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Drawing to Learn: A Classroom Case Study

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Abstract
As early childhood educators of young children, we recognize that children draw what they know from cultural transmissions, moving through many developmental transitions with drawing. As children's skills developed, a PreK/Kindergarten teacher in a university laboratory school classroom with 27 children was interested in studying ways children can use drawing to enhance their learning of critical concepts within the curriculum. This paper explores her teacher research, a case study using an action research approach guided by these questions: (1) How do young children use drawing during short and long-term projects? (2) What can teachers learn from close attention to children's representation drawing? A Drawing to Learn protocol was developed to study children's drawings of curriculum topics like the wind, affording opportunities to use drawing to express their understanding of motion and their theories of how something works. The teacher research was organized around the Cycle of Inquiry process typically used for curriculum planning in the classroom. The curriculum planning data (observation, interpretation, questions, reflections) informed teachers' understanding of the meaning of children's drawings and guided teachers as to how to proceed to inquire more deeply into meaning and discovery with children. The findings of this two-semester study indicate multiple purposes and strategies for using drawings in the learning process (predict, study functions of objects, revisit and reflect, and plan).

Keywords Drawing to learn · Representation · Emergent inquiry curriculum · PreK/K

This *Drawing to Learn* (Forman 1987; Anning 1999) study communicates the inquiries and findings of Cyndi McAuliffe's action research within her PreK-K classroom. Action research focuses on issues practitioners identify and study in their specific settings (Otto et al. 2017; Castle 2012). Cyndi is the lead teacher in her classroom at the early childhood education center (ECEC) on the campus of the University of Michigan-Dearborn, which serves children (1–6 years) of university families and the surrounding community. Guided by their pedagogical leader, Seong Bock Hong the program implements a classroom-based, teacher research process for teachers to reflect on and study their teaching. Each school year, teachers choose a research question, collect data from their own and students' experiences (children and preservice teachers), and analyze the findings. At the end of school year teachers report their findings and offer peers suggestions for further research. Cyndi's co-authors developed a Cycle of inquiry system (COI) (Broderick and Hong 2011; Broderick et al. 2018), which is the tool used by ECEC teachers for their action research. Both co-authors support Cyndi and other teachers in the laboratory school settings at their two schools.

The ECEC employs a Reggio inspired philosophy where teachers listen to and document children's theories and ideas (Edwards et al. 2012), using the COI system for observation and planning. They encourage representations of thinking through multiple representations and many voices, striving to use drawing as a language for children's knowledge construction. Observational drawing and using drawing for learning is part of the culture in Cyndi's classroom.

Cyndi's Prek/K classroom is comprised of 27 children and many preservice students. There were 13 preschoolers and 14 kindergarteners (18 males, 9 females, 4 with special needs, 2 children who are English language learners). Two preservice teachers in this study were students from an early

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childhood strategies course using the COI to observe, document, interpret, reflect, plan and implement a short-term project (45 h per term). One preservice teacher in this study was an intern conducting short and long-term emergent inquiry projects using the COI (180 h per term). These preservice teachers are support staff to Cyndi, meaning they were hired to assist for hours beyond their assigned practicum.

In this setting, lead teachers facilitate preservice teachers' understanding and implementation of emergent curriculum generated from children's inquiry and teacher research using the COI observation and planning system (Broderick and Hong 2011; Broderick et al. 2018; Edwards et al. 2012; Gandini and Goldhaber 2001). In the previous year, Cyndi's teacher research focused on the exploration of drawing tools, writing tools, and papers to learn the affordances for particular drawing purposes within the context of observational drawing. *Drawing to Learn* was often discussed in ECEC teacher meetings, which led Cyndi to develop an interest in studying *Drawing to Learn* during one academic year.

Theoretical Framework

Drawing to Learn is a theory grounded in knowledge of children's development with drawing, and redirects the ways teachers typically use drawing in Prek/K classrooms. It also diverges from a popular view of drawing as merely expressive of emotions. From a stance outside a focus on art, *Drawing to Learn* builds on children's ability to represent and reason about the world they explore through drawing and is the theory guiding this study.

Children's Development with Drawing

Children's drawings represent their knowledge of the world, their feelings, and interests (Chang 2012). Drawing appeals to children for thinking through ideas (Forman 1989; Forman et al. 1998; Lowenfeld 1987). Early scribbles are imitative and then expressive and develop in coordination with intellect (Piaget 1926; Quaglia et al. 2015; Morra 2002). Drawing is dynamic and relational for children. Responsive interactions with children about their scribbling and drawings encourage them to continue to create marks and represent ideas (Anning 1999; Chang 2012; Dunst and Gorman 2009).

Early representations of the real world include components of objects, though each component (e.g., mouth, nose, eyes of a face) may be placed randomly in the drawing. As they develop, children integrate the function of the object into their best fit representations; what they think makes the drawing most readable (Longobardi et al. 2001 as cited in Quaglia et al. 2015). So, a side view image of a horse with two legs would not fit the child's concept of a horse that requires four legs to move. There is a dynamic relational association of the child's theories about the function of the drawing with the function of the object (Quaglia et al. 2015). Communicating with children about the functions of objects in their drawings helps teachers to interpret their reasoning and theories (Anning 1999; Forman et al. 1998). *Drawing to Learn* builds on this dynamic relational approach. It incorporates careful facilitation by teachers to organize opportunities for children to revisit and reflect on their drawings, and to engage in conversations about the success of their drawings in communicating their thinking.

Typical Stance for Drawing in Early Childhood

Preschool teachers see drawing as one of many opportunities for exploratory play. Drawing is encouraged and shared with families. Drawing naturally represents and extends children's interests, what they pretend and imagine (Quaglia et al. 2015), yet children rarely see adults using drawing or expressive images (Anning 1999). Typically, teachers tend to use written words to decode children's drawings. Using the symbol system of letters and words to represent the child's ideas on their drawings may communicate to children that the words hold more significance than the drawings (Anning 1999; Chang 2012).

Drawings are used to represent children's emotions in relation to trauma and assist counselors in the development of treatment (Chang 2012). Children's drawings about specific events and settings (school, learning in general, literacy) have been used to evaluate and modify the learning environment. These representations of children's emotional perceptions engage children in reasoning (Chang 2012), yet there is even greater potential for using drawing as a learning strategy (Anning 1999; Kolbe 2005).

Drawing to Represent Reasoning

Drawings help children engage in science learning. They are a vehicle for children to represent science concepts like predicting the outcomes of cause and effect events. Children can illustrate their understanding of quantity or how things work by the choice of features in their representations (Ainsworth et al. 2011; Forman et al. 1998). Drawing is comfortable for children. In a science learning setting children experience drawing as a natural process (Ainsworth et al. 2011; Kolbe 2005) and extension of their play explorations (Anning 1999; Kolbe 2005).

Children have more facility with drawing than words for expressing what they know about how the world works (Anning 1999; Edwards et al. 1998, 2012). Drawing has been promoted as a strategy for learning in the schools of Reggio Emilia, Italy (Edwards et al. 1998, 2012). It is one of many media teachers rely on as a vehicle for

communicating existing knowledge and transformations in children's understanding. While Reggio inspired teachers encourage children to enact, observe, use photos, clay, or other media, they ask children to draw before and after experiences with other materials (Anning 1999; Forman et al. 1998; Kolbe 2005). The drawings are a jumping off point for beginning an investigation or transitioning through learning processes in long-term projects. In this way drawings serve as formative and summative assessments (Ainsworth et al. 2011; Otto et al. 2017). Using more than one form of data to represent children's knowledge (drawing, enacting, verbal discussion) is a method of triangulation that validates the action research approach of the teachers in the ECEC (Castle 2012; Otto et al. 2017).

Drawing to Learn

It is important to distinguish "learning to draw" from *Drawing to Learn* (Forman 1987). Learning to draw is learning skills that someone might teach you, like learning how to use specific lines, shapes, shading and perspective to recreate something or create something new (Anning 1999; Kolbe 2007). Educators have discovered that after a period of "learning to draw" children shift their intent toward *Drawing to Learn* (Anning 1999; Edwards et al. 1998, 2012; Kolbe 2005). When immersed in the content about which they ponder children are *Drawing to Learn.* They are making their thinking explicit, specific, visible, and public for debates with peers and teachers (Ainsworth et al. 2011). These interactions encourage shifts in thinking and construction of new knowledge (Anning 1999; Forman 1987; Forman et al. 1998).

Drawing to Learn is a cyclical process that begins with children drawing about the phenomenon, moves on to children engaging in experiences in relation to the phenomenon with materials and possible discussions. Then, following these experiences, children reflect on their experiences through drawing (Anning 1999; Forman et al. 1998). It centers on processes of drawing to capture a child's initial theory of how something works, which is later confirmed or adjusted by the child through experiences with the phenomena and subsequent drawings. The subsequent drawings represent modifications in children's thinking following their new experiences with the content related materials. Teachers interpret the new thinking in the drawings in each iteration. Reflections before and after hands on experiences guide teacher's curriculum planning. Conversations with children about the meaning of their drawings and comparisons to previous drawings reveal misconceptions and new directions for exploration that can extend and challenge the children's thinking (Anning 1999; Forman et al. 1998).

Cycle of Inquiry and Emergent Curriculum

The COI system (Broderick and Hong 2011) is a curriculum planning process for implementing emergent curriculum. It includes five forms for recording teachers' observations of children and their reasoning in planning curriculum based on the observations. Emergent curriculum has been referred to as an action research approach for developing curriculum (Broderick and Hong 2011). Teachers develop emergent curricula plans from careful observations and interpretive analysis, which leads to next steps for inquiry and learning. Then teachers' observations from the next steps plans lead to a next phase of interpretive analysis and planning. The COI is organized around the types of data used in action research: observations, interpretations, action questions, action plans and reflections (Broderick and Hong 2011; Castle 2012; Stremmel 2007) (Fig. 1).

The COI process is ongoing and cyclical. Teachers write memos alongside their observation records, articulate hypotheses about what children are thinking and their questions about the reasoning for children's actions (Broderick and Hong 2011). When a teacher questions why a child touches a worm and documents the resulting actions of the worm, the teacher is speculating on the child's possible theory (Forman and Hall 2013) that "touching the worm makes it wiggle and move." Emergent curriculum relies on teachers' speculations and their expert knowledge about the content related to children's behaviors. Interpretations are subjective speculations that become more valid when agreed upon by more than one researcher.

They should be developed and shared among teaching teams (Cresswell and Cresswell 2018).

Teachers using the COI develop curriculum based on their hypotheses about what children think or question and predict where the learning might go (Giudici et al. 2001) if they were to provide new materials to extend or challenge children's thinking (Broderick and Hong 2011). The extensive documentation in the COI demonstrates the teacher's role in the ongoing curricular planning and accounts for researcher bias and triangulation, the gathering of data about a topic from more than one source (Castle 2012). Teachers working with the COI and emergent curriculum triangulate by engaging children in conversations to describe their drawings and the actions depicted in their drawings. They compare the conversations and drawings to their observation records (written, photos, and video). This relational approach with a variety of data provides different perspectives that assist with the interpretation (Rinaldi 2006).

Cyndi's Study Focus

Few articles are published (Anning 1999; Forman 1987) on the concept of *Drawing to Learn*, which led Cyndi

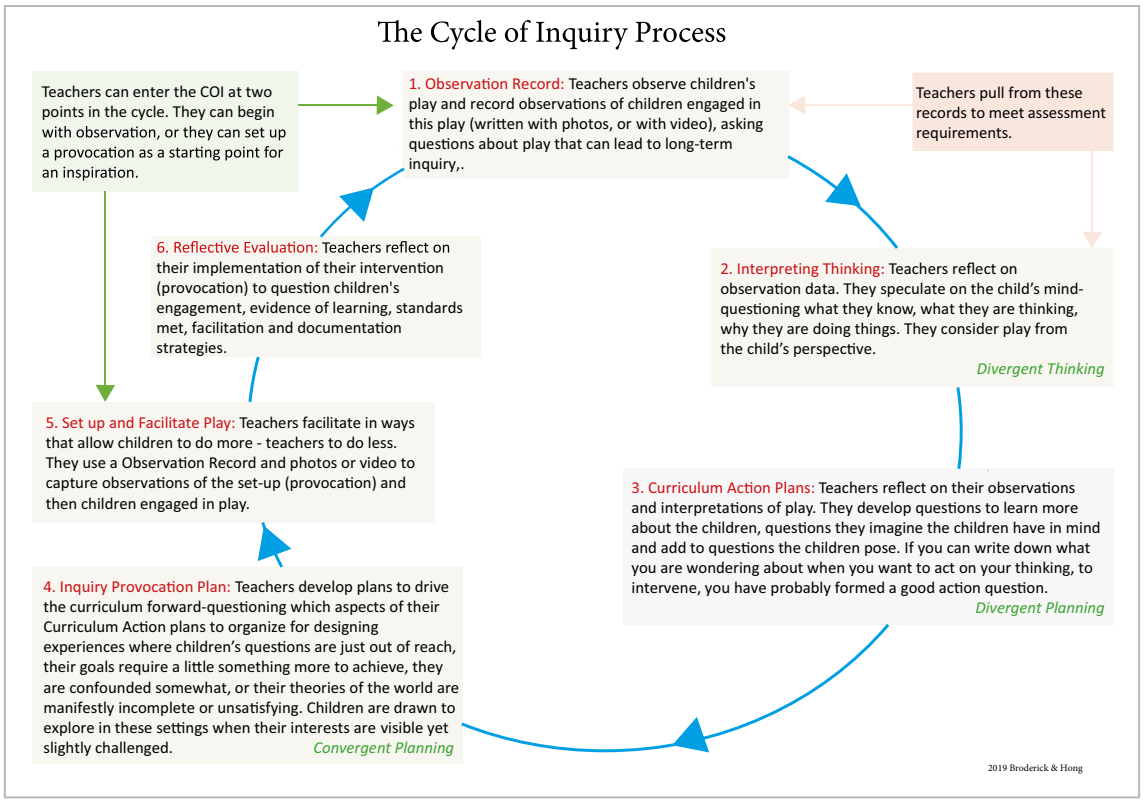

Fig. 1 The cycle of inquiry system

to study this concept throughout one academic year. The study focused on motion because it had potential to engage children for a long time and it's a visible but intangible concept that can be explored through interactions with many materials, including drawing. Cyndi had been using the COI system to develop emergent curriculum in her PreK-K classroom for many years and would use it to address her study questions: How do children use drawing during short and long-term projects? What can teachers learn from close attention to children's representation and drawing?

Method

Cyndi and three preservice teachers implemented an emergent curriculum in her Prek-K classroom as an action research approach to explore the *Drawing to Learn* research questions. Drawing in the classroom and the use of the COI were consistent with previous years. The research focus and the use of a *Drawing to Learn* protocol were the only new features.

Data Collection and Analysis Approach

Observation data was collected daily for designing responsive emergent curriculum using the COI. Children's drawings and teachers' thinking in the COI forms guided the action research approach to curriculum development (Broderick and Hong 2011; Castle 2012; Stremmel 2007). Each preservice teacher met weekly with Cyndi to review and interpret the COI data (written observation records, photos, video and children's work samples—drawings, photos of artifacts, etc.) and plan together. They interpreted and planned in a manner consistent with action research as described in the previous section on the COI. Their emphasis for analysis was to determine how children's drawings describe what children think about motion.

Procedure

Cyndi developed a *Drawing to Learn* protocol (Table 1) to use for this project. She and the three preservice teachers collected drawings before and after experiences with phenomena. This assured that all teachers involved in the study

Table 1 Drawing to Learn protocol

Drawing to Learn protocol
1. Limit the materials to the problem at hand in order to focus the drawing
2. Children drew and represented prior knowledge before entering into experiences focusing on the concept of motion
3. They drew again following each topic-related experience
4. Teachers documented the experiences (video, photo, written observation records) and collected these drawings
5. Teachers interpreted the learning during the *Drawing to Learn* process by reviewing the drawings along with video, photo, and written observation records to develop theories about the children's thinking. Teachers looked beyond what the children said to interpret the meaning in their drawings
6. The drawings were presented to children for their own reflection
7. Documentation of these reflective conservations (observation transcripts and photos or video) provided information about the drawing and learning, and used for review, as noted in step 4

were reliably using the same format for collecting meaningful data. It relies on evidence that children are figuring things out, mentally constructing as they experience and represent through drawing (Avery et al. 2016).

To set up the study Cyndi thought it necessary to design two opportunities for children to experience the ways motion could be represented by marks based on factors outside the child's control. A third experience was also planned for children to conceptualize motion through drawing.

First children used a marker while spinning a lazy-Susan. Next, they observed the tracking of marks while spinning tops that were dipped in paint. Both provided opportunities to track motion and see how mark making tools leave a track. These distinctions provided children some familiarity with the language of motion in relation to the language of drawing.

The third experience for conceptualizing motion through drawing focused on a pinwheel that had been on display in the classroom. Children were invited to observe one pinwheel placed in the middle of a table, and to think through and use drawing to represent their ideas about how the pinwheel worked. Drawing before going outside to investigate the wind's effect on the pinwheel gave children opportunity to draw their ideas of the function of the pinwheel. This provided baseline information on their understanding and information to test when children encountered the pinwheel in relation to wind (Forman et al. 1998). Through this experience teachers established their use of COI observation data and planning processes for the study where each phase was designed around observations and interpretations of the previous phase.

Findings

This *Drawing to Learn* study includes observations and analysis from a full academic year, with more data than we can report in one article. In her data analysis at the end of the school year Cyndi discovered patterns describing the reasons children used drawing. Therefore, the findings section shares these patterns, with examples for each, rather than the chronological trajectory of the study. Interpretations in this section are from teachers' COI records and conversations with children.

Drawing to Predict

Observation data from the pinwheel exploration revealed an interesting drawing trajectory. The photo sequence indicated to teachers that Charlie (5 year) edited his earlier drawing predicting the movement of the wind in relation to the pinwheel and likely shifted his thinking after his interactions with the pinwheel outdoors, and his conversations with the preservice teachers and his classmates. The early photos of his drawing show a curved line circling around on itself as it reaches up and over the left side of the pinwheel, representing what teachers speculate as his theory about the movement of the wind as it enters the pinwheel (Fig. 2). In the later photos he adds a line to his original drawing that seems to represent the wind exiting the pinwheel on the right side, showing the follow through of the wind's movement (Fig. 2).

Another prediction experience was in relation to the teeter-totter preservice teachers created (Fig. 3). A ball could roll on top or marbles could roll through tubes. Children's initial drawings predicted movement they anticipated and revealed things they didn't understand. Additional play clarified new understandings that were represented in their next drawings.

Ginger (4 year) and Cody (4 year) explored with this apparatus, first drawing their ideas of what might happen when putting a marble into the teeter-totter. Ginger drew a single marble inside the tube (top left Fig. 4). Teachers interpreted this as representation of a theory that the marble will be static when the tube is flat. They speculate that her second drawing of a tilted tube reveals her idea that some motion will occur from tilting (second from top left Fig. 4). The two marbles inside the tube in this second drawing seem to represent motion as a progression of the

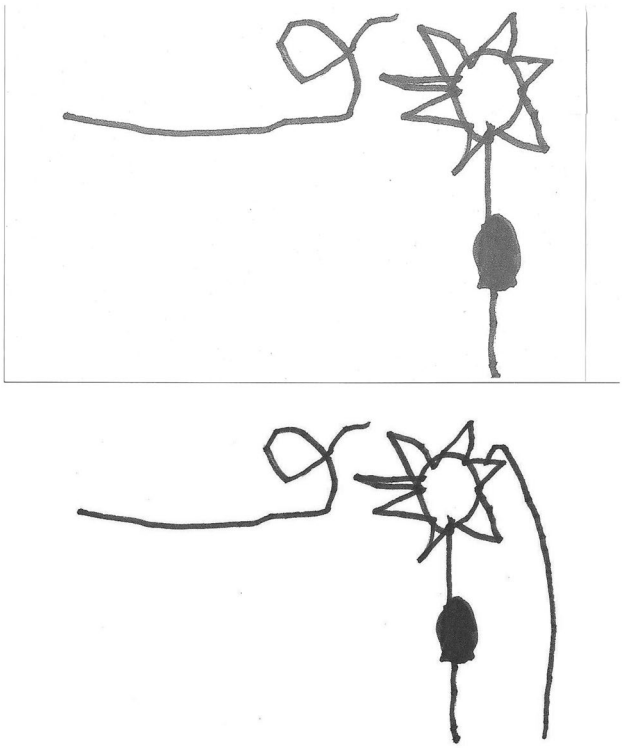

Fig. 2 Charlie's drawing of wind entering the pinwheel and the edit showing wind exiting the pinwheel

Fig. 3 Cody and Ginger explore the teeter-totter

same marble moving through the tube. After exploring the teeter-totter with balls and marbles, and then drawing again, Ginger's representations of the teeter-totter appear to be of a side, front, and top view, as seen in Fig. 4 in the two-bottom drawings on the left those to the right. In addition to motion, Ginger was learning about perspective. *Drawing to Learn* helped Ginger slow down the active exploration of the teeter-totter to represent her observations and changes in her thinking.

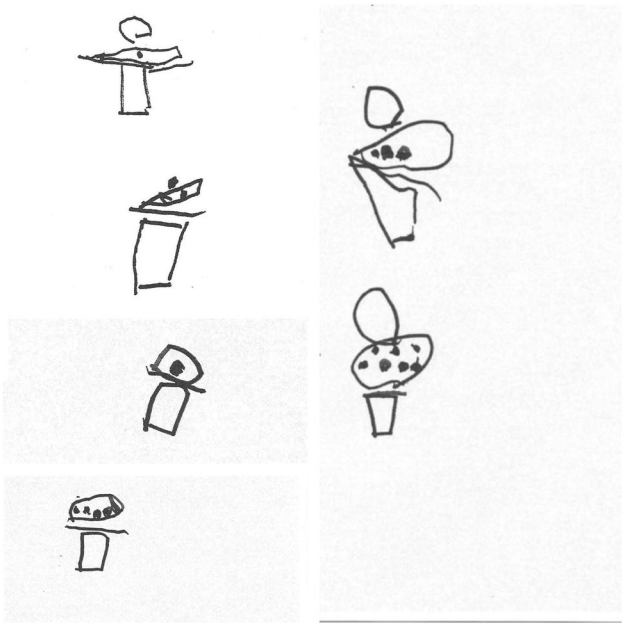

Fig. 4 Ginger's teeter totter drawings show her progression of thinking about the ball in a stable state and her ideas about its movement in a tilted object

Drawing to Learn How Something Functions

The pendulum project consisted of a pendulum hanging from the ceiling to knock down bowling pins. The participating preservice teacher's observations recognized Warren's (4 year) interest in the directional change of the pendulum after its impact with the pins. She invited him to draw his experience to clarify his thinking. When revisiting his drawings, Warren stated that, "You throw the ball this way, and then it hits down the bowling pins, and then it goes that way." Drawing provided another language for representing and explaining.

Warren's drawing depicts a set of symbols for the direction of the pendulum, the pendulum, and the pins (Fig. 5). A vertical line ending with a circle references the hanging pendulum. Five rectangles representing the pins are topped by smaller rectangles, possibly to determine the position of each in space. Arrow symbols represent what he stated as the directional force of movement, depicting what is not visibly tangible yet mentally perceived. The drawing is a mediator for his understanding. It is the language he used to tell the viewer, his preservice teacher, that a force (arrow) can move the pendulum from left to right, can knock down the bowling pins, and then move the pendulum from right to left.

The teaching team reflected deeply on the photos of Warren with the pendulum as they carefully revisited his drawing to interpret his possible intentions with this symbol system. He could use the arrow to simultaneously show change in direction and describe the force on more than one object.

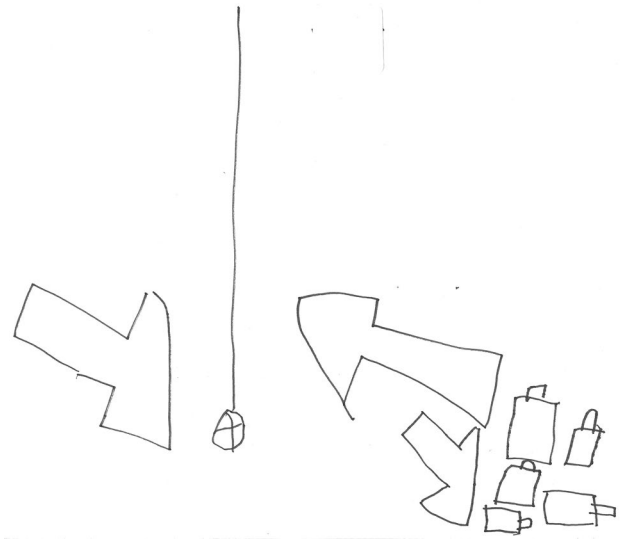

Fig. 5 Warren's drawing of the pendulum's direction of motion

Fig. 6 Connor's sensing of the force of the pendulum

The varied directions of the bowling pins reveals an understanding of the effect of the force from the left.

Drawing to Revisit and Reflect Understanding

Connor's drawing (Fig. 6) shows the fluid and unpredictable motions of the pendulum, reflecting the results of different forces applied to launch it, smooth, long swings after gentle pushes and, long twisting swings after more forceful pushes. Connor drew as he revisited videos of his group playing with the pendulum, which encouraged serious thinking about drawing in relation to his findings. This revisiting gave him a lot of time to think about and use drawing to represent new understanding about the motions he observed.

Hailey's (preservice teacher) observation record (Table 2) illustrates the way that she used drawing and conversation with children to revisit and articulate their experiences and thinking about the teeter totter. It includes the questions she used to guide the experience, the children's dialogue, and her interpretive thinking following the observation. Cyndi incorporates her mentoring notes into this COI form to scaffold the preservice teacher's process with children. The conversation illustrates the way the children are able to describe their thinking in relation to drawings.

Using Copies of Drawings to Revisit and Focus Thinking

Drawings provided common artifacts for teachers to analyze together to assess change in children's thinking and share their "teacher" theories about the drawings as foundation for planning further learning experiences. When misconceptions were observed, drawing sessions were encouraged to extend children's theories. To provide differentiation between the new developments in thinking and the child's original hypothesis, subsequent ideas were added to a drawing "copy" with a different color ink. This helped children and teachers develop awareness about observed phenomena and make comparisons between the observations represented on paper and the children's actions during play.

Lizzy's (4 year) experience at the water table represents this strategy. Her initial drawing, in black ink (Fig. 7), represents the setting around the water table and some imaginal thinking, stars and map that did not exist in the room. The detailed tubes appear to include marks as symbols of the water inside, but teachers wanted to be sure, especially since children were thinking about the motion of the water. On a copy of her drawing Lizzy used a colored marker to show new thinking in response to the question, "How does the water move?" She stated that her purple marks represent the water in the tubes, and herself, which she perceives as the force for moving the water (Fig. 7).

Drawing Supports Re-representation in Another Medium

Children's drawings helped teachers plan in relation to each child's thinking, like supporting Hayden (5 year) to represent ideas about the pendulum in clay. Clay had been the focus of another extensive study. Hayden hadn't shown interest in clay until his experience with the pendulum compelled him to use clay to process his thinking. He first drew the pendulum on an angle on his paper, which seemed to represent the movement of the bottom of the pendulum to the right. He then watched a video of his experience with the pendulum's movement before fashioning the pendulum from clay. Teachers intentionally brought his drawing to the clay table for him to revisit previous thinking about the pendulum and its movement as he transformed thinking from his drawing into a clay product. Hayden worked thoughtfully to connect the clay ball to a string. When his clay model dried, he

Table 2 Revisiting teeter totter drawings with children

Cycle of Inquiry Observation record	Part 1 of 3	**OR**

Tag: Green comments provided to preservice students by C. McAuliffe **Date of observation: 10/31** **Page:**

Observers: Hailey

AREA: Research Center
PARTICIPANTS:
SETUP: Teeter totter, paper and writing utensils to record data

By working with documentation of children's **actions** and **words** we focus our discussions on "evidence" and de-privatize our discussions about children's thinking. (Reggio Study Group) ***When using video note the start / end time frames of clip you reference in name column.***

NAMES: Distinguish teacher's names from children's.	**DESCRIPTION:** **ACTIONS** **(what you see)** In parentheses; **WORDS** **what you hear** Not in parentheses	**MEMOS:** Raise your questions about the meanings of children's actions and words. Why did they do / say this? What do they know?
Hailey	Do you guys remember playing with the teeter totter the other day? Remember to use open-ended questions.	Hoping children would remember. We had pictures just in case.
All	Yes	Yay they remembered ☺
Hailey	I would like you ~~guys~~ to draw me a picture of what you know about the teeter totter and what it does.	Hopefully we can get some information about what the children know.
Cameron	I balanced the ball.	Glad that he used the word balance. He understood what it meant. Your theory is that if he uses the word he understands. Is this true?
Aran	We were putting the balls through the tubes.	Aran knows that the ball would fall out if the board was not balanced but did not verbalize about balance. Having the board level/flat is equal to balance Your theory about what he thinks
Jack	When you (referring to Hailey) and me held it flat, it stayed still.	
Hailey	What were we doing with the teeter totter?	Tried to get the balance concept going again. Don't try to push an idea. Drawing is a chance for you to see what they're thinking. Be open.
Jack	We were moving the marble with the teeter totter and moving it. You were on that side and I was on this side and it would stay straight (the board) and it (the marble) stayed and did not move.	Jack knows that keeping the board still would keep the ball still. Straight and not moving = balance. ☺
Hailey	I gave the children time [☺ Time is important] to work on their illustrations. After we asked them what they had drawn … … … … … … … Tell me about your picture.	Hoping we could get more info.
Aran	This is the carpet, this is the teeter totter, I was tilting (tilting motion with both hands) it, and the marble was moving (doing a hand motion like a downward slope) and coming out.	Aran was trying to balance the ball by moving the board quickly and let the ball fall out. This is what he did in the last lesson. What is your theory about why he moved his hand in a downward slope?
Hailey	Aran, when you moved the teeter totter, what happened to the marble?	
Aran	It went down	He meant it came out. But think about what he just did with his hands.
Hailey	What do you know about what was happening when you were using the teeter totter? (Asking Wes)	
Wes	The marble went faster than the big ball.	Wonder if he understood that the marble was heavier than the big ball? How do you know it is heavier?
Hailey	What also happened?	How come the ball fell out? How can we get the ball to stay in the tube? Who is thinking this? Be specific?
Wes	It fell out of the tube, like four spaces (points to carpet and shows how the ball went) like right here … … … I am just writing the instructions.	

Fig. 7 Using a different color marker to show edits to thinking in drawings

was able to push and observe it move just like the original pendulum (Fig. 8).

Drawing as a Planning Tool

In the pendulum explorations, each child had an idea for arranging the pins. Warren set them in a cluster and when none fell, he returned to setting them in a line. His actions reveal a possible perception that the pin arrangement is an important factor. This observation led Cyndi to facilitate learning about other factors (aim, force, location) in relation to the pendulum. She invited children to draw an arrangement of the pins as a plan for setting them in preparation for launching the pendulum. Children represented the location, arrangement, and number of fallen pins, sorting out the factors influencing the knocking down of pins. Drawing and sharing ideas inhibited earlier random impulses to push the pendulum and introduced the idea of drawing as a planning tool.

By the end of the semester *Drawing to Learn* was embedded in the classroom culture. Drawing among small learning groups produced discussions that developed cohesion and common understanding. Drawings organized thinking and planning for construction processes, and bridged understanding across explorations and media.

For example, a drawing plan for a three-dimensional wire skyscraper included walls of the same size. These drawings became blueprints for measuring when building. Brody (preservice teacher) modeled ways to match wire to the lines in the drawing as a way to measure for construction purposes (Fig. 9).

Another planning opportunity was to use drawing to formulate ideas about the relationships of a long tube and a shorter tube that children wanted to combine to build a tree in the classroom. Before getting out the saw, they also used their drawings as a communication tool, listing all the tools they would need and articulating procedural instructions.

Fig. 8 Hayden uses his drawing as a plan for constructing a 3D pendulum out of clay

Fig. 9 Preservice teacher models how to use drawing to measure wire needed for construction

Ginger represented many components in her plan for the tree trunk (Fig. 10). According to Ginger, she includes the materials (two tubes, one inside the other) and the tools needed (ruler and saw). She also said that she represented one tube a second time, to show its entire length and used a thick line to show where to cut it so it could fit inside the other tube. Three arrows pointing upward indicate the motion of the saw when cutting the tube. Another arrow pointing to the left shows the direction of her plan for inserting one tube inside the other.

Discussion and Conclusions

This case study sheds light on the participating teachers' insights that can help preschool teachers use *Drawing to Learn* protocols though it cannot be generalized due to the limited sample size and context. Strategies for planning, interpreting, and facilitating the *Drawing to Learn* process are highlighted here.

A systematic approach for observing and planning develops a shared language for communication among teachers. Use the COI to discipline teachers and preservice teachers to think and grow through the same structural thinking processes with consistency (Broderick and Hong 2011). Document during drawing experiences to notice what is not discussed, the order of the children's thinking processes (Broderick and Hong 2011; Kolbe 2005), like the way children drew the wind before and after their outdoor experiences with the pendulum. Engage children in conversations about their drawings to elicit and clarify their ideas about their representations.

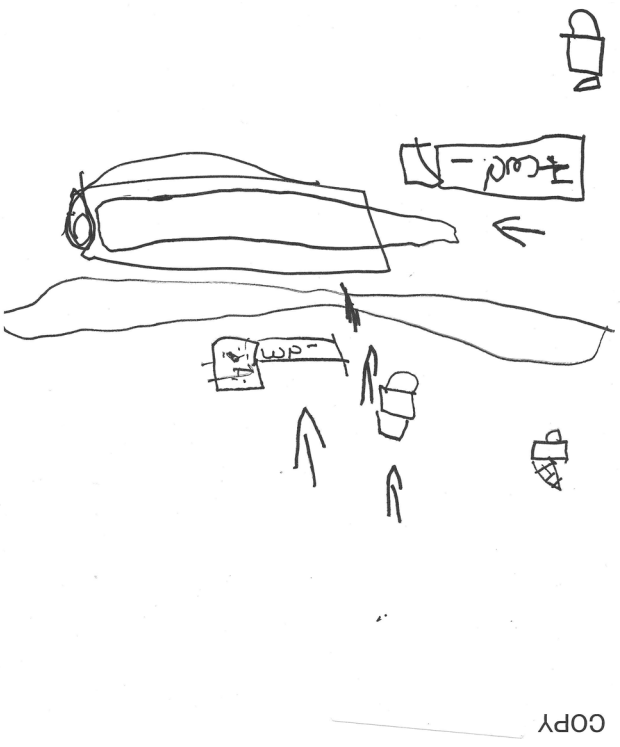

Fig. 10 Ginger's plan to build a classroom tree

Create a culture of drawing in the preschool classroom that gradually emphasizes and nurtures observational drawing processes (Anning 1999; Kolbe 2005). Then adopt a draw-experience-draw protocol for consistency of approach where edits or new drawings indicate reflection and new understanding of phenomena (Forman et al. 1998). Keep drawings throughout the year to make children's progress visible, from scribbles, to conceptual representations, to planning, and inclusion of text (Isbell and Raines 2003).

Use drawing to help children slow down and articulate thinking that might otherwise be missed. Invite several children to create their own drawing of a phenomenon to encourage individualized in-depth thinking without overshadowing others' thinking, similar to children's processes for drawing plans to set up pins in preparation for launching their pendulum. Children can show more of their thinking in drawing than they can articulate in words (Anning 1999; Edwards et al. 1998, 2012; Kolbe 2005).

Educators can help children develop perspective taking skills by sharing different points of view in drawings and related conversations with peers (Anning 1999; Kolbe 2005). Children can represent abstract science concepts such as motion (Ainsworth et al. 2011), and use drawing to plan for construction and solving problems, such as where to cut wood in order for a piece to fit. Drawing assists in the development of observation, prediction, and conclusion skills. Children can represent mathematical thinking, like the relationship of parts to whole in the tree measurement and construction, and invented writing emerged through deliberations about drawings. By encouraging children to use drawings over time, children can intentionally use drawing in independent endeavors, solving problems that are integral to daily play and exploring processes like those cited in this study of motion.

Their *Drawing to Learn* study led to many questions particularly related to language and literacy development, like its effects on vocabulary. Could further study include keeping track of verbal capabilities in relation to children's drawing to discover how verbal skills correlate to details in drawings? Do children with speech delays draw with more or less detail when compared to typically developing peers? Can research determine the frequency of drawing changes in relation to a child's verbal tendencies or abilities? Do children with speech delays draw more, or less often? Gender could be tracked in relation to details, drawing frequency, and interest or ability to include emergent text. Who draws more, those with technical drawing skills or those who are

interested in the project focus? These questions are worthy of future study.

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