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Between the Red and Yellow Windows: A Fine-Grained Focus on Supporting Children's Spatial Thinking During Play

Karri Hedge[1] and Caroline Cohrssen[1]

Abstract

With the decline in Australian school children's mathematics skills, the spotlight is shining on the quality of early childhood mathematics teaching and learning in the preschool years. Spatial thinking—which includes spatial orientation and spatial visualization—contributes to early mathematical thinking and children have the capacity to demonstrate abstract spatial concepts both verbally and nonverbally, yet may be overlooked in practice. This qualitative study analyses selected excerpts from a corpus of video data of 4- and 5-year-old children participating in a 6-week project designed to support children's spatial thinking skills. A conversation analytic approach is taken to demonstrate children's spatial thinking made visible through gesture and action. Showing how this is done by analyzing the verbal and nonverbal elements of back-and-forth interactions, with explicit attention to the "how" of intentional teaching, reveals the interrelationship between learning and teaching. In addition, the critical role played by in-the-moment formative assessment of children's demonstrated spatial thinking and the maximization of opportunities for teachers to support concept acquisition are emphasized. The analysis of authentic interactions thus serves as a provocation for professional learning.

Keywords

early childhood mathematics, spatial thinking, formative assessment, intentional teaching, play-based learning

Introduction

In line with international early childhood education priorities, the quality of Australian early learning occurring in the context of informal, play-based curricula has been in the spotlight for some time. This focus is evidenced at national policy level through the National Quality Framework (Australian Children's Education & Care Quality Authority, 2011), which mandates the implementation of the Early Years Learning Framework (Department of Education, Employment and Workplace Relations [DEEWR], 2009). Streamlining transitions from the home learning environment through early childhood education and care, into formal school education and beyond, is also being addressed at State and Territory level (cf. Department of Education, 2016; Department of Education and Training, 2016). Consequently, there is increasing focus on the teaching and learning of mathematics in early childhood education and care settings. This coincides with evidence that Australian learners' mathematics performance on the Trends in International Mathematics and Science Study (TIMSS), undertaken in Year 4 and Year 8 of school, is declining (Thomson, Wernert, O'Grady, & Rodrigues, 2017).

The focus of this article is to illustrate how spatial thinking skills, as one element of mathematical thinking, were supported during play. The article presents short transcripts of video data gathered during a 6-week project that focused on a topic of great interest to children at the end of their final preschool year: transitioning to formal school education (Cohrssen, de Quadros-Wander, Page, & Klarin, 2017). In these short episodes, it is demonstrated how, through joining in with children's play, their teacher encouraged and facilitated back and forth conversations that modeled and encouraged directional and locational language. This provided opportunities for children to engage in spatial visualization and to learn and rehearse relevant vocabulary. Joining in with the children's play also created authentic opportunities for the teacher to observe and assess children's competencies with regard to this oft-overlooked strand of mathematics. It emerged that children's communication of spatial thinking may be nonverbal, highlighting the importance of teachers being alert to

[1]Melbourne Graduate School of Education, The University of Melbourne, Victoria, Australia

Corresponding Author:
Caroline Cohrssen, Melbourne Graduate School of Education, The University of Melbourne, 4/100 Leicester Street, Melbourne, Victoria 3010, Australia.
Email: ccoh@unimelb.edu.au

such instances as indications of understanding as well as opportunities to model new vocabulary.

Responsive Teaching of Mathematics in Early Childhood

Children bring "mathematical power" when they start school (Perry & Dockett, 2005), fuelled by knowledge they have acquired over several years of active playful engagement with the world around them. In the context of formal early childhood education, the role of the early childhood professional is to recognize, support consolidation, and extend mathematical thinking during play.

At times, opportunities to mathematize play-based activities may be missed—for example, an educator may observe a child sharing a large lump of playdough equally between four friends and comment on the kindness of the child sharing equally without recognizing the opportunity to mathematize the child's behavior by talking about four quarters making one whole. Furthermore, children may use gesture rather than spoken words to demonstrate understanding. Here too, educators need to be alert to nonverbal communication to support learning by narrating the child's gesture and in this way, modeling appropriate language.

The Importance of Teacher Pedagogical Content Knowledge

To recognize and respond appropriately to such learning opportunities, it is important for early childhood educators to possess mathematics content knowledge and knowledge of play-based pedagogical strategies. They also require clinical judgment skills that equip them to observe and evaluate the impact of their teaching practice on children's learning (McLean Davies et al., 2012). Mathematics content knowledge equips early childhood educators to recognize evidence of mathematical thinking in the things that children make, say, and do. Knowledge of developmentally appropriate pedagogical strategies equips early childhood practitioners to facilitate the consolidation and gradual extension of children's knowledge—playfully. Pedagogical content knowledge acquisition begins during initial teacher education, but the provision of targeted professional learning is also important as this has been found to increase teacher confidence (Cohrssen, Church, & Tayler, 2016). Assessing what children know and enhancing their learning by sensitively extending their knowledge require both understanding of the child's learning trajectory (Clements & Sarama, 2014) and responsiveness to the diverse competencies demonstrated by individual children. Responsiveness "enables educators to respectfully enter children's play and ongoing projects, stimulate their thinking and enrich their learning" (Department of Education, Employment and Workplace Relations, 2009, p. 15).

Assessment for Learning

Informal curricula in Australian early childhood education and care settings are underpinned by the Early Years Planning Cycle (EYLF; Department of Education and Training, 2016). Early childhood educators observe and analyze children's behavior to assess what the child already knows. Contingent learning experiences are then planned to provide opportunities for children's existing skills to be rehearsed and consolidated, or extended. Finally, educators reflect on the extent to which the intended learning objectives were achieved by observing the child's participation in the experience and beyond. The cycle continues when educators plan new experiences (or refine the original experience) based on these reflections.

It stands to reason that for educators to recognize mathematical thinking as it emerges in children's play and to respond to such opportunities as they arise, educators need to possess mathematics content knowledge—particularly because children's demonstrations of mathematical thinking are frequently embodied or gestured rather than verbal. A focus on spatial skills may be overlooked, as early childhood teachers are likely to prioritize counting and shape naming when planning the mathematics-related components of their preschool curricula, perhaps because number and object counting, and shape-naming, are aspects of early childhood mathematics in which teachers feel most confident.

The Importance of Spatial Skills

Spatial skills have "evolutionary and adaptive significance" for mobile organisms needing to navigate their worlds to survive; they provide necessary strategies for a range of complex cognitive processes such as reasoning and problem solving (Newcombe & Frick, 2010, p. 102). Clements and Sarama (2014) theorize that core competencies can be grouped into two sets of abilities: "spatial orientation"—understanding one's position in space and the ability to move through space (p. 124) and "imagery and spatial visualisation"—cognitive processes that enable us to generate and manipulate mental images (p. 127). Pollman (2010) includes spatial literacy (specifying a range of operations that are enacted upon visualized objects), representation, and reasoning skills as elements of this construct.

Cross-cultural research indicates that core geometric knowledge is a universal human capability (Clements & Sarama, 2011) and a focus on spatial thinking in particular "allows mathematics to become a more visual endeavour and connects with what 'real' mathematicians do when they are exploring patterns in the world and making discoveries" (Ontario Ministry of Education, 2014). Spatial intelligence appears to be malleable: Learning generalizes to new tasks and is sustained over time (Newcombe & Frick, 2010; Uttal, Miller, & Newcombe, 2013), lending support to the importance of children being systematically provided with opportunities to rehearse spatial skills in ordinary playful contexts.

The Development of Children's Spatial Skills

Teaching and learning in the context of informal early childhood curricula are multimodal processes as children engage in play with a wide range of resources. When children use their hands to manipulate an object, two haptic subsystems are engaged. A sensory subsystem with cutaneous, thermal, and kinaesthetic sensors (for planar variation), and a motor subsystem that involves prehensile and manipulative abilities, come into play (Lederman & Klatzky, 1987). These interdependent subsystems enable haptic assessment of the properties of an object and haptic categorization of the assessed properties of the object. By manipulating the object, children receive sensori-motor feedback from their hand movements and are able to control "the pace, speed, direction, and magnitude of the exploration" (Chan & Black, 2006, p. 4). Research to determine precisely *how* haptic stimulation influences preschool-aged children's learning is necessary (Clements, 1999; Ginsburg & Golbeck, 2004; Minogue & Jones, 2006). Nonetheless, this also supports the argument that children should be provided with opportunities to manipulate, observe, and discuss the characteristics and position of objects in their environment, as it is foundational to spatial visualization and spatial thinking. The teacher's role is to move in and out of the play, drawing attention to the attributes of the shape, or modeling directional and locational language, as appropriate.

Maximizing Opportunities to Focus Explicitly on Spatial Thinking

Environmental input contributes to the development of spatial skills in children (Clarke, 2004; Ehrlich, Levine, & Goldin-Meadow, 2006; Uttal, Meadow, et al., 2013). Children's spatial structuring abilities support emergent number sense, including part–whole concepts and the ability to subitise (Bobis, 2008). Providing children with multiple opportunities to recognize the "pattern" of two, three, or five objects' arrangement facilitates a shift from using concrete objects to see, hold, and move, to conceptual subitising. This in turn supports skills such as mental arithmetic and problem solving once children have mastered the two-ness of two, the three-ness of three, and the five-ness of five.

In typical early childhood programs, much shape naming occurs at the collage table, at the easel, and in the block corner. However, teachers support the development of robust, dynamic, and flexible concept images when they extend child learning beyond simply naming prototypical shapes by ensuring that children explore a range of shapes (Clements & Sarama, 2011; Newcombe & Frick, 2010), particularly when encouraging conversations about the attributes of shapes to compare, sort, and classify them. Puzzle-playing between the ages of 26 months and 46 months predicts performance on spatial transformation tasks at 54 months, especially for boys (Levine, Ratliff, Huttenlocher, & Cannon, 2012). Four- and 5-year-old children used maps effectively to solve a maze even when the maps were scaled up or down, or made more abstract (Jirout & Newcombe, 2014). Storytelling has also been investigated as a means of contextualizing mathematics learning for kindergarten children in multicultural urban settings. Findings indicated that open-ended play activities without narrative contextualization appeared to be sufficient to support boys' acquisition of spatial thinking skills, whereas girls appeared to benefit from an intervention combining storytelling with geometry designed to promote spatial thinking skills (Casey, Erkut, Ceder, & Young, 2008).

So, how do early childhood teachers set about supporting children's spatial thinking skills and model the associated language?

The Teacher's Role in Developing Children's Spatial Skills

Children demonstrate functional thinking—generalizing about relationships between quantities, representing these relationships in various ways, and using reasoning skills to predict what will come next—yet few early childhood teachers recognize patterning behaviors and conversations as opportunities to mathematize the behaviors (Highfield & Mulligan, 2007). This could be achieved by drawing children's attention to spatial relationships and supporting the application or extension of the underpinning concepts to the same activity within which the thinking has emerged, or to other activities in which the child is interested. This process supports children's ability to abstract and generalize ideas, promoting mathematical learning (Mulligan, Mitchelmore, Kemp, Marston, & Highfield, 2008).

Children spontaneously represent spatial relationships through patterning in multimodal ways (whether spatial structure patterns or repeating patterns), including the use of concrete objects, manipulation of virtual objects on touch screens, drawing, block constructions, collage activities, and dance (Deans & Cohrssen, 2016). When early childhood teachers set the stage by intentionally creating opportunities for child-initiated interactions in the context of playful learning experiences that will create opportunities for children to share their ideas and demonstrate their spatial thinking, authentic assessment of what the child already knows and what the child is ready to explore next becomes possible. This gets to the heart of intentional teaching: early childhood teachers using evidence of child capabilities to inform learning objectives that consolidate and extend learning while following children's interests in a play-based curriculum.

Indeed, one important interactional strategy to create such authentic assessment opportunities in the context of teacher–child interactions during play is the use of purposeful and protracted pauses to enable children to process information at their own pace and to share their ideas. Cohrssen, Church and Tayler (2014a, 2014b) compare mathematical interactions during conversations characterized by protracted pauses. Interactions in which pauses were used by teachers allowed children to think, develop hypotheses, and formulate answers in their own words resulted in interactions that were balanced between teacher and child interlocutors. On the contrary, when pauses were not present, the talk was dominated by the teacher, providing few opportunities for the teacher to make evidence-based assessments of children's knowledge. The intentional incorporation of protracted pauses will be observed in the data we present.

Methodology and Method

At times, children convey meaning through gesture without articulating the meaning in speech—either when no verbal utterances are made at all, or, for example, when their gestures indicate movement while their speech focuses on the attributes of a shape (Ehrlich et al., 2006). Indeed, Ehrlich et al. (2006) report that children who performed better on transformation tasks were found to use gesture rather than words to demonstrate movement. To understand what children know by observing their talk and gesture, children and their teacher were video-recorded during the morning program on Mondays and Fridays over a 6-week period and the video transcribed to reflect talk and gesture. We chose an analytic approach to the data which allows us to see how spatial thinking may be embodied; how the choreography of talk and gesture reveals children's knowledge (Goodwin, 2014).

Ethics approval was obtained for the project (for a detailed description of the project, see Cohrssen et al., 2017). Nineteen boys and girls aged between 4 years 2 months and 5 years 10 months participated in the project. Informed consent was obtained from the families of each participating child, the center director, and the teacher. Ongoing assent was obtained from children. Pseudonyms have been used in the data presented below to protect the identities of children and the teacher.

Conversation Analysis (CA)

CA is both methodology and method. It allows the researcher to investigate not only children's knowledge in interaction but also how this knowledge is elicited, used in problem solving, and extended by the teacher (Cohrssen et al., 2016), As a methodology, CA avoids a priori categorization of practices in favor of close observation of how practices unfold in typical, naturalistic settings (Sidnell, 2016). In other words, CA allows us to see what children actually do and say, rather than making assumptions about aspects of learning-in-interaction that may be significant. Video recordings of interactions allow repeated analysis of teaching and learning. Close transcription of these interactions allows the researcher to engage in unmotivated observation (Schegloff, 1996) of the ways in which children attend to tasks, objects, concepts, other children, and teachers in the learning environment, and—importantly—how teachers respond.

Video observations are transcribed with as much detail as is possible in a written format, capturing overlaps, emphasis (e.g., pitch variation and volume), pauses, both within and between turns, and embodied actions where possible (see the appendix for conventions used in this article). The video itself remains the preliminary data, with analysts reviewing the observations many times over to see what is being done, providing insights into how children and teachers collaboratively achieve concept development. Moreover, CA is used productively across education settings (e.g., Gardner, 2013), detailing trajectories of interaction in which children and teachers build on prior turns beyond Initiation-Response-Evaluation sequences (see Lee, 2007; Macbeth, 2003).

The application of a conversation analytic approach enables us to identify how children provide evidence of their spatial thinking, and how this evidence is seen or responded to by teachers. Close analysis of the embodied expression of children's spatial visualization provides insights for assessment and learning that teachers may not notice as they engage in real-time interactions in the context of a busy preschool classroom. Furthermore, the application of CA in this research allows us to illuminate the moment-by-moment work of intentional teaching. The data here provide insights into the "how" of teaching spatial visualization and orientation, and the analysis allows us to see exactly how this can be achieved.

Data

Data comprise excerpts of video-recordings of children participating in two of a range of learning experiences delivered over 6 consecutive weeks at a Melbourne kindergarten. The project was designed to provide 4- and 5-year-old children with multiple opportunities for spatial thinking—and *demonstrations* of spatial thinking—in multimodal ways, rehearsing basic ideas until concepts had been mastered (Bruner, 1965). Learning experiences in the broader project were connected by a focus on starting school, as all participating children were at the end of the final year prior to transitioning to school. As such, children were regarded as experts in the transition process and learning experiences provided opportunities for them to share their expertise (such as knowledge of the layout of their school, of the route from home to school and so on). Each learning experience, however, was also designed to provide opportunities for children to engage in and represent spatial thinking.

In line with a conversation analytic approach, the data and the analysis of the data are presented below. Two excerpts have been selected because they are examples of learning experiences frequently offered in preschool programs: a shapes activity (Excerpt 1) and block play (Excerpt 2). Here, we highlight how the teacher maximized opportunities during the play for the children to consolidate and extend spatial thinking skills.

Excerpt 1: "It's Nearly There"

The first excerpt focuses on the challenging concept of spatial orientation. While the learning experience had been set up on a lightbox, it could be enacted on any flat surface. It had been set up for some time in the room as a symmetry game and the children in the room were familiar with the aims of the game. There is a line down the center of the lightbox and two girls have created a symmetrical pattern using colored, square and triangular tiles taking turns to set out shapes, one by one, the second child creating a mirror image of the pattern of shapes created by the first child.

The teacher has approached to admire their work and asks the children to describe what they have created. There is some talk of diamonds within the pattern and properties of the children's clothing that are symmetrical ("the pockets are the same") or not quite symmetrical ("because there is a tag on this side"). Through these conversations, the children demonstrate their emerging understanding of the concept of symmetry, which has been a topic of discussion during the spatial thinking project. The teacher then asks Keira and Amanda to put their images on the lightbox—full length photographs of each child measuring about 10 cm are routinely used by the children to identify their work. We join the conversation here with the teacher asking Amanda if she can put her image in a symmetrical position to Keira's image:

7	TEA	now. (1.2) Keira why don't you put yours in- >in a<
8		different spot somewhere on the: (02) lightbox?
9		(0.8)
10	TEA :	<somewhere> on one of the shapes¿(.) on top of one of
11		the shapes,
12	AMA:	I know! (0.2) sh[e can] put it on <that pa::r:t>.
13	TEA:	[and-]
14	KEI:	ye:ah.=
15	TEA:	= >and then< Amanda you see if you can put your pie:ce
16		(0.9) so that [it is syme-] [so that] it is=
17	KEI:	[he:y look!] [how my-](0.2)
18	TEA:	[=symmetrical]

Throughout this extended sequence, each of the children—with additional contributions from Jessie, who joins the discussion—makes a series of embodied responses to the teacher's questions, by moving the image to cover two different blocks or to reorient the image.

During this discussion, the teacher creates opportunities at each point of question or prompt for the children, providing long pauses for them to identify the spatial relationship between the objects (e.g., lines 26, 37). These extended pauses are productive in supporting concept development: Each subsequent response from the children provides a new formulation, as they appear to attempt to visualize and represent the correctly mirrored relationship between the objects on each side of the center line.

21	TEA:	so Amanda you see where Keira's put hers¿ and you see
22		if you can put yours in the same- (0.8) so it's
23		symmetrical.
24	*KEI:*	*(2.9) puts her photograph spanning two blocks parallel with Amanda's picture on the other side of the centre line*
25	TEA:	is that it?
26		(2.2)
27	KEI:	yea:h¿
28	LU?:	[yeah].
29	TEA:	[but]have a look he:re? (0.3) I'm just gonna throw a
30		little (0.7) spanner in the works here¿ have a look
31		he:re and see that Keira's head (0.7) is actually
32		close to the li:ne (0.5) but her feet are pointing
33		towards the other side.
34		(0.5)
35	TEA:	now if you were to look at that o:ne (1.2) Amanda's
36		head (0.6) should be where.
37	TEA:	(2.2)
38	AMA:	this side.
39	JES:	that si:de.
40	TEA:	yea:h >look it<- (0.5) Jessie's figured it out.
41		(1.9)
42	JES:	°so her head's [(inaudible)]°
43	TEA:	[what's] making it a little bit
44		trickier is these green shapes.
45		(1.2)

46	TEA:	if we move this green shape (0.4) if I just move th:is
47		one and put that the:re¿ (0.7) this might help you
48		figure it out.=coz now: have a look. (1.1) both these
49		these green shapes are pointing in the same way?
50		(1.0)
51	TEA:	Keira we'll put yours back where you had it befo:re
52		(0.8) so look¿ (0.6) her head is towards the li:ne?
53		(0.3) it's >facing towards the line< and her feet are
54		pushing off the table that way.
55		(1.7)
56	TEA:	so let's stand back (.) let (0.2) Amanda have a look¿ (0.4)
57	TEA:	Amanda come over here to the middle?
58		(1.6)
59	TEA:	come and stand in the middle here¿= Lucy move back so
60		we can let Amanda have a look.
61	AMA:	(2.1) Amanda looks at Keira's placement on the opposite squares then carefully lines her image on parallel squares
62	TEA:	see how Keira is¿
63		(2.7)
64	TEA:	is that right?
65	AMA:	mmmm:.
66	TEA:	it's NEArly there. (0.4) it's nearly there it's no:t
67		quite there.

In each instance, Amanda repeatedly places her photograph in a parallel position in relation to Keira's photograph on two squares, rather than a symmetrical position. The teacher does not correct the attempt as error, but rather prompts the children to reflect on the spatial orientation of, and relationship between, the objects. The teacher prompts the children to revisit their embodied response by asking "is that it?" (line 25), "is that right?" (line 64). But more important is the sequential position of these questions: They occur after an extended pause, providing the children with an opportunity to revise or self-repair their action. These prompts provided by the teacher are not only carefully placed in the unfolding activity, but are characterized by a warm, smiling, encouraging tone of voice, such as "it's nearly there; it's not quite there" (lines 66-67). With the teacher's support, paying careful attention to landmarks (the edge of the lightbox and the line down the center), the children achieve success and are praised for their perseverance.

Throughout this discussion, the teacher purposefully uses locational and directional language, stating, "facing towards the line" (line 53) and "pushing off the table" (line 540. These support the children's spatial visualization, the language itself providing the referent for the spatial orientation (Clements & Sarama, 2014). This is further reinforced by repetition, because in these sequences the teacher reformulates the question or summary of concept while tapping the relevant square for each deictic term. The gesture and repetition reinforce the concept and provide additional cues.

89	TEA:	look. (0.4) Keira is on this ↑one (0.6) what's the-
90		what's the oppositeof that one. *on 'this' and 'that' teacher touches block closest to centre*
91		(0.8)
92	TEA:	what's the opposite of this block.

The most compelling feature of this excerpt is that the teacher does not provide the answer for the children, but rather identifies features of the orientation as cues. Each error affords opportunities for assessment-in-action and iterative demonstrations of children's spatial thinking, specifically the methods the children are using to resolve spatial orientation. The cues themselves build on concepts mastered by the children (such as "facing" and "pointing toward"). This intentional teaching unfolds over 3 min of carefully attuned talk-in-interaction, creating opportunities for the children to think about spatial relationships between objects, during which time the children arrive at the answer (i.e., placing their images in a symmetrical position).

Excerpt 2: "Humphrey Highpants"

In the second excerpt, we join three children (Humphrey, Christian and Gary) and their teacher. The children had built a block construction of the new school that all three would be attending at the start of the following year. The teacher had planned to join in with the play, taking on the role of a furniture delivery person and thus had several drawings of objects to be delivered such as a computer, a box of toys, and some books. The teacher's objective was for the children to place the objects in positions that made possible an assessment of accurate understanding of the operational spatial word in the instruction. However, the learning experience did not go as planned: The children demonstrated high levels of excitement and the focus of their attention was not always on the teacher. This is evidenced through frequent examples of overlapping speech (indicated by the use of square brackets), such as at lines 4 and 5, where Gary and Chris are engaged in a parallel conversation. The teacher, speaking to Humphrey says "I have a delivery 'at the same time as one of the other boys says, 'the darkest spot."

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4   GAR/CHR:   [(inaudible)  [the darkest spot-
5   TEA   :    [I havva delivery=c'n you tell wo=this=is,
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At times, children's simultaneous responses to the teacher's talk are nonverbal. At line 11, Humphrey's response to the teacher by raising his hand is enacted at the same time as the teacher utters the words, "needs to go" (at line 10).

```
5   TEA:          [I havva delivery=c'n you tell
                  wo=this=is,
6   HUM:          computer!
                  out of shot
7   GAR and CHR:  laughing, Christian makes a downwards motion
                  with his hand
8   GAR:          exaggerated laugh in response to Christian
9   TEA:          computer, well done, now this computer,
10                [needs ta go::,] on top of the::: red no=in
11                between a red an yellow window, please.
                  passes card to Humphrey
12  HUM:          [raises his right hand to represent
13                speaking on a tele-phone] then lowers hand
14                and takes the card (okay,) walks around
15                the table to a position opposite the
16                teacher
```

Indeed, while the teacher is engaged in a discussion with Humphrey about the delivery of a computer, Gary and Christian are engaged in a parallel discussion about a snake. However, while Gary and Christian's conversation may at first glance suggest that they are not paying attention to the teacher, they are using spatial language and gesture while discussing where the snake should have been placed. They are observing, manipulating, and discussing the position of the snake in relation to its spatial position and thus demonstrating their spatial thinking and using spatial language, making both available to the teacher for assessment.

Viewing these negotiations through the eye of the camera, so to speak, we are unable to observe precisely where Gary placed the snake (line 20), and so we turn now to focus on Humphrey. At line 10, the teacher asks Humphrey first to place the computer "on top of" a red (window) and then changes the instruction to put the computer "between" a red and yellow window (line 11), repeating this at line 19. Changing the position from on top of one window to between two windows of specified colors increases the complexity of the task and is in response to a broader objective of assessing children's understanding of the word "between" since an earlier observation established that this concept was challenging to some of the children in the group.

To place the computer "on top of" or "between" the red and yellow windows, the child needs to identify where these windows are on the three-dimensional construction. Next, the child needs to visualize where the computer should be in relation to the named landmarks—the windows. The teacher's rephrased request requires the child to understand the word "between," the locational concept of "between," and to comply with the teacher's request. The extent to which the child accurately enacts the request thus presents multiple opportunities for assessment of language use and conceptual understanding.

Humphrey appears to quickly establish a mental visualization of where the computer should be placed. He walks around the block construction and repeats to himself, "red and yellow window" before placing the computer first on top of the red and yellow window (line 29). Then, Humphrey removes the computer from "on top" and slides it "between" the red and yellow windows (lines 32-33), demonstrating his understanding of the revised instruction. That this self-correction was deliberate is reinforced by his action at lines 36-37 when he replaces the computer in the correct position after it falls out. Furthermore, we see no evidence that he is distracted by the parallel conversation taking place between Gary and Christian. Humphrey's immediate response (lines 12-16, 23-25), repetition of part of the instruction (line 29), and self-correction (lines 32-33) are in response to the teacher's direction (lines 10-11). Importantly, his attention to the teacher's direction is not disrupted by the laughing at lines 7-8, Gary and Christian's ongoing conversation about the snake (lines 17-18, 20 and 26-28).

```
9   TEA:   computer, well done, now this computer,
10         [needs ta go::,] on top of the::: red no=in
11         between a red an yellow window, please.
           passes card to Humphrey
12  HUM:   [raises his right hand to represent
13         speaking on a tele-phone] then lowers hand
14         and takes the card (okay,) walks around
15         the table to a position opposite the
```

16 *teacher*
17 GAR/
CHR: where's the snake?
18 CHR: *gestures towards snake*
19 TEA: [in=between, a red an yellow window. (4.0)
20 GAR: *[removes the snake and puts it in a low*
21 *position that is obscured from the camera by*
22 *the construction*
23 HUM: *walks around the table, looking at the sides*
24 *of the block construction of a school*
25 *building*
26 GAR: it's=supposed tah go hee-yah! *gesturing towards the building*
27 CHR: *watching Gary's gesture, places something*
28 GAR: giggle
29 HUM: red=an=yellow window. (3.0) *walks back around the table then places card on top of red and yellow window*
30 TEA: hello=I have a box of toy::s *holding a small laminated card in left hand, 'telephone' in right hand (.)*
31 TEA: [hello?
32 HUM: *[removes card and slides it between the red and*
33 *yellow translucent centred blocks*
34 HAR: hah=loh::::
35 TEA: [hi Gary,
36 HUGO: *[card slips out and he slides it back*
37 *between the red and yellow blocks*

Further evidence of Humphrey's understanding of the concept of "between" is evident when he calls Christian over to observe the nonsensical position of the computer—between the red and yellow windows (lines 41-42):

41 HUM: [hey, look (wheh=the) look () look where
42 the compudah went, *walks around the table, pats Christian twice on the arm*

As the delivery person's requests continue to be nonsensical, the children find it increasingly funny. However, we observe that in lines 117-119, Humphrey uses the word "through" rather than "between"—this is evidence that perhaps he has not yet fully mastered the correct positional language:

117 HUM: ↑an he tole me tah put the computer frew,
118 frew the windows.
119 CHILDREN: *silly laughing voices*

While a teacher may elect to respond in the moment to correct the word choice and the associated concept, a teacher may prefer to return to this at a later stage rather than disrupting the high level of engagement of all children playing. Indeed, this assessment activity had been planned to follow up on an earlier observation that additional opportunities should be prioritized for children to demonstrate, use and extend their understanding of positional language—in particular the word "between." This observation thus provides an opportunity for formative assessment to inform future intentional teaching. This could include learning experiences that once again address positional language or may be as light-touch as the teacher purposefully supporting Humphrey's accurate application of the word "between" during every day routines—such as suggesting Humphrey place the large shells between the small shells in his repeating pattern, or that he place the orange paint pot between the purple and green pots. The teacher could then ask the child to describe his actions: "Humphrey, remind me where we put the orange paint?"

This brief video excerpt lasted 2 min 2 s, yet presented multiple further opportunities for children to demonstrate their understanding of positional language: "on top of" (line 10) and "between" (line 19) and later in the discussion "underneath," "top" and "highest." By observing the children's response to his directions, issued while assuming a role to join in with the play, the teacher set up opportunities for authentic assessment within the context of play.

Engaging in formative assessment of mathematical thinking during play requires teacher sensitivity to children's demonstrations of emotional and academic learning (Pianta, La Paro, & Hamre, 2008). The teacher/furniture delivery person entered the children's play with the purposeful objective to assess children's understanding of positional language. It is quickly apparent that the children's energy levels are high and there are frequent instances of dramatic laughter (lines 7-8), giggles (lines 28) and later in the play, jumping up and down, and high-pitched exaggerated voices. For the duration of the play, both teacher and children pretend to be on telephones. The teacher quickly assessed the nature of the children's engagement and responded with matched affect. By persevering and joining in the children's play, despite the elevated excitement, the teacher was able to achieve the assessment objectives.

Conclusion

There is growing recognition that addressing Australian school learners' declining mathematics performance on the TIMSS starts with improving the quality of mathematics teaching and learning in the context of play-based early childhood programs: Learning is cumulative and strong foundations are necessary. Strengthening the foundations began with the roll-out of the national Early Years Learning Framework (DEEWR, 2009). Supporting early childhood teachers' recognition of mathematical thinking when it emerges, and responding to consolidate and extend this thinking through play, requires ongoing professional learning and mentoring. Children who were 3 years old in 2009 when the EYLF was first rolled out were starting school as the EYLF was becoming established in the sector. These children are now 13 years old. What has yet to be investigated is the extent to which the explicit requirement to support children's numeracy skills in the early childhood phase of education influences learners' mathematics performance on the TIMSS when they are assessed at the Year 4 and Year 8 levels in Australian schools.

The aim of this article was to focus specifically on the ways in which children demonstrate spatial thinking in verbal and nonverbal ways by providing authentic examples of learning-in-interaction. In addition, we set out to demonstrate how teachers are able to recognize and respond to evidence of spatial thinking, whilst following children's interests, when learning experiences are underpinned by purposeful learning objectives. The excerpts presented provide clear evidence of teacher–child and peer conversations that focus on demonstrations of spatial thinking while engaging in play. The nature of the children's engagement with the second learning experience differs markedly from that reflected in the first learning experience. In the first, three children are jointly attuned to one problem: the placement of the children's photographs in symmetrical positions on the tile pattern. In the second, two simultaneous conversations are taking place and the teacher is challenged at times to ensure that the children remain on task. Despite the children's engagement teetering on the edge of silliness, the teacher is still afforded opportunities to recognize and assess children's understanding of locational language and gesture when they occurred, due to his clarity of purpose.

Planning learning experiences with intentional learning objectives, informed by evidence of child competencies, create opportunities for early childhood teachers to support each child's progression along their individual learning trajectories while simultaneously responding to teachable moments as they present themselves, thus enacting differentiated teaching.

Two characteristics of the interactions reported here have implications that extend beyond the context of spatial learning to all opportunities for intentional teaching. First, it is important for the teacher to purposefully provide extended pauses after questions to allow children to formulate the concept. At times, such pauses create opportunities for children to process thoughts before initiating conversation or responding to a provocation (Cohrssen et al., 2014a, 2014b). As a result, the teacher obtains evidence of the child's current conceptual understanding. Second, child participation is not uniform: In the second excerpt provided in this article, we have seen the teacher responding to the children's hilarity and high spirits by joining in the play and building the learning objectives into the children's play script (i.e., nonsensical directions for delivering objects). The data demonstrate that the children continued to engage in, and demonstrate, spatial thinking despite ongoing jokes and one-upmanship. The teacher did not try to redirect their attention but instead intentionally pursued the teaching objectives while joining in with the children's play. It is thus apparent that quiet and calm are not essential conditions for learning. Rather, teacher content knowledge and pedagogical knowledge are essential. These equip early childhood professionals with the skills to recognize mathematical thinking when it is demonstrated, assess what they have observed, plan learning experiences that deliberately consolidate and extend children's thinking, and adapt their plans in the moment to follow children's interests and dispositions, while remaining focused on the intended learning outcomes.

Appendix

Transcription Conventions

The transcription conventions used throughout this article follow the original work of Sacks, Schegloff, and Jefferson (1974).

.	falling intonation
,	slightly rising or continuing intonation
?	rising intonation
¿	intonation that rises more than a comma but less than a question mark
:	lengthened syllable
↓	sharp fall in pitch
↑	sharp rise in pitch
[ ]	overlapping talk
( )	unintelligible stretch
(0.5)	length of silence, in tenths of a second
> <	increase in tempo, rushed stretch of talk
< >	slower tempo
° °	talk that is quieter than the surrounding talk
([ ])	description of accompanying behavior
→	points to a phenomenon of particular interest

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Author Biographies

Karri Hedge is a teacher with experience in a diverse range of early childhood settings. She has worked with a team developing curriculum resources to better connect early childhood and primary school mathematics and science learning. Her research investigates spatial aspects of mathematical teaching and learning in early childhood.

Caroline Cohrssen's research interests include mathematics teaching and learning in the years prior to formal school education. This encompasses children's diverse demonstrations of mathematical thinking in the home numeracy environment as well as in early childhood education settings, and the ways in which adults respond.