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A cultural-historical study of teacher development: how early childhood teachers meet the demands of a theoretical problem in STEM for practice change

Abstract

The longstanding literature into the professional learning of early childhood teachers brings forward the central problem of teacher development. What is not well understood is the psychological content of that development. To answer the question of what is developing, this chapter reports on the outcomes of a two-year educational experiment and a 2 year follow up interview of two teachers (digitally recorded practices, interviews, weekly reflections) engaged in STEM teaching. The major conclusion was teacher theoretical thinking was the leading activity which brought forward new conceptions of STEM practice, and the dialectical relations between child motives and teacher motivated actions resulted in a relational model of how to bring STEM concepts into play.

Keywords: early childhood; teacher development; cultural-historical; professional development;

Introduction

This chapter contributes to answering the fundamental question of what is developing for the early childhood teacher when engaged in professional practice change in support of STEM teaching. It builds on previous research (Marilyn Fleer, 2021) by focusing on how the method of engagement in research - an educational experiment - creates developmental conditions for teachers. In drawing upon cultural-historical theory, this chapter also examines previous studies and theoretical papers on teacher development in order to better understand what might be the suite of concepts needed for explaining observed early childhood teacher

development during the process of participating in an educational experiment of introducing STEM teaching into play based settings.

Because Vygotsky's system of concepts was oriented to child development, new rules for relationally bringing existing concepts together are needed. But also new concepts are needed to fill gaps. Therefore, this chapter begins with what is known about a cultural-historical conception of teacher development, followed by a study of early childhood teacher development over two years, where a new conceptual framework is introduced to give directions for explaining what might be the source and content of early childhood teacher development when engaged in STEM teaching.

A Cultural-historical Conceptualisation of Teacher Development

In order to achieve the goal of this chapter, consideration is given to bringing forward what is known about teacher development from a cultural-historical perspective. Five core ideas are discussed.

First, Barohny Eun (2008) has insightfully argued that because Vygotsky's theory was on child development, researchers studying professional development (PD) need to proceed with caution. For instance, Eun stated that, "the applications of his theories to professional development, which lies in the realm of adult learning, may seem to be stretching the scope of theoretical implications" (Eun, 2008, p. 151). It is suggested by Eun (2008) that when an analysis of the core concepts of child development is considered alongside of the foundational principle of studying the process rather than the product of development, "the process inherent in learning and development is essentially the same for adults and children alike" (Eun, 2008, p. 151). But herein lies a theoretical contradiction. Vygotsky himself wrote, "pedology is the science of the child in development and not that of the person's

development to the end of life (reproduced xv, Lev Semenovich Vygotsky, 2019; David Kellogg and Nikolai Veresov). In stating this he drew attention to the point that one cannot simply place the child and the adult on the same psychological trajectory. This key theoretical point is worthy of elaboration, and is reproduced here. Vygotsky said,

> I think that those who wish to extend pedology from the cradle to the grave, those who wish to put on the same plane of development that of the child and that development which adults go through, are, without realizing it, doing the same thing as the authors of antiquity who affirmed that the child is only a midget adult, that is to say, they deny the qualitative uniqueness of the processes of development of the child is comparison to the processes and changes that are produced in a relatively stable situation (reproduced xv, Vygotsky, 2019; Kellogg and Veresov).

Vygotsky's point is that the child is not a miniature adult, and therefore an adult's development cannot be conceptualised as though it is the full and complete form of what it means to be human simply because the person is no longer a child. If Vygotsky himself identified this as problematic, the challenge that arises for researchers is how can we study and theorise teacher development from a cultural-historical perspective when engaged in STEM teaching?

Second, researchers need a way of conceptualising development of a teacher over time. In Lev Semenovich Vygotsky's (1998) conception of periodisation he discussed how there are periods of development where crises give new conditions for development, which is evidenced when children's motive orientation changes over their life course. But Vygotsky did not go beyond children in his categorisation of motives to discuss adult development. In using the metaphor of a passport, Vygotsky (2019) said that it is "not the passport age of the

child, but his [sic] pedalogical age" (Vygotsky, 2019, p. 6) that we should be considering in understanding children's development. This is because in Vygotsky's writing, he framed development in terms of 'cultural age periods' and not 'biological age' periods. Could the idea of 'pedalogical age' as part of conceptualising adult age periods, foreground the significance of the institutional practices in which a person is located? Further, could 'cultural age period' be associated with the institution, such as the university, the apprenticeships or professional practice or work settings? Thereby in extending this idea to the development of adults, the cultural age could be tied to different institutional pathways. This opens up a conceptual point on what might be the institutional contexts that act as a source of development for adults, and additionally, what might be the motives that develop for teachers engaged in professional practice in STEM? Vygotsky offers some guidance when he said,

> I do not think that adults do not develop, but I believe that they develop according to other rules and that for this development there are other characteristics lines than those of the child; (reproduced xv, Vygotsky, 2019; Kellogg and Veresov).

But what might be these rules and characteristic lines of development for teachers? Vygotsky did not offer any suggestions on this but did introduce the concept of transformation (see Helen Grimmett, 2014; Vygotsky, 2019). Taken together, we could ask what then are the motives that emerge and change during adult transformation and what might be the institutional contexts that act as a source of teacher development?

Third, there are studies that have grappled with the problem of using cultural-historical concepts when studying teacher development. Of significance is the research of Anne Edwards, Jessica Chan and Desmond Tan (2019) who said, "we have refashioned the concept

of the social situation of development to help us with the task of understanding teachers professional learning" (p. 212). Like Eun (2008), Edwards and colleagues (2019) are cautious in their use of Vygotskian concepts when studying teacher development. What they point to is the gap in concepts. In Table 1 below is summarised those studies/theoretical works where cultural-historical concepts (column 2) and how they have been used to theorise teacher development (column 3) are presented as a useful beginning point for the study of early childhood teacher development. The selection of papers for Table 1 was based on articles that broadly used cultural-historical/activity theory/sociocultural concepts and were oriented to teacher PD (in-service primarily) and are indicative of what is in the literature.

Table 1. Cultural-historical conceptions of teacher development generally

Researchers	**Cultural-historical concept/terms as named and deployed by the researcher**	**Claims theorised in relation to cultural-historical concepts**
Thomas Tasker Karen E Johnson and Tracy S Davis (2010)	Vygotsky's dialogic process of external artifacts into internal representations	Inquiry-based
Karim Shabani (2016)	Vygotsky's social origin of mental functions, unity of behaviour and consciousness, mediation, and psychological systems; learning precedes development; zone of proximal development (ZPD); Social situation of development and everyday and scientific concepts	Teacher development includes *cognitive*, *affective*, *social* and *contextual* dimensions
Eun (2008)	Vygotsky's social origin of mental functions; unity of behaviour and consciousness; mediation; psychological systems, serves as evidence of development.	Psychological systems that focus on changing attitudes and instructional practices
Barohny Eun (2011)	Vygotsky's ZPD; mediation; inter and intra-psychological functioning	Cultural tools in mediating instructional interactions;

		development; theory-into-practice and practice-into-theory dynamic
Hui Shi (2017)	Vygotsky's ZPD; mediation; Activity theory	Micro-structure of the person's context and the macro-structure of the sociocultural model
Samon Ebadi and Nouzar Gheisari (2016)	Vygotsky's internal mediation, everyday and scientific teaching concepts and Lave and Wenger's peripheral participation of teachers	Classroom discourse and moment-to-moment complexities of teaching
Grimmett (2014)	Vygotsky's general genetic law of cultural development, including, crisis, ZPD, the social situation of development, intersubjectivity, perezhivanie and obshchenie, agency, imagination, motives, and concept development. Mariane Hedegaard's concept of the double move	Motive 1: To merely attend the PD Motive 2: To change practice Motive 3: To develop as a professional
Christopher P Brown and Brian Mowry (2017)	Primarily Hedegaard's concept of double move	Double move - personal experience and theoretical sense-making; Teacher inquiry in groups for future visions and historical imagination of practices.
Colette Murphy, Kathryn Scantlebury and Cathrine Milne (2015)	Vygotsky's dramatic collision, zone of proximal development, ideal and real form, imitation, unity of affect and intellect, regression/recursion	Coplanning, coreflection, copractice and coteaching.
Edwards et al. (2019)	Vygotsky's social situation and social situation of development; motives; agency; dialectics between person and practice; Hedegaard's societal, institutional and personal perspectives, where demands and motives within activity settings are part of the practices of institutions.	SSD was realised through how teachers positioned themselves; Motive orientation, demands of practice
Viv Ellis (2007)	Lave and Wenger's conception of communities of practice, Shulman's typology and personal constructs	Social situation of teachers' subject knowledge; collaborative professional enquiry to understand and to transform subject knowledge

The studies presented in Table 1 draw on cultural-historical theory to either theorise or research teacher development, such as Edwards et al. (2019), Murphy et al. (2015) and Grimmett (2014). But like Vygotsky, most struggle to illuminate what might be the concepts and the rules needed for explaining the lines of teacher development. For instance, Eun (2008) sought to give an "overview of Vygotsky's theories of development, emphasizing the aspects of the theory that have direct relevance for professional development" (p. 135). He sought to ground PD "models within the sociocultural developmental theories of Vygotsky, in order to understand the mechanism underlying the process of teacher development" (p. 135) and in his later work he gave "a firm theoretical foundation in which to ground professional development" (Eun, 2011, p. 320). But he did not do empirical work to take this forward. However, Grimmett (2014) did, and she makes a compelling case for Vygotsky's system of concepts, but goes one step further by bringing the concepts together as a model of PD that theorises the outcomes of her model of WITHIN practice PD. She studied teacher transformation in one school setting and deployed most of Vygotsky's concepts on child development, in order to explain teacher motive development for practice change.

What can be observed across those theoretical works shown in Table 1 is a broad set of concepts: mediation, inter- and intra-psychological functioning, social situation of development (SSD), ideal and real form of development, imitation, everyday and scientific concepts, and the zone of proximal development (ZPD). These concepts are directly related to Vygotsky's system of concepts for theorising child development.

Fourth, if we drill down into those papers summarised in Table 1 we can identify some studies that advance new concepts to locate teacher development within the institutional

practice traditions of schools. For instance, in empirical research Edwards et al. (2019) examined both pre- and in-service teacher development. In drawing upon the concepts of motives and demands (Mariane Hedegaard, 2012) and the institutional practices of secondary schools, they brought into focus the Vygotskian concept of the social situation of development (Vygotsky, 1998) to theorise teacher agency and teacher motive orientation when in challenging situations as in-service teachers or during professional placement of pre-service teachers. In examining the recurrent demands in practice, Edwards et al. (2019) reveal the dialectical formation of teachers as professionals, and in so doing, bring out some important differences between professional learning and development. They argue that when considering teacher SSD there is a tension that is held constant between the dialectical relation of agency and demands. This is showcased through how the teachers meet the demands of the profession (over controlling) or where no demands are made on them (lack of interest). They suggest that the teachers' agency is in response to the recurrent demands, which in turn creates a developmental niche located within the institutional practices of the schools. Edwards' et al. (2019) nicely show how cultural-historical concept of SSD and Hedegaardian conception of motives and demands within institutional practices, can reveal teacher development. The motive orientation of the teachers is aligned with the practice tradition, and the content of development appears to be expressed as teacher agency within the recurrent demands of professional practice. This sophisticated theorisation of teacher development goes beyond teacher learning of practice and introduces a suite of concepts for understanding the nature and content of teacher development. They take forward Vygotsky's conception of adult transformation and advance new rules that are located in the practice tradition of the school. However, secondary schools are different to preschools, because preschools have play-based programs that give different kinds of social situations and

practice traditions. The institutional practices are different and therefore the concepts and practices that are held in tension within the SSD may also be different.

Related to Edwards et al. (2019) study is that of Ellis (2007) who also theorised teacher development. Ellis was interested in the problem of professional knowledge that is often formulated as recipes in a context of subject matter knowledge. He specifically shows how complexity and dynamic social situation of teachers' subject knowledge is accessed and developed through culture, practice and agents. It is more than a recipe of action. In collaborative professional enquiry between school subject departments, interns and a university-based teacher educator, they sought to understand and to transform subject knowledge. In line with Hedegaard's (Edwards, et al., 2019) work, Ellis (2007) illuminates the institutional demands of practice found in secondary contexts, as well as identifying the motives of the teachers who enter into the practice tradition of secondary subject matter knowledge. But all these studies are located within different contexts to that of preschools where teachers' motives and the expected institutional practices will be different.

Unsurprisingly, the literature on cultural-historical conceptions of teacher development appears to be anchored in the practice traditions in which teacher development is taking place. But under what conditions do we see adult transformation in play-based settings? Are there key psychological functions developing for teacher in the different social situations of their practices? Can we study teachers' SSD as suggested by Edwards, et al. (2019)? Can we conceptualise professional development and teachers' practice context as a relation between the ideal and real form of teacher development as suggested by Grimmett (2014)? Is teacher professional development located in the knowledges of the different discipline areas as

proposed by Ellis (2007)? What might be the unique professional practice conditions that support teacher development of early childhood teachers?

Fifth, in agreement with Eun (2011), is that Vygotsky's system of concepts gives a very good starting point from which to theorise teacher development, and from which to draw concepts for the analysis of teacher transformation in context of PD. As stated so eloquently by Eun (2011), "Vygotsky's theory of development has provided a fertile ground to explore the mechanism of teacher development as this theory pays special attention to the role that culture and its tools play in human interactions" (p. 330). However, given the unique institutional practices of early childhood (social situation), what have cultural-historical studies of teacher development identified? In Table 2 are the studies (Column 1), the cultural-historical concepts used (Column 2) and how they have been drawn upon or theorised in relation to the early childhood PD (Column 3).

Table 2. Cultural-historical conceptions of early childhood teacher development

Researchers	**Cultural-historical concept/terms as named and deployed by the researcher**	**Claims theorised in relation to cultural-historical concepts**
Joce Nuttall (2013)	Engestrom's Developmental Work Research (DWR) with the relational dimensions of Contradiction; Cultural tools; Division of Labour; Rules; Motives, etc.	PD is collective, situated, historically accumulating, and multi-vocal; Contradiction between object of effective teaching and division of labour
Joce Nuttall Susan Edwards, Ana Mantilla, Sue Grieshaber & Elizabeth Wood (2015).	Engestrom's Object Motives of teachers	Motive objects Development: teacher development cannot be thought of as an individual phenomenon
Kelly Johnson, Fay Hadley & Manjula	Apprenticeship and guided participation as presented by Barbara Rogoff	Practitioner inquiry utilising Rogoff's planes of analysis, with concept of intersubjectivity.

Waniganayake (2020)		
Lori A Caudle (2013)	Communities of practice as described by Jean Lave and Etienne Wenger	Community of inquiry

What we know from this summary of research papers shown in Table 2, is a recognition that "Amidst debates about the nature of professional development in early childhood education, the most neglected aspect seems to be what is meant by 'development' (Nuttall et al., 2015, p. 225). This is in keeping with Vygotsky's (2019) claim that teacher transformation needs different rules to that of studying children's development. Directly relevant to the focus of this paper, Nuttall et al. (2015) noted contradiction, individual-collective dynamic, and motive object, as core theoretical foundations for the study of early childhood teachers' development. The contradictions pointed to the object motive in relation to the content of the PD. As part of conceptualising new practices in the context of the motivate for being involved in PD, Nuttall et al. (2015) identified that when using a cultural tool to create a contradiction during PD that this supported consciousness-raising and problem solving for positive teacher practice change. This work gives renewed emphasis to motives but does so by identifying motivating conditions in relation to contradictions in the beliefs and practices of the early childhood profession. Therefore, teacher motives and contradictions appear to be important concepts for understanding early childhood teacher development.

Taken together, we believe that the literature presented in this section gives some direction for the theoretical problem of what is developing during PD of the early childhood teachers. But to answer this more completely, we need to identify what concepts and the new system of rules that are needed to explain early childhood teacher development. To contribute to filling this theoretical gap, we investigated *the process of teacher development* where like Edwards et al. (2019), the *social situation* of the unique *institutional practices* of early childhood

education conditions were foregrounded, and where the concept of crisis and a change in motives, were used to point to the moments of possible *teacher development.*

Study Design – an *Educational Experiment*

An educational experiment is a collaboration between researchers and teachers on a theoretical problem, rather than just a problem of practice (Mariane Hedegaard, 2008). The researchers and teachers worked over four period on the theoretical problem of how to bring concepts into children's play.

The research questions that drove the study were: What is developing when early childhood teachers participate in practice change in a context of STEM teaching? What is the content of their development and under what conditions does development take place?

Participants

Rather than a problem of practice dealt with by teachers engaging in PD, this study sought to bring teachers and researchers together to work on a theoretical problem of how to bring into play-based settings authentic STEM concepts and problems that children solve through play. The two teachers (Ruth and Olivia) who participated in educational experiment each had a 4 year university degree qualification and had over ten years of teaching experience. Two classrooms - preschool (4yr olds) and the first year of school (5yr olds) - came together twice a week for each of the playworlds that were implemented (a series of 5 playworlds, which later in research was theorised as a Conceptual PlayWorld).

The researchers supported the teachers each week in Period 1 (6 months), then the teachers worked independent of the researchers in Period 2 (6 months), and then the researchers

collaborated with the teachers weekly for Period 3 (12 months). In Period 4 the teachers participated in leading PD programs on a Conceptual PlayWorld (see Fleer, 2021).

A Conceptual PlayWorld is a model of practice that begins with the reading of a story (teachers select a book which has contradiction and drama). The theme of the story is used to change an area in the preschool (inside or outside) into an imaginary space, such as, the fair ground in the story of Charlotte's Web or Sherwood Castle and Forest in the legend of Robin Hood. Children and teachers enter the Conceptual PlayWorld and imagine being characters from the story, reliving the adventures of the story, but also meeting problems that teachers introduce (a letter is sent from a character in the story) which need solutions by researching and using STEM concepts. The characters ask the children for help and the children solve the problem in the imaginary situation – such as, using google earth to prepare a map and escape route, meeting the caste engineer back in time to learn about pulleys and drawbridges, and in turn using what they learn to continue their play in the Conceptual PlayWorld.

The researchers supported the teachers weekly planning and evaluation by suggesting ideas and asking questions, provided PD on Gunilla Lindqvist's (1995) playworld model in Period 1, shared information about Vygotskian concepts, responded to email queries, and were given digital devices and resources to support program development throughout the 2 years. The focus of the collaboration was on the theoretical problem, and as mentioned previously, this was how to introduce into children's play conceptual learning that is authentic to children, and which helps them to keep their play going. That is, the theoretical problem is how concepts act in service of children's play. The conceptual problem to be learned is different to the theoretical problem. For example, the concept of design is shown through drawing a design for the escape route in a plan view perspective or exploring the concept of Force when

testing the chain's strength in a drawbridge, or understanding pulley systems, gears, load, and a fulcrum when modelling how to bring down the drawbridge in their play.

Data Collection

The process of data collection involved both digital video recordings of teacher practices when team teaching (152hrs), digital recording of weekly reflections and planning (32hrs), copying planning documentation, emails between researchers and teachers, photographs of displays/practices, children's designs, drawings, and products, and an interviews over the 2 years (Period 2: 2hrs), at the end of the 2 years of the educational experiment (Periods 3: 1hr), and again two years later (Period 4: 1hr).

Analysis

The study looked at how the teachers entered into, were shaped by, and also shaped the activity settings as part of the educational experiment. In order to determine how the teachers met the new demands during points of crisis, the concepts of motives/motivation (Hedegaard, 2012), and social situation/SSD (Lev Semenovich Vygotsky, 1994) were used to support the analysis of the collective practices and participation of teachers in the educational experiment.

Study Findings

The study sought to understand what was developing for early childhood teachers when engaged with the central theoretical problem of how to bring conceptual learning of STEM into children's play.

Working on A Theoretical Problem Created New Psychological Conditions for Teachers

Whilst the literature showcases processes, such as, mentoring (Helen Trevethan and Susan Sandretto, 2017), inquiries (Johnston et al., 2020) and the use of an outside expert in relation to problems of practice (Hadley et al., 2015), it does not bring out educators' engagement in a theoretical problem. Predictably, the theoretical problem began in relation to teacher practice of implementing a playworld where STEM concepts could be intentionally taught to children as part of their play.

In Period 1, it was found that the demands placed on the teacher as they entered into the new STEM practices, brought forward a level of conceptual engagement with the children. In the second period this came out more explicitly as the teachers sought to build conceptual knowledge through supporting children to create a relational model of the concepts they were learning.

> …we introduced the idea of the diorama. It's not something I had introduced to children before, and they just loved it. … it was an opportunity to show how all of the concepts interrelate [in the playworld]. So, they understood. They made the forest, the floor, nocturnal, endangered animals, solar system. They put in the threats – wood cutter, fire. They wrote messages for their families about re-cycling…in terms of developing their own model of a particular eco-system (Ruth).

During Period 2, the teachers created new conditions for the children. The teachers used the structure of a diorama to represent in miniature form the relational concepts within an ecosystem – and through this they were able to show how changing one part of the system, as 'a threat', changed the other parts of the system. Interestingly. In Period 3 the teachers' theoretical problem of how to bring STEM concepts into children's play, meant that the

teachers conceptualised and planned their teaching beyond isolated teaching of a single concept or setting up a science experience. In Period 4, however, they focused more on their own science knowledge and what was the STEM concept to be taught to children:

> Olivia: I think about the many possibilities of how science can be weaved in the everyday for children. In everyday experiences, and I am understanding the essential role we have as early childhood educators in developing those science concepts with children, and having the language.

> Ruth: We didn't have the knowledge to support the science concepts. So really without a few people helping us, I am not sure how we would have refined the knowledge enough to teach it to the children with such complex concepts. That information is very hard to access, often online it is inaccurate. The Learning Frameworks [curriculum documents] talk more about learning dispositions than science content.
>
> If you are not scientifically trained, it's very hard to distil it, into one sentence that young children are capable of understanding. Whereas, if you are a trained scientist, I find, they have that skill. Because we would just go too deep, and get off track [from the essence of the concept].

What emerged from the study was how the teachers researched to build their science knowledge in relation to the problem and what would be the essence of the big ideas in science (Period 4). They moved towards distilling meaningful concepts for children. That is, from the 'noise of the science knowledge and potentially misinformation available or incomplete', they sought out what might be the essence of a particular concept. But also,

what would be credible to very young children and therefore meaningfully integrated into the playworld as a problem to be solved, as Olivia explains:

> The other thing was thinking about the problem and how credible it was to the children. Going back to the story, and even though children were empathising with the characters, we were always thinking about the problem, was it credible and was it motivating children. This is the ongoing discussions that Ruth and I have had, and reflecting on this after each session, and in our planning.

The essence of the conceptual content across periods is shown in Table 3. The teachers' brought to the theoretical problem in Period 1 a focus on STEM concepts in relation to the book. The same theoretical problem was then interpreted in Period 2 in relation to the general STEM knowledge they needed. However, in Period 3 more attention was directed to the essence of the concepts they were bringing into the playworld where the children needed a particular STEM concept for enriching the play or for maturing the play. However, it was during Period 4 that the teachers were able to identify what mattered for solving the theoretical problem of how to bring concepts into children's play.

Table 3. Solving the theoretical problem associated with STEM learning in children's play

Dialectical relations	Theoretical problem Period 1	Theoretical problem Period 2	Theoretical problem Period 3	Theoretical problem Period 4
Teacher motives	What STEM concepts could be used with the narrative of the chosen book?	What was the STEM knowledge needed?	What was the essence of the STEM concept?	Was the STEM problem credible to the children?
Children's motives as motivating conditions	Moving from the book to generating the narrative that brings forward STEM play and	Dialectical relations between everyday knowledge and	Modeling: Children generate a model to capture the	Motivating conditions for children to want to solve the problem.

for teachers	problems to be solved.	scientific knowledge	essence of STEM concept	

In summary, it was found that working on a theoretical problem across two years created a different kind of context for the teachers planning and teaching. What dominated their weekly planning and evaluation of the children's learning and their pedagogical practices, was not a problem of practice. But rather, the theoretical problem of how to meaningfully bring STEM concepts into children's play at the same time as distilling the big ideas in STEM as credible concepts for children's learning, and the development of their play. While this was an ongoing point of crisis for the teachers, it was found, like Edwards et al. (2019), that the drama of the problem gave motivating conditions for their development. That is, the teachers viewed the same practice situation differently at different points over the two years. The teachers entered into the theoretical problem differently, as their own SSD was changing.

We now turn to the second theme where a different theoretical orientation to the concept of play was needed for professional practice change.

The Educational Experiment Brought Changes in the Dominating Motives of the Teachers

Studies following a cultural-historical tradition have identified that early childhood teachers object motive is towards their practice (Nuttall et al., 2015). One distinguishing feature of early childhood teachers' practices is planning educational programs for play-based settings. In this study it was found that although teachers created new motivating conditions towards learning concepts in children's play, they also met another theoretical demand in relation to their role in children's play. During Period 1 the teachers expressed a crisis that they had to resolve if they wanted to solve the theoretical problem of how to bring concepts into

children's play. For instance, Ruth identified her anxieties about how to be a character that was convincing to children:

> [initially] I felt nervous that I had to convince that child that I was that character. But the children know we are pretending. They have different levels depending on their age and their ability. So, some will say, "You're not really the Mad Hatter", whilst another will call you [putting up her hand], "Mr Mad Hatter, Mr Mad Hatter". So they will relate to you at different levels, and all of that is fine. It's all part of the play. I didn't have to convince them to play with them now, and I understand that now (nodding head). (Ruth)

This is consistent with the practice tradition of many centres in Australia. Teachers believe that play is the domain of children and teachers do not play with children, as noted by Olivia in Period 2.

> …obviously there is always a debate about how much to interfere with children's play, but in terms of this approach, it gave us a lot of confidence too, in when they get stuck, and then how more complex the play can be (Olivia).

Both teachers identified a shift in their role in a playworld:

> I feel much more confident now. So if the children are playing and they get stuck, I will jump in and say, "We need a …." or "No we forgot the… rain. Who is going to be the rain?" When I can see that something is missing, I just take the above position. I feel really comfortable to do that. Because I know that the play will continue to

> develop. Otherwise it gets stuck. If you just ask open ended questions or you watch children's free play, it reaches a stage where it just gets stuck. With the teachers feeling confident to jump in, when its needed, then you can continue the play (Ruth).

The expressed nervousness about being a play partner is in keeping with Pentti Hakkarainen Hakkarainen, Milda Brėdikytė, Kaisa Jakkula, and Hilkka Munter (2013), who identified that adults had to learn how to become play partners with children. But different to Hakkarainen et al. (2013), was the theoretical thinking of the teachers when planning to enter teachers and children playworld.

In Period 3, the teachers explicitly brought this forward. In building on Hakkarainen et al. (2013), this study found that what was specifically unique to entering and exiting of a playworld was the mind shift from individual or pair play to whole group play. This needed play planning, as Olivia identified:

> It's important to plan the play with the children. With the children we share the same goals. When you are going out to play, if we are all playing a different game it wouldn't work. To have that common motive, like we are saving the dragon, and sometimes some children will go off, like dig a bone, and that's fine. It is still connected. Circle time is also, where we gather the knowledge to go deeper [in play]. We have a whole shared [play] history (Olivia)

In this illustrative example of this finding, a shared motive for collective imaginary play was brought forward by Olivia. This did not mean that children did not have agency to bring new problems and plots into their play. Rather, it meant that the children showed behaviours

suggestive of being in the same imaginary situation. And this was afforded when entry and exist as a whole group was planned. Olivia explained in Period 3, the need for the planned motivating condition of a shared imaginary play situation, where a common motive to solve a problem in play, or to relive the story in some way, was key. This established a shared play history for everyone.

> I didn't really understand the intention at the beginning. And understanding how important it was for building the collective in the imaginary space. It took a while. I don't know why professionally? But that is something that has really stood out, in terms of reflecting now. Maybe I didn't understand or appreciate the intention of it, that we all go together into the imaginary space. And even though we were going through the tunnel like in Alice in wonderland (rabbit hole), or going through the trees (The secret Garden) using a key, and we were thinking more and more about the scientific concept and the knowledge, and our position. I have realised how crucial and important that [planning for whole group entering and exiting] is (Olivia).

During Period 4 of the educational experiment a crucial conceptual link between the shared imaginary play with a problem to be solved, and the maturing of play in ways that brought out the imagining of the STEM concepts were identified. The teachers suggested that the link between imagination in play and therefore imagination of STEM concepts was the foundation for the abstract dimensions of the intentional teaching of concepts. As Olivia notes:

> In imagination, the possibilities open up, helps with understanding. That imagination is the higher order thinking to develop those conceptual understandings. And think in the abstract, and encouraging that so well. And how we work with positioning, to

support children's conceptual thinking. Are we in the above or below or with? I really loved how that was made so clear in this [playworld] (Olivia, Period 4)

The four periods of solving the theoretical problem of how teachers enter into the play are brought together in Table 4.

Table 4. Solving the theoretical problem associated with how teachers enter children's play

Dialectical relations	Theoretical problem Period 1	Theoretical problem Period 2	Theoretical problem Period 3	Theoretical problem Period 4
Teacher motives	How to change positions from the teacher role to a play partner? How to be a believable play partner from the children's perspective	Professional perspective of not interfering in children's play	How to motivate all children into collective play?	Links between imaginary play and abstract thinking in play
Children's motives as motivating conditions for teachers	Children know teachers are pretending	Interacting with teachers as play partners, rather than as teachers in charge.	Finding the roles/characters to bring individual children into the playworld.	Motivating conditions where the concept/research solves the problem and keeps the play going.

In summary, when the four period are considered together, it is possible to see how the theoretical problem changed over two years. Like Lindqvist (1995), we also identified in the educational experiment over the first year that it was hard for teachers to be with the children inside of the playworld acting as a play partner (Period 1 and 2). But the study found a marked shift from Periods 1 and 2, to Periods 3 and 4 (Table 4). In Period 3 the teachers conceptualised play theoretically. They identified that they needed a new conception of play. Play had to be seen as a collective imaginary situation. Different to Lindqvist (1995) who was

interested in the aesthetics of a common playworld, in Periods 3 and 4 the theoretical problem became more focused on how to bring concepts into collective play. It was during Periods 3 and 4 that new insights into this problem were articulated by the teachers. They theorised collective imaginary play as foundational for motivating and developing abstract thinking for understanding/learning the STEM concepts associated with the problem in the story/play.

Discussion

A Vygotskian reading of development generally suggests that the formation of new psychological functions or consciousness is linked to the participation of the individual in specific forms of social practice or activity. In this study the educational experiment brought changes in the dominating motives of the teachers as they worked with a theoretical problem. The study found there was a doubleness in the educational experiment associated with the theoretical problem – for STEM concepts (Table 3) and for a new conception of play (Table 4), and when taken together, this appeared to create motivating condition for teacher development. In line with Nuttall et al. (2013), the study repositioned teachers "…not as individuals whose practice needs to be 'fixed' through modelling or coaching" (p. 208) but as collaborators with researchers seeking to solve a theoretical problem. A genuine problem brought about by a societal expectation in Australia for preschools to deliver greater cognitive outcomes associated with the intentional teaching of discipline concepts in play-based programs. This societal expectation brought new demands upon the teachers. By bringing out the essence of the expectation as a theoretical problem, and using this as the foundation for an educational experiment, this recognised that teachers were, "participants in complex systems of collective activity" (Nuttall et al., 2013, p. 208) who go beyond problems of practice and engage in theoretical thinking.

What is different to Nuttall et al. (2013), is that it was not just contradictions which act as the "springboard for developing practice" (p. 208), but it was the theoretical problem. Focusing on a theoretical problem meant that teachers were oriented differently to their practice. Over 2 years the teachers and the researchers could work towards theorising a new model of practice – one that solved the problem of how to bring concepts into play.

Moreover, if we examine the second rows in Tables 3 and 4, it becomes possible to see how the new motivating conditions that were introduced to children affected the teachers own motives. That is, teachers paid close attention to the children's motive development in relation to the motivating conditions they designed. The dialectical relations between motives of the children and the motivating conditions within the theoretical problem acted as the source of development for the teachers.

But to understand what is developing for teachers, we had to examine how the theoretical problem changed over time (Columns in Tables 3 and 4). In this study it was the unique content of the educational experiment with it's theoretical problem. The theoretical problem of how to meaningfully bring STEM concepts into children's play at the same time as distilling the big ideas in STEM as credible concepts for children's learning and development of their play emerged. The teachers' brought to the theoretical problem STEM concepts (Table 3) in relation to the book (Period 1), STEM knowledge (Period 2), what is the essence of the STEM concept (Period 3) and how credible is the problem (Period 4) when solving the theoretical problem of how to bring concepts into children's play.

The different periods capture how the theoretical problem developed over time. Theoretical thinking acted as an important psychological condition for the teachers for solving the

theoretical problem (Figure 1 below), where the content of that thinking was initially oriented to the book, then to the STEM knowledge needed, and then to examining the essence of the STEM concept, and back to designing a credible problem for children to solve as part of the story and play.

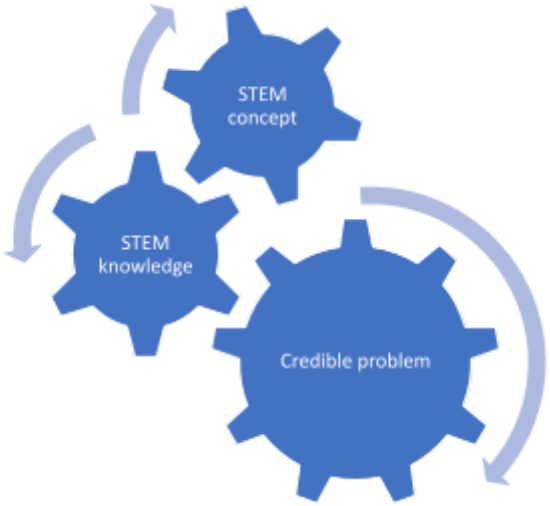

Figure 1. Teacher theoretical thinking: Relational model of how to bring STEM concepts into children's play

Conversely, the teachers also brought into the theoretical problem of the educational experiment how to be a play partner (Period 1), how to retheorise their conception of play (Period 2), how to create collective play conditions (Period 3), and how imaginary play brings abstract thinking for learning the STEM concepts (Period 4). We determined that theoretical thinking was developing for the teachers as they began to develop a new theoretical model of play that included STEM learning during the process of solving the theoretical problem. See Figure 2 below.

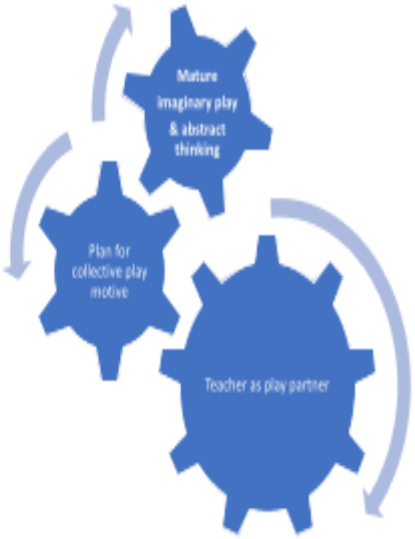

Figure 2. Teacher theoretical thinking: Relational model of imagination in play and imagination in STEM

We were mindful that the object of the activity for teachers had to be children and the pedagogy they created (see Nuttall et al., 2015)), but children's motives as motivating conditions for teachers is not something that has emerged in the PD literature. By paying attention to both the motives and the motivating conditions (Row 2 in both Tables 3 and 4), we were able to begin to theorise that the leading activity of the teachers as bounded by their profession, and always in relation to the everyday life of the children, was theoretical thinking.

Conclusion

The research question centred on what is developing for the early childhood teacher when engaged in professional practice change in STEM. The recurrent demands of practice (source) were met with theoretical thinking about play and STEM concepts (content), and this appeared to be propelled forward through the dialectical tension between the motives and the motivating conditions of the educational experiment over the four periods of the study (development). When viewed holistically, the educational experiment appeared to create new developmental conditions for teachers, because the theoretical problem brought changes in

the dominating motives of the teachers from practice to theoretical thinking. The source of development for the teachers in this study was found to be the demands made upon their practices through engaging with a theoretical problem. Therefore, teacher transformation must be conceptualised not as a simple problem of practice change, but as was shown in this study, as a maturing of theoretical thinking by early childhood teachers through solving the problem of play and STEM concept formation. These findings contribute to filling the gap in understanding about what are the conditions and content that act as a source of teacher development when engaged in STEM PD.

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