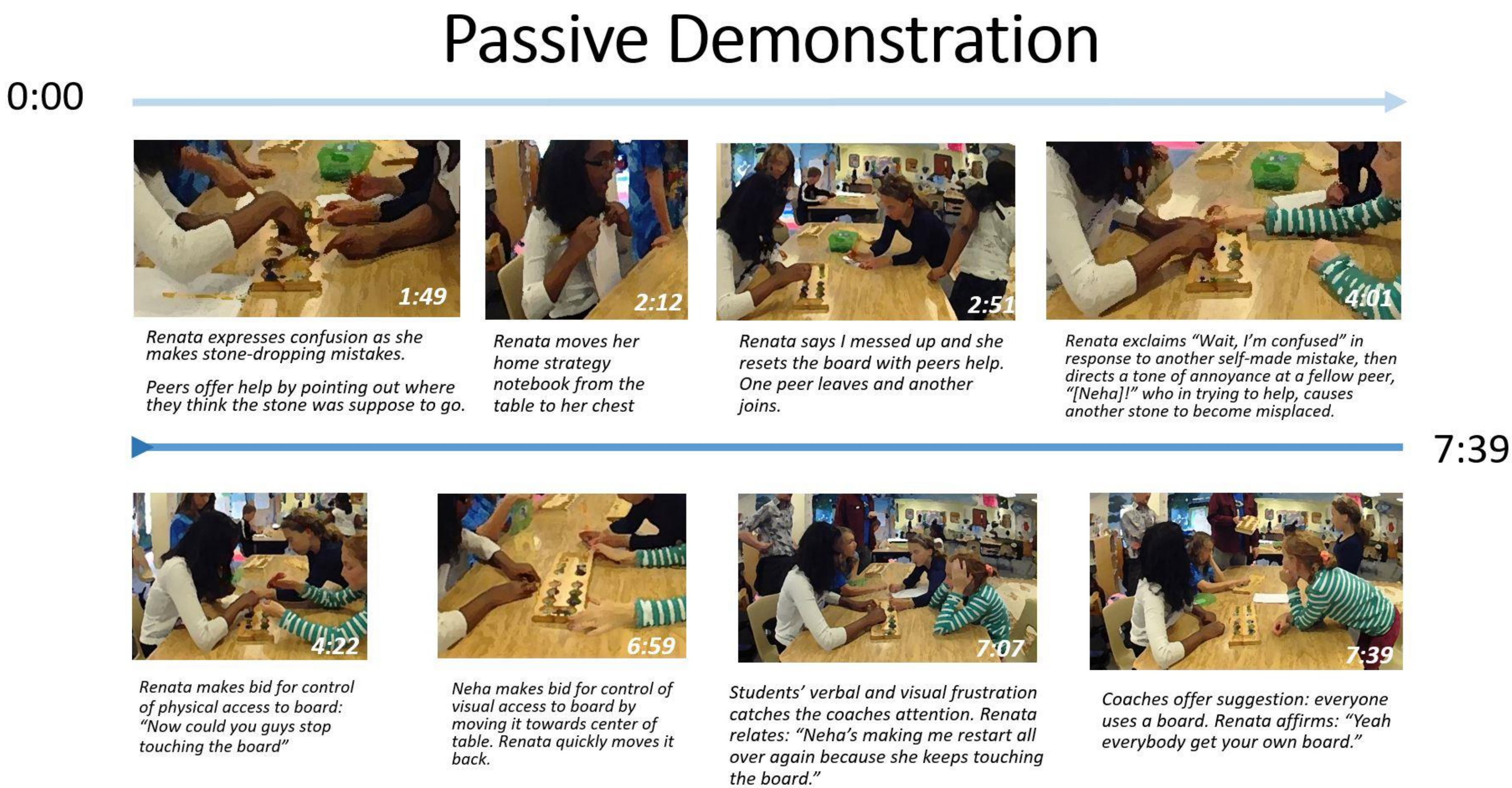

Figure 3.5. Passive Demonstration

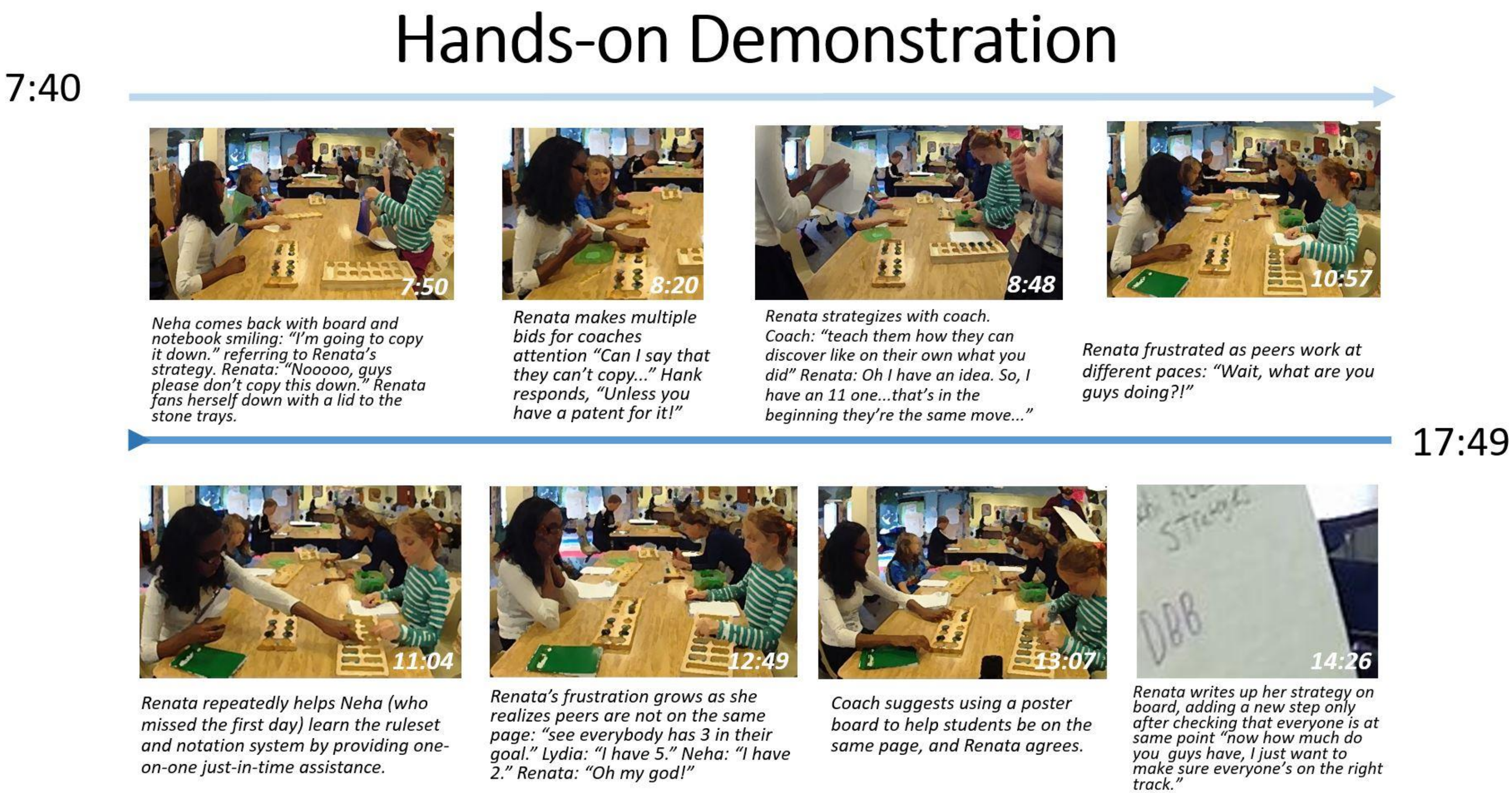

Figure 3.6. Hands-on Demonstration

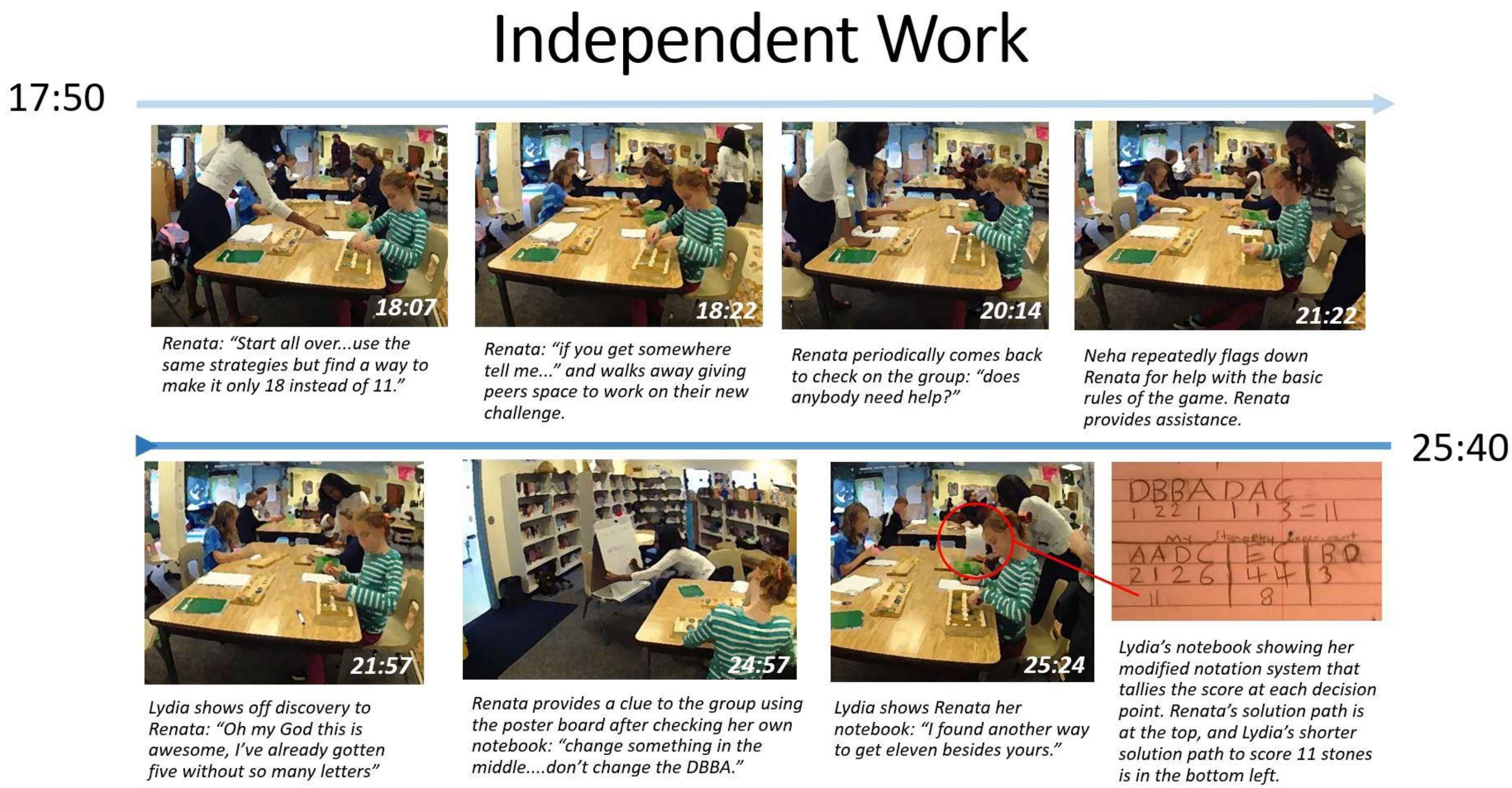

Figure 3.7. Independent Work

Figure 3.8. Small Group Share-out

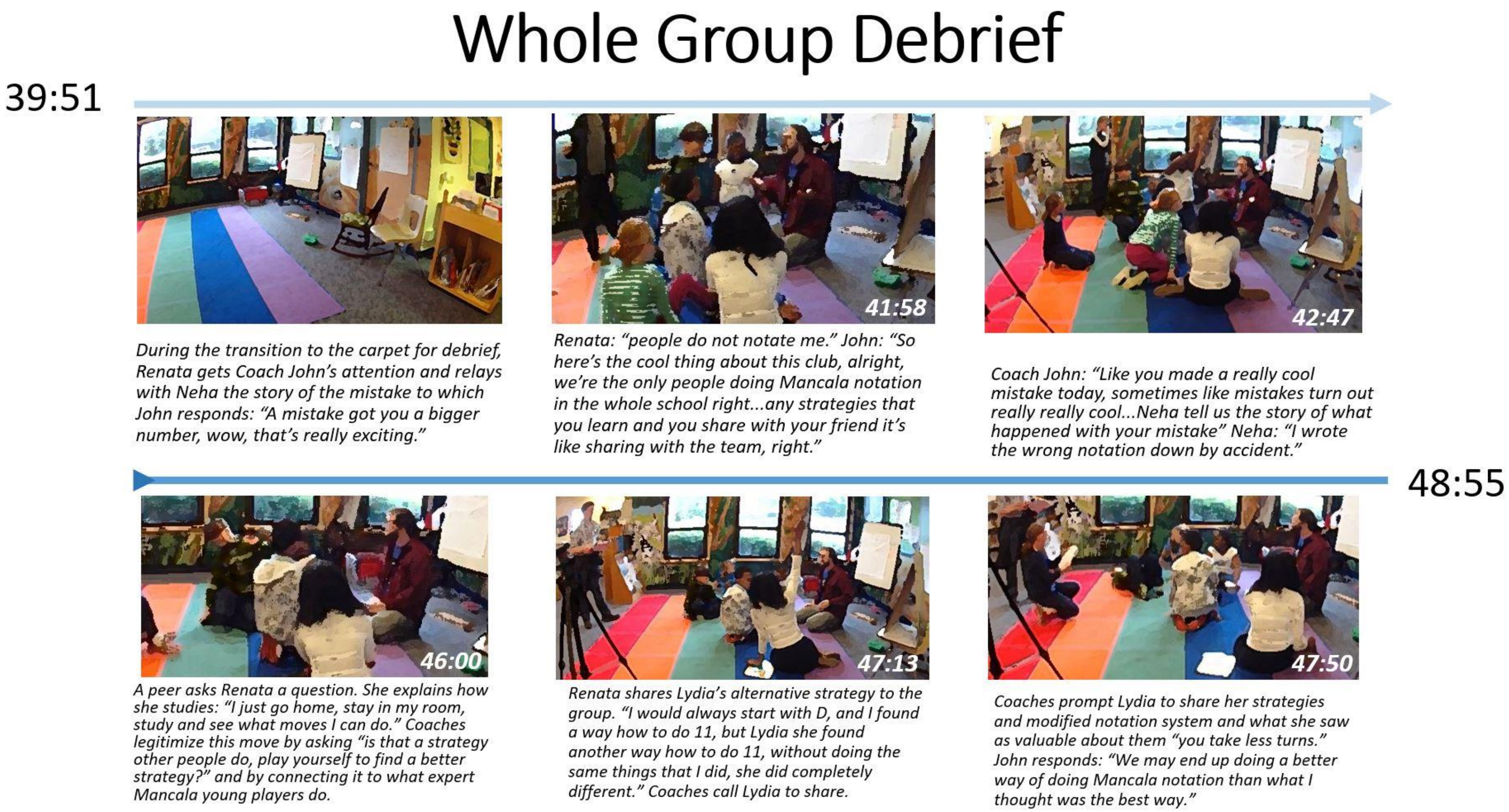

Figure 3.9. Whole Group Debrief

of these inquiry practices were constrained during the demonstration phases because Renata's peers did not have the freedom to experiment on their own.

A number of authentic inquiry practices were also unique to the small group share-out phase. The process of publicly sharing out each other's work allowed Renata and her peers to productively reframe mistakes, re-address the issue of knowledge ownership, hold each other accountable, report findings, give and accept critical feedback, show commitment to others' growth, and confer dignity to peer's who were visibly struggling. The pro-social nature of these interactions attests to the growth Renata and her peers made from their antagonistic beginnings in the demonstration phases of the activity. That initial antagonism seemed to constrain pro-social interactions such as showing commitment to others' growth and being respectful and non-judgmental.

Lastly, the whole group debrief offered unique opportunities for peers to take ownership of their work and to share their resources with the class. Renata elicited participation from her peers by broadcasting their work to the whole group which led to the group directly interacting with Neha and Lydia. Inquiry practices that emerged earlier recur here as well, but at a larger scale as Renata, her peers, and the whole group including the coaches work to build a local language, take each others' perspectives, and transform the learning opportunities of the club-at-large (such as when coach John explicitly remarks that learners may find better ways to notate than what John thought was the best).

As described above these shifts across activity structures and the dynamics of the relations of power, affect, spatial orientation and social positioning appeared to have a profound impact on equitable participation (see Figure 3.11 for a summary). First, a number of moves occur that help expand who gets to participate meaningfully in this Ultimate First Turn Challenge session led by

Renata. For Renata's peers access to the means of investigation shifted from the passive demonstration to the hands-on demonstration and again in independent work when Lydia begins to devise her own means of investigation. Access to the conversational floor becomes most pronounced during the whole group debrief when Neha, Renata, and Lydia each get to present their discoveries and advice in detail. Relational interactions begin negatively in the passive demonstration phase but grows slowly throughout, then reaches its peak during the small-group share out phase when Renata works patiently to transform Neha's frustration over 'making a mistake' into a joyful discovery.

Second, several moves help expand who benefits from participating in this challenge. Initially, Renata makes moves to accomplish her own self-stated goal: keeping her 18-stone solution a secret. This goal is in line with the doing school frame, in which the teacher knows the answer but does not simply share it with students. This is not necessarily the goal of her peers. Renata's peers' goals become most apparent during the independent phase in which Lydia does not work to find Renata's 18-stone solution, but rather works to find solutions that minimize the number of moves a player needs to take. Lydia's new notation-convention helps to make this salient, and her elated mood as she makes discoveries with her new tool suggests that she has carved out her own way to benefit from this investigation. Dalton and Neha too may be benefitting from this investigation during the independent phase as they discover 13- and 14-stone solutions. During the whole-group debrief the work of Renata's group begins to benefit the Club as a whole as they share productive norms around mistake-making, successful study strategies, and innovative notation conventions with the whole group. During this phase, a discussion emerges (in response to a contradiction made salient by Renata) that allows the coaches to reframe the Club not as a group of competitive individuals but as a team working to the benefit of all.

	Passive	Hands-on	Independent Work	Small Group Share-out	Whole Group Debrief
Power	Peers struggle for access to the 'means' of the investigation.	Peers struggle for access to the 'solution' of the investigation.	Peers take up 'unscripted' investigations.	Peers show solidarity by siding with Renata in her struggle with others over access to the 'solution' of the investigation.	Peers show solidarity as they make space to share each other's 'unscripted' investigations.
Affect	Frustration, Confusion, Chastising over stone-dropping errors.	Frustration and Confusion over difficulties coordinating joint work.	Joy and excitement over new discoveries.	Positive and patient encouragement…in light of one peer experiencing frustration over a notation mistake.	Excitement over sharing discoveries.
Spatial Orientation	Peers lean over into Renata's quadrant (of the rectangle table).	Peers and Renata sit in their own quadrants.	Renata floats between tables giving peers space and time to work, as well as floats to peers' quadrants upon their request.	Renata floats to each peer's quadrant, leaning in or kneeling down side-by-side.	At the carpet, Coach John sits at the head of the carpet, learners sit side-by-side at carpet. Yet attention continually turns to Renata, Lydia, and Neha.
Social Positioning	Peers have Minimal Agency and Authority.	Peers take up Disciplinary Agency.	Peers take up Conceptual Agency.	Peers take up Authority.	Peers take up Emerging Contributorship.
Authentic Inquiry Practices (Research, Organization, Motivation, Collaboration, and Innovation. See Figure 3.11 for Equity Practices)	Peers and Renata take up: Navigating Fragility (persisting through a series of mistakes)	Peers and Renata take up: Conducting Investigations; Negotiating Inquiry Norms; Managing Investigations; Coordinating Joint Work; Constructing Meaning; Iterating Progressively.	Peers and Renata take up: Conducting Investigations; Interpreting Phenomena; Documenting Work; Taking Interest; Engaging Feelings; Constructing Meaning; Building Capacity; Iterating Progressively.	Peers and Renata take up: Negotiating Inquiry Norms; Documenting Work; Engaging Feelings; Taking Satisfaction; Coordinating Group Work; Building Trust	Peers and Renata take up: Taking Interest; Engaging Feelings; Constructing Meaning; Building Trust; Building Capacity

Figure 3.10. Summary of Shifting Dynamics by Phase

Third, throughout the phases a variety of shifts occur in what counts as valued participation for Renata and her peers. Shifts in valued ways of doing are most noticeable when a peer switches from not valuing a specific inquiry practice to explicitly valuing it. This occurs for example when Neha expresses her frustration at making a mistake and tries to erase the mistake so that Renata cannot help her work through it. After Renata does help Neha work through the mistake, Neha comes to see the value of working through mistakes—because the mistake can lead to a higher score. Another clear example is seen when Renata does not validate Lydia's search for alternative solutions during the independent phase (reminding her and the group to follow Renata's instructions), yet during the whole group debrief Renata appears pleased to call attention to—and to show the value in—Lydia's alternative solution path. In this way valued norms around mistake-making and multiple solutions emerged. Shifts in valued ways of being were quite noticeable as well. In the passive demonstration phase Renata appeared to adopt the traditional classroom teacher frame, valuing students for being quiet and still listeners and chastising them when they were not. Yet, throughout each phase Renata's peers became increasingly socially positioned with agency and authority which Renata helped to orchestrate. Agency and authority allowed Renata's peers to act in non-passive ways which Renata came to appreciate (as evidenced in her sharing the discoveries of Neha and Lydia to the coaches) and to respect (her protecting the discovery of Dalton from Clay). Additionally, Renata herself appears to make a substantive shift from the role of traditional teacher in the doing school frame to a coaching frame (Hand, Penuel, & Gutiérrez, 2013). Renata's coaching frame, most evident in the small-group share out and whole group debrief, entails the non-judgmental treatment of mistakes as natural learning opportunities, and the situating of individual's gamplay moves, strategies and discoveries as objectives of analysis and collective discussion (Hand, Penuel, & Gutiérrez, 2013).

	Passive	Hands-on	Independent Work	Small Group Share-out	Whole Group Debrief
Accessing the Means of Investigation		Renata's peers are able to use Mancala boards, stones, and notebooks.	Lydia modifies the means of investigation.		
Accessing the Conversational Floor					Neha, Renata, and Lydia share their strategies and discoveries on the conversational floor.
Accessing Positive Interactions				Renata works patiently to discover and show Neha the value in Neha's mistake.	
Pursuing Personal Goals			Lydia investigates an emergent interest: finding multiple solutions and contrasting which require the fewest moves.		
Pursuing Collective Goals					Renata responds to a peer's request for advice and Neha and Lydia share discoveries that can benefit all of Mancala Club.
Expanding ways of Knowing					
Expanding ways of Doing				Neha comes to value working through her mistakes.	Renata comes to value finding multiple solutions.
Expanding ways of Being			Lydia increases her agency as she pursues her own investigation.	Renata shifts from traditional teacher role to coach role.	Renata and her peers increase their authority as they share insights.

Figure 3.11. Key Moments that Expanded Equitable Participation by Phase

Discussion

This analysis of the Ultimate First Turn Challenge reveals the ways that a small group of 3rd and 4th graders can successfully expand equitable participation by re-mediating relations of power, affect, spatial orientation, and social positioning during moment-to-moment interactions across shifting activity structures. At a summary level this analysis reports that the first two activity structures (passive and hands-on demonstration) were marked by power struggles and negative affect between Renata (who facilitated the activity) and her peers. In contrast, during the subsequent activity structures (independent work, small group share-out and whole-group debrief) Renata used her power to respect, honor, and publicly legitimize her peers' solutions and contributions to the problem-solving process. Affect shifted from frustration to excitement and joy. Across each phase, Renata's peers became positioned with increasing levels of agency and authority. Her peers successfully took these positions up and drew on them to use a more robust constellation of authentic inquiry practices including equitable practices that expanded access to the means of investigation, the conversational floor, positive relational interactions, that benefitted the learners' themselves and the Mancala Club at large, and that transformed what counts as valued participation within this inquiry. Renata, in turn, working with peers who were increasingly positioned as her 'equal' (often by her) engaged in more authentic inquiry practices (especially collaboration and equity practices) as well. Overall, this analysis deepens understanding of the contentious work that is entailed in authentic inquiry learning environments (which are always situated in relations of power, affect, social positions, and spatial orientations) and of the capabilities and competencies of young learners for successfully performing this work.

Implications for Theory

By zooming in on one session within the Ultimate First Turn Challenge and foregrounded one dimension of authentic inquiry practices—equity practices—this study was able to analyze how moment-to-moment shifts in the web of relations between power, affect, spatial orientation, and social orientation mattered for young learners' ability to, willingness for, and consequences of participating in collective inquiry. This work contributes to the field's understanding of how inequities get reproduced as well as interrupted in moment-to-moment interactions. It builds on other scholars' analyses of the relations of power, affect, spatial orientation, and social positioning by bringing all four of these dynamics into focus simultaneously and by showing how learners as young as 3rd and 4th grade come to successfully maneuver these dynamics.

This holds implications for how the field conceptualizes authentic inquiry, as well as how the field conceptualizes the capabilities and competencies of young learners as inquirers. This study shows that a number of equity practices are important for supporting and sustaining authentic inquiry. That is, authentic inquiry entails equity-expanding moves that engender learners to more meaningfully participate, to get more out of their participation, and to redefine what counts as valued participation in their inquiry. This vision itself expands the narrow conception of authentic inquiry as performing a series of canonized research practices in a value-neutral setting. That young learners are capable of enacting these equity practices, and are able to do so through re-mediating relations of power, affect, spatial orientation, and social positioning speaks volumes about their capabilities and competencies as inquirers. Future research should continue to explore the resourceful ways that young learners can interrupt inequitable relations by investigating these and additional dynamics (to power, affect, etc.).

Implications for Practice

It would be oversimplistic (and a misunderstanding of activity theory and critical theory) to use these findings to argue that designers should work to eliminate power struggles, negative affect, antagonistic spatial arrangements, and asymmetrical social positionings from learning environments. An alternative perspective, evidenced by this study, shows how relations of power, affect, spatial orientation, and social positioning pervade learning environments and carry within them the seeds of their own transformation into novel configurations that can afford the more equitable enactment of authentic learning practices. Indeed, a fine-grained analysis of these activity structures reveals the productive role the initial power struggles and negative affect held—they created a number of contradictions whose resolutions appeared to directly lead to the transformation of the activity structure over time. It also reveals the work that learners performed to re-mediate their learning environment to transform their opportunities for participation. At key moments throughout the lesson Renata and her peers worked to shift their power relations, affect, social positions, and spatial orientations.

In light of these findings, Activity Theory invites us to ask how can we as designers better support learners in the process of making these contradictions salient and in providing learners with resources to work through these contradictions? Critical Theory, simultaneously, invites us to ask, how can we support learners in interrupting the inequities and oppressions that particular configurations of power, affect, spatial orientation, and social positioning reproduce within their learning environment?

Following these implications, further research is needed to make visible the equity work that learners perform in authentic inquiry learning environments, as well as the specific strategies and practices that young learners resource to perform this work. By making this equity work visible, as well as young learners' developing competencies and capabilities at navigating it, further research will make important advancements for educational theory and practice.

Limitations

The central claim of this study is that young children can capably and competently navigate the contentious dimension of their collective inquiry. This claim is substantiated through a close analysis of how a small group of 3rd and 4th graders re-mediated their learning environment in face of the many contradictions and conflicts they experienced during a play-based inquiry task. There are several analytic moves that could have further substantiated this claim by more deeply contextualizing the collective inquiry process studied here. These analytic moves include attending to the histories that learners bring with them, attending to the intersectional interplay of race, gender, language, and socio-economic status, and attending to the meaning that learners themselves were making of their experiences (these analytic moves are more fully detailed in Dissertation Article 2).

In short, expanding the data collection and analytic techniques of this study to portray the historical, intersectional, and experiential dynamics of the collective inquiry process would have helped to further unpack the contentious interactions between this group of 3rd and 4th graders. Yet, even if the dynamics that constituted young learners' inquiry work are not fully elucidated, the central claim, as evidenced by the analysis above, still holds: Young learners can capably and competently re-mediate their learning environment in response to the contentious dimension of collective inquiry.

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