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Methodological principles of educational experiment: Conceptual PlayWorld with families for children's STEM learning in their home setting

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Highlights

- Educational experiment methodology for studying STEM concept formation in children in early years
- Conceptual PlayWorld pedagogical intervention to create collective imaginary play
- Bootstrapping model for developing transformative pedagogic approach
- Children's potentialities, theoretical-dialectical knowledge and relational collaboration are central features of educational experiment methodological design

Methodological principles of educational experiment: Conceptual PlayWorld with families for children's STEM learning in their home setting

Abstract

The focus of this paper is to further unpack methodological principles that help in studying potentialities of children especially their psychological function of imagination and concept learning in early years. The study uses a case example from one of the educational experiments done in Playgroup Victoria in Melbourne, Australia with 12 children and their families to explicates the methodological principles underlying development of new motivating conditions for children's STEM concept learning in their home setting. Conceptual PlayWorld (Fleer, 2017a, 2020) was used as a model of pedagogic intervention in this research. Children and their families participated in six bi-weekly Conceptual PlayWorld sessions via zoom during the COVID-19 pandemic. Children's storybook Rosie's walk was used to teach the concept of lever to children in the age range of 2 year 8 months to 4 year 6 months. The analysis shows that age-specific potentialities of children; relational collaborations among the researcher and researched person; and use of theoretical-dialectical knowledge (Davydov, 1990) are central to designing the educational experiment.

Keywords: social situation of development, potential, relational, pedagogical practice, demands, activity setting

1. Introduction

In his preface to Zaporozhets and Elkonin's (1971) book on "The Psychology of Preschool Children", Urie Bronfenbrenner mentions one of the hallmark of the Soviet (read cultural-historical) approach in psychology could be characterised as "the developing organism is not seen as a passive receptor of stimuli but an active agent…infant's psychological capacities develop through his practical activity with the world of material objects, a world that becomes progressively more complex both in content and structure" (Bronfenbrenner, 1971, p.X). This clearly highlights a distinct approach to researching children's development where their "psychological development is shaped primarily through intervention of other persons" (Bronfenbrenner, 1971, p.X). Zuckerman (2011) calls this professional psychological-pedagogical thinking dedicated to "studying the potentialities of the development of children and adolescents with the tools of education" (p.45). This pedagogical inventiveness for studying human potentialities (Fleer, 2018, 2020, 2021) is one of the central features of our work at Monash PlayLab. The study reported in this paper is focused on creating motivating conditions for children's STEM learning in their home settings using Conceptual PlayWorld model. The paper specially delineates the

methodological design of educational experiment and argues for a bootstrapping reflective model that draws on potentialities of the participants, collaborates with them using theoretical-dialectical knowledge.

Supporting children's concept learning in early years is a challenging endeavour. In our previous work (Fleer, Fragkiadaki & Rai, 2020) we have highlighted the methodological challenges of studying children's development as we use Conceptual PlayWorld to create new transformative conditions for their learning. The concept of living laboratory (Fleer, Fragkiadaki & Rai, 2020) was used to argue for capturing development in-motion and not studying fossilised complete forms. Our work specially draws on educational experiment methodology, an approach of designing theoretically planned intervention for the development of new transformative practices. This paper presents a case example from one of our interventions done in an Australian Playgroup, purposefully designed for teaching STEM concepts to children in their home settings. The study was done during the COVID-19 pandemic lockdown. Families with their children participated through zoom video sessions (further details are mentioned in data collection section).

The prime aim in this paper is to detail the methodological principles guiding the design of educational experiment in our research. The paper is divided into four broad parts- The first three sections presents the methodological crisis and theoretical foundations of educational experiment methodology; second section starting from data collection process spells out the intervention model; third section, focuses on the result and main findings; the final section comprising of discussion and conclusions synthesises the main arguments of the paper highlights the multiple activity settings created through the educational experiment.

2. Methodological crisis and educational experiments

While critiquing experimental methodology of his time Vygotsky (1997) suggested to move away from *stimulus-response as a central idea for organising methodology*. The new psychology, he asserted, which considered experimental method for empirical and objective investigation did not take the decisive step to move beyond the "old ground of stimulus-response" (Vygotsky, 1997, p. 31). Structural understanding of the mental processes stayed the focus with an assumption that the mental processes are response to the stimuli eliciting them.

> "Psychological methods and research strategies have developed and matured in accordance with this tendency to study separate, isolated, abstracted processes. The

> problem of the connections among the various mental functions -- the problem of their organization in the integrated structure of consciousness -- has not been included within the scope of the research". (Vygotsky, 1987, Vol. 1, p.43)

The limitation of psychological research to the structural understanding of the mental process is guided by three interrelated challenges according to Vygotsky (1997):

i) stimulus-response principle as a common root of all psychological methods
ii) experiments designed for adults done on children
iii) undermining the complexity and interrelatedness of psychological functions

The focus on segregating stimulus from their social situation, studying one stimulus at a time and inability to acknowledge the interconnected nature of psychological functions has led to simplistic research designs. Moreover, the design of studying lower mental fucntions are also used to study complex mental operations. The effort was to look for the unit of analysis i.e. most simplified element of the complex psychological function. This experimental tradition thus missed to understand the holistic process of developmental of psychological functions. Vygotsky (1997) highlighted these challenges as he asserted that

> "Not one stimulus, but a whole series of stimuli, sometimes complexly constructed groups of stimuli and, corresponding to this, not one response, but a long chain of responses or their complex combinations characterize an experiment. Frequently, the subject is confronted by a more or less complex task that requires a coordinated system of responses directed toward a certain goal and deserving to be called a mental operation" (Vygotsky, 1997, p. 31).

While studying psychological functions in children the research orientations focused on the adult world and emphasised on preparing children for adulthood, therefore underestimating or forgetting the value of childhood. Davydov claimed that "the need of children and adults to develop personal, non-utilized relationships is sacrificed for the sake of the educational process. From such a sacrifice, the content of education is dehumanized, and a 'human component' becomes lost" (Davydov, 1988, p. 4)". (cited in Hakkarainen & Bredikyte, 2021). A humane and holistic understanding of human psychological functioning demands a holistic perspective. One of the fundamental concerns that Vygotsky kept coming back to in his writings is that method must be adequate to the object of inquiry or research problem (Vygotsky, 1997, p. 27). He further unpacked this challenge that methodology can take multiple directions depending on the

i) focus of the research inquiry (e.g. psychological functions being studied- imagination, creativity, memory, logical thinking etc.);
ii) age period of the child
iii) task of the research (developing a genetic understanding of a process, analysis, description etc.) and
iv) nature of research (experimental or clinical)

3. Educational experiment: A distinct methodological approach for creating transformative conditions of learning and development

Hedegaard picks up on these arguments in developing a holistic approach to researching children's development. Her argument is to value the dialectical interactions between the individual child and the societal collective situation s/he participates in. Unlike classical psychology which has a clear boundary categorisation of innate/ natural properties of an individual and social environment; the cultural-historical approach sees them as a (dialectical) unity. The methodological focus then is on the situated dynamics as child participates in multiple institutional practices in their home, early learning centre, playground, hobby classes etc.

Inspired by Hedegaard's (2008) methodological work on developing a holistic approach for studying children's development; our work at Monash PlayLab is focused on developing educational experiment in collaboration with families that support their children's STEM concept learning. Central to this approach is a transformative stance to practice drawing from the work of Davydov (1990, 1998). The educational experiment "is a multifaceted planned preparation of teaching which has, as its goal, the creation of optimal conditions for the learning and development of the participating children" (Hedegaard, 2008, p.185). Drawing on Davydov (1972, 1998, 2008) and Hedegaard & Fleer (2008) three central principles are of considerable importance while designing educational activity using educational experiment methodology-

i) *Potentiality principle-*

One of the central concerns in educational experiment is to create optimal learning condition for the researched person. The focus is not limited to the concrete practices in which child participates but expands to creating new motivating conditions for development. *The quest is for the potential person who is yet to come*. Puzyrei (2007) explains that:

"knowledge" would have to be knowledge about the "potential person," "experiments on the person" from the viewpoint of what he may be or, consequently, what he ought yet to become, rather than knowledge about or experiments on the person as he already is, the "present person." (p.35)

It is worth highlighting that these potentialities are completely concrete reconstruction that demands agentic participation of the individual, it is not a future envisaged by the researcher for the researched person or participants. Drawing on Elkonin-Davydov educational system the emphasis is on professional pedagogical thinking that develops an "experimental method of studying the potentialities of the development of children and adolescents with the tools of education" (Zuckerman, 2011, p.45).

ii) *Theoretical-dialectical knowledge principle-*

Creating motivating conditions that offers opportunity for person's potentialities to come to foreground is a complex task. It demands both a concrete analysis of child's social situation of development and understanding of particular artificial adjuncts or pedagogical models (in our case Conceptual PlayWorld) to plan a systematic intervention. Hedegaard (2008) and Davydov (1990) suggests in educational experiments systematic planned intervention are guided by theoretical thinking. Unlike action research it is not merely guided by practice commitment but a clear theoretical commitment to knowledge. Davydov (1972) proposes that "thought can be subdivided into empirical and theoretical, without connecting each of this internally with any particular form of implementation" (p.93). He further explicated:

> "[i]n the dialectical materialist theory of cognition a concept is characterized, not on the basis of "abstractness" (consequently, not according to a departure from "figurativeness" and "visuality"), but according to the person's having command of a *universal* method of reproducing and constructing the respective object (therefore a concept can be "effective" and "sensory")." (Davydov, 1972/1990, p.93)

Theoretical-dialectical knowledge is not an attempt to develop generalisation but to trace the "interconnections between separate objects within a whole, within the system that brought it about" (Davydov, 1972/1990, p.275). The purpose of theoretical-dialectical knowledge is twofold- developing a undivided holistic understanding of the object of inquiry and second to analyse "interconnections in the specific object, thus identify those units in which the characteristics of the whole are present" (Vygotsky, 1987, p.47).

iii) Relationality principle-

In an educational experiment the researcher does not occupy an objective position removed from the object of study. The researcher actively collaborates with the participants to carry out the pedagogical intervention. It is worth noting that creation of new practice is informed by multiple perspectives of the participants. To design a pedagogical intervention the researcher or theoretician has a different purpose than the instructional designer or educator or parents. The relational nature of educational experiment could save it from the dangerous predominance of abstract component guided by theory or pragmatic component guided by practicalities of the settings. The collaboration brings a collective commitment to practice arrived through refining the practice at multiple stages thus making it a joint educational activity. The activity settings thus created are not dominated by researcher's values and positions but guided by commitment to transformative practices that creates new developmental possibilities for children and at the same time offer opportunity for theory building.

Researcher has an important role in designing the intervention.

> "Modern psychology's commitment to producing objective knowledge about human behavior via controlled experiments remains susceptible to reflexive questioning. How do experimenters stand outside themselves as human kinds to generate objective knowledge uninflected by their own subjectivity? How do subjects respond to being cast as "scientific objects" and not autonomous beings? What knowledge of self and other informs these experimental practices?" (Morawski, 2015, p.572).

The commitment in educational experiment is not to the objective knowledge in theory building but to creating transformative practices where researcher's professional commitments are as much part of creating the new practice as the participants' motives and expectations.

4. Understanding the researched persons' social situation

Rogoff (1990, 2003) and Hedegaard (2008, 2012) have elaborated upon Vygotsky's seminal work and have provided further explanations of child development in the context of the child's relationship with their social situation. Vygotsky's approach to children's development points at different development periods in relation to changes in the child's social situation. Vygotsky (1998) defined the social situation of development as being "a system of relations between the child of a given age and social reality" (p. 199). The concept of the social situation of development according to Hedegaard (2012) is critical to understand the dynamic nature of children's development and to incorporate child's perspective in a given age period.

> "The social situation of development represents the initial moments for all dynamic changes that occur in development during a given [age] period. …The social situation of development specific to each age [period] determines strictly regularly the whole picture of the child's life or his social existence." (Vygotsky, 1998, p. 198, as cited in Hedegaard, 2012, p. 12).

Vygotsky (1998) expressed concern of theorisations of child development that only considered the external conditions affecting the child. Such theorisation refers to child's conditions "without reference to the child" (p. 198) and the internal developmental processes. Therefore, the conditions of development can be both objective and subjective (Karabanova, 2010; Polivanova, 2015). In his analysis of the development of the mind of a child, Vygotsky introduced the concept of 'social situation of development, which denotes:

> "the special combination of internal developmental processes and external conditions that are typical of each developmental stage and that condition both the dynamic of mental development for the duration of the corresponding developmental period and the new qualitatively distinct psychological formations that emerge toward its end." (Bozhovich, 2009, p. 66)

The external conditions expressed through the societal and institutional (e.g. family, preschool) demands are specific to particular age periods of the child. Vygotsky in his writings has not emphasised "biological age in itself but [refers] to age period defined by societal traditions that then becomes reflected in the child's experiential relation to the world" (Hedegaard, 2012, p. 11-12). This is an important insight for understanding how children negotiate different institutional demands as they engage in the teaching-learning situation. In drawing upon a large corpus of cross-cultural research, Rogoff (1990, 2003) also highlights the importance of examining culture to understand development, arguing that "development can be understood only in the light of the cultural practices and circumstances of their communities—which also change. In essence, culture determines not only the principles for defining development but also frames the contexts in which the development of children is supported (Rogoff, 2003, p. 3–4).

5. Data collection process

5.1 Design of the pedagogical intervention – Conceptual PlayWorld model

The study used Conceptual PlayWorld (Fleer, 2017a, 2018, 2020) as a model of planned intervention in children's home setting. Conceptual PlayWorld is a theoretically informed play-based model that creates motivating conditions for children's concept formation using children's stories. The research team and families used following five key characteristics of the Conceptual PlayWorld to develop the collective imaginary play : a) selecting a story that has drama and a complex plot that could engage children and introduces a problem situation that demands learning a STEM concept; b) designing the play space that gives children the opportunity to explore STEM concepts and different characters from the story; c) plan entry and exit from PlayWorld so that family members are in the same imaginary situation and create collective learning experiences, d) planning inquiries and detailing the problem scenario, based on the story plot. Children should have sufficient information to understand the problem scenario and attempt to solve the problem with the adults. The problem scenario is not scripted but a general idea of the problem is planned so that parents and children could explore them based on their interaction; and e) planning teacher's role as he/she joins the imaginary space in order to interact with the children (more details in Fleer, 2017a, 2018). Fleer (2017b) has argued that the use of "digital devices… in PlayWorlds, amplified the children's play in scientific ways, which in turn created new conditions for children's development" (p.303). While playing within the Conceptual PlayWorld, young children develop their understandings about the natural, technical, and technological world in relation to their social and cultural reality. The arguments developed in this paper shows that Conceptual PlayWorld as a pedagogic model carries with it the societal needs, institutional practices in which the person navigates as part of the process of how person and digital technologies become mutually constituted.

We have argued elsewhere (Rai, Fleer and Fragkiadaki, 2022) that technology creates amplified play opportunities for children. Within Conceptual PlayWorld play-based model, technology is theorised as a means that creates multiple and dynamic educational affordances for young children. The technology in this educational experiment helped to create a collaborative relationship between the researcher and participants.

5.2 Playgroups-the context of intervention

Playgroup are unique site in Australian early childhood educational context which offers opportunities for families with children in early years to network with the community and other children in their neighbourhood. Our expansive review of research on Playgroups suggests that Playgroups lead to positive social outcomes, smoother transition for children to

primary school, increases parental confidence and give them know-how to navigate the Australian education system (Wang, Rai, Fleer and Fragkiadaki, under review). Playgroups have been an important site for early years education and care in Australian context particularly for immigrant and disadvantaged communities. The literature review also revealed that there is limited work in Playgroups on children's STEM learning and nearly none from a play-based perspective. Our educational experiment thus introduced a new practice tradition for Playgroup families.

5.3 Participants background

12 families participated in this work, eight of them came regularly for most of the bi-weekly sessions. The group had families from Chinese, Vietnamese, Indian, Spanish, Irish and Australian ethnicities. 7 boys and 5 girls in the age range of 2 year 8 months to 4 year 6 months participated in the study. In total 6 sessions were done over a period of four weeks.

5.4 Researchers' team

The data collection and intervention were led by first author. A consultant with expertise in instruction design (Dr Rebecca Lewis) and story teller with extensive experience as an early childhood educator (Ms. Oriana Ramunno) developed the pedagogical design of Conceptual PlayWorld using children's storybook- Rosie's Walk.

5.5 Video data collection

All the bi-weekly sessions were done through zoom. These sessions were video recorded generating in total 391 minutes (i.e. 6 hour 31 minutes) of video content. Families also participated in a brief interview with the researcher to understand their children's everyday activities and family's expectations from the Conceptual PlayWorld sessions. These interviews were conducted through zoom and video recorded. Some of the families also shared short videos after the bi-weekly session to share their own Conceptual PlayWorlds they have created in their home settings. Researchers' debrief and team meetings were also recorded.

5.6 Analysis procedure

Following Hedegaard's dialectical-interactive approach the effort was to understand the researched person's perspective in relation to the activity and the institutional practices there were located in. An effort was made to demarcate various activity settings created because of the researcher's intervention (for further details see Figure 04). Following four steps were followed in organising the analysis-

Step 1- the data were tagged according to the various stages of the study and stored in separate folders. For example, pre-intervention interviews, bi-weekly sessions, parents forum, data from family were stored in separately for easy access.

Step 2- In this stage data was coded in relation to activity setting and perspectives. These were open codes to tag data in relation to motives and demands presented by the participants.

Step 3- Patterns across various sessions and activity settings were noted to understand the development of educational experiment. Short videos and screenshots from the video images were collated in a folder for further analysis.

Step 4- Lastly, a theoretical analysis was done to understand the methodological nuances underlying creation of the Conceptual PlayWorld. The interpretations here were guided by the aim of the research i.e. explicating methodological principles underlying educational experiment.

6. Results

6.1 Story and Focus of the Conceptual PlayWorld

In consultation with families we chose Rosie's walk, a very popular children's story book written by Pat Huthcins to be design our Conceptual PlayWorld sessions. The story is about a very sneaky fox who is chasing Rosie, the hen. One day as Rosie goes on her walk in a farm the fox jumps to catch her but only unsuccessfully landing in pond, haystack and lastly into a beehive. We designed this Conceptual PlayWorld to teach children the science concept of "lever". At the end of the story children were introduced to a problem situation that the young fox somehow has come out of the forest and feeling very lonely. The fox's family is looking for her in the jungle. The young fox's birthday is coming. Rosie and her friends came to know about this problem and wanted to help the fox reach her family. The children had to design a get-home machine which could help to catch the young fox and send it back to the forest. Designing this 'get-home machine' for the fox became an emotionally engaging problem for the children. We saw many different versions of the solutions. Over a period of four weeks we did six bi-weekly sessions of each one of them were approximately 30 minutes. The effort in these sessions were to create with parents and children a collective imaginary situation which they could use for introducing the authentic problem-solving task in their home setting.

6.2 Components of Conceptual PlayWorld intervention

These are not sequential stages of intervention, the component here is to signify that they are part of the wholistic approach to support children learning and development.

Component 1: Development and practice analysis

The researchers' team started working on the study design. They deliberated on the science concepts which could interest children and their parents. Detailed discussion on this aspect between the researcher (first author), instructional design consultant and storyteller (early childhood educator) explored various everyday activities which could create possibilities to talk about levers. As these sessions were delivered over zoom we also thought about how to create an imaginary situation where children and families could relate with the story characters. Hand puppets and a design of the farm was made by the storyteller to show that she is on the farm. Detailing the creation of this artificial condition was central to doing this Conceptual PlayWorld using video conferencing tool like zoom.

Component 2: Understanding children's activities in their everyday situation

Families were recruited through Playgroup Victoria's network. As a first step they were invited to participate in approximately 20 minutes zoom interview with the first author. The focus of the interview was to understand children's everyday routine, what matters most for the families with respect to their children's development, parents' understanding of play and their intention of participating in the Conceptual PlayWorld. This brief meeting helped to build a rapport with the parents and understand their demands and expectations from the PlayWorld sessions. These meetings also offered an opportunity to share PlayLab research team's expectations from the families and children. This effort to make eachother's motives of participation visible helped in creating common knowledge (Edwards, 2010; Rai, 2017, 2019) that offered insights to the research team in developing pedagogic approach that was responsive to parent's and children's interest and could be weaved into their everyday practice. These meetings offered us understanding of the children's activities. Parents readily shared information about child's siblings and other family members (e.g. grandparents, cousins, uncle, aunt etc.) who they play with. Knowledge of these practices helped us to understand children's social situation of development.

Component 3: Refining the pedagogical design and developing a communication strategy

The understanding of children's everyday activities promoted us to refine in our pedagogical design to create possibilities for the entire family to play together. We also understood that working with a multilingual group for whom English is not the first language, sending them a copy of the rhymes and activities we plan to do in the session could support their

participation. A welcome email was sent to all the families explaining the structure of the sessions and expectations from the parents.

Hi Parents,

We're so excited to have you on board for this online playgroup that will be running for 4 weeks twice a week.

My name is Oriana and I'll be facilitating the sessions. My colleague Rebecca will be available in the zoom chat function if you have any questions. So please ask any questions throughout the sessions.

This brief video is to help you support your child during the online conceptual playworld session. PlayWorlds helps children to engage with science, maths, design and engineering thinking.

In each session we begin with an Acknowledgement of Country like you normally do in a Play Group and then a 'hello' song.

The focus of the first session is the story. A PlayWorld is inspired by a children's book and we've chosen a book called Rosie's Walk. I'll be reading the story and using actions and gestures. It would be really helpful if you join in at home to support your child. Together we will be wondering things like "I wonder what it would be like to be Rosie the Hen … she is very wise". You might walk like a hen for example.

Then I'll be playing and I encourage you to play along at home. Be the story characters - Rosie or the fox!

There will be times when I ask the children questions and I hope they share their ideas and experiences about farms.

We will be encouraging online interaction between the families at home to create a group experience .

And then we will end each session with a 'goodbye' song.

Remember, the most important thing is to have fun.

Figure 01: Screenshot of email sent to parents to apprise them of the structure of the Conceptual PlayWorld.

A clear communication strategy as part of the research design prepared parents and children to participate and align with the research purpose. These cooperative interactions set the stage for communicating the pre-decided goals of the sessions.

Component 4: Developing a joint educational activity- Bi-weekly story telling sessions

These Conceptual PlayWorld sessions were main pedagogic intervention of our educational experiment. These sessions were led by our expert storyteller (Ms. Oriana Ramunno, part of the Monash PlayLab research team). The first session focused on setting the stage and introducing various characters from the story. They followed the storyteller when she introduced a special walk like hen. The expectation was that children and families become part of the imaginary narrative and play like one of the characters from the book- to act like Rosie the hen, fox or introduce other characters like Rosie's friend or fox's mother etc. To familiarise children to the story narrative and explore different characters of the story, families were encouraged to re-read the book in their home setting. These re-readings helped

in maintaining the continuity of the discourse between the bi-weekly session. Families also developed their own props and ways of telling the story. Many of them shared their experiences of exploring the play narrative in their home setting.

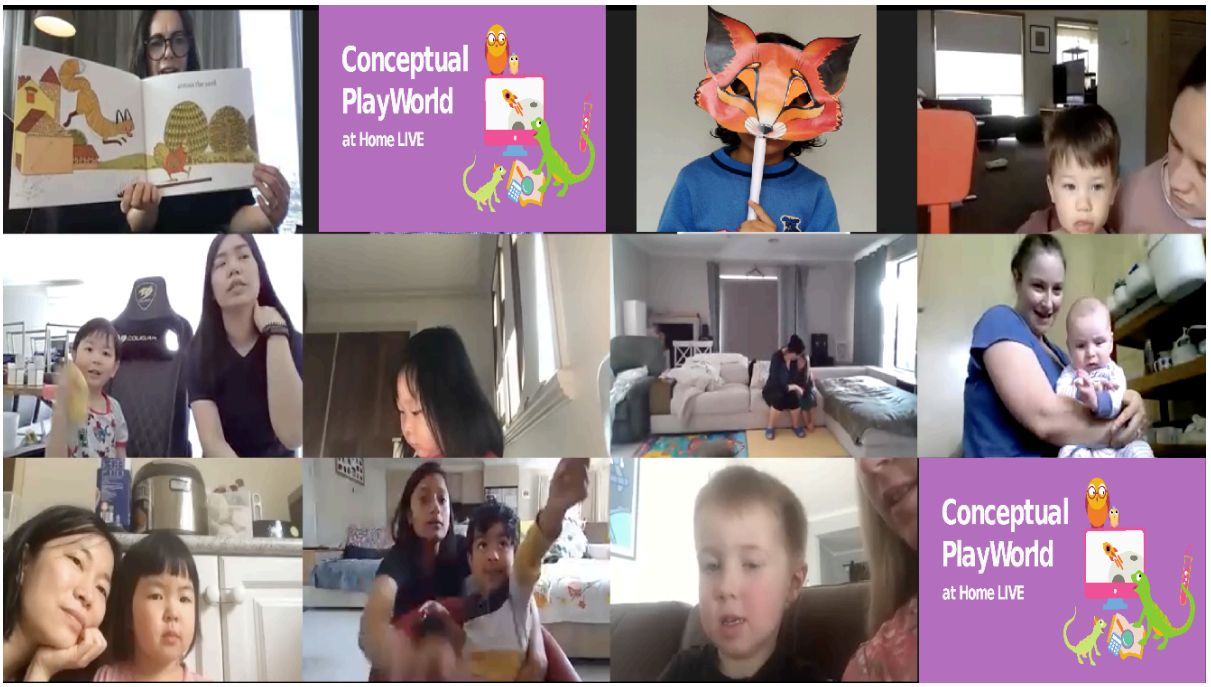


Figure 02: Families participating in a bi-weekly Conceptual PlayWorld story telling session via zoom

In the second session while retelling the story the storyteller made an effort to further detail each character- telling children about the fox's mother, Rosie's friends etc. She also shared more information about Hens and Foxes. Alongside this session the research team shared videos on how to make origami hen and rhymes which were closer to the story narrative. These digital tools helped families to develop further proximity with the characters. In the third session when story teller introduced the problem scenario that children have to help Rosie in making a get-home machine so that fox could be sent back to jungle it became personally meaningful for children. They were able to align with this new demand in the activity setting because they were playing as one of the characters in the story. Embodying the story characters and developing empathy for the challenge fox and Rosie were facing motivated children to think of ways to solve the problem. The challenge was to make children

believe that they are small like hen and fox is way bigger in size so they cannot lift fox easily. They will have to find a way to solve this problem.

1. Setting the stage and storytelling	2. Exploring the play narrative and retelling the story	3. Children and families embodying the story characters & introducing the problem scenario
4. Exploring the problem scenario and introducing the concept of 'lever' (and simple machine)	5. Families sharing their STEM learning and solutions.	6. Celebrating children's solution and seeking parents' feedback

Table 01- Table showing focus of the six Conceptual PlayWorld sessions

In the next session the storyteller explored the problem further and also shared information with them which could help to solve the problem. She introduced children to a female designer. The designer had experience in designing different kinds of machine and she introduced children with the concept of lever. After the session more information on levers were shared with parents so that they feel confident in supporting their children in the problem-solving task.

Component 5: Conceptual PlayWorld in the home setting

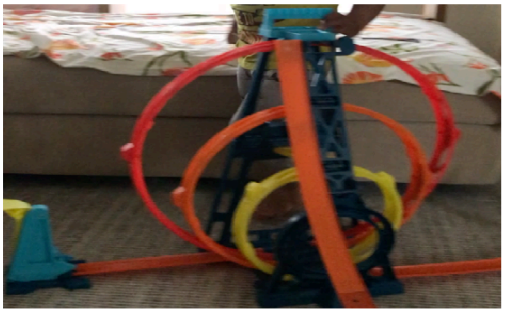
While planning for the intervention the research team curated a set of resources which families could use to create new play opportunities or gather more information about Hen, Fox, simple machines or lever. In their pre-intervention interviews parents shared that they are not very confident in teaching STEM concepts. While offering worksheets, fact sheets and games like origami and drawing the researchers made an attempt to offer opportunities for exploration both for children and their parents. Parents were not given list of instructions or tight narrative to follow rather the Conceptual PlayWorld offered them opportunity to bring their own play activities into the Rosie's PlayWorld. The effort in the Conceptual

PlayWorld is not offering opportunities for instructional teaching in play but amplify children's play while being a play partner.

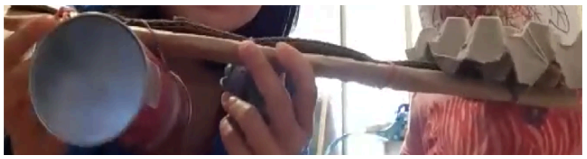
Component 6: Problem solving scenario- Making concept learning visible

Get-home machine designed by Neil

Get-home machine designed by Lexi



Get-home machine designed by Anant



Get-home machine designed by Kim

Figure 03: Figure showing some of the solutions designed and presented by children as a get-home machine to solve the problem

Families made different kinds of get-home machines, while working on the problem they also made children's conceptual learning visible to the group. Some of them enthusiastically started adding new characters in the story and new problems. The last session was focussed on celebrating children's design and seeking feedback from the families on challenges and problems they faced while implementing the Conceptual PlayWorld. They also shared how the pedagogical model helped in creating new opportunities for play in their home setting.

Component 7: Understanding research participants perspective: Parents forum

Parents were invited to share their feedback on their participation in the Conceptual PlayWorld. Cara participated with her son Neil in the session. She shared that "It really worked well for me. These were new concepts for my kid. It was interesting to see a two and half year old trying to understand how it works. I do have a seven-year-old as well and for him these were interesting concepts as well. He always asked "what did you do in playgroup

today?"…they both played. I could see that playing was learning. One day I went to the park and he saw a see-saw and said look… a get-home machine. He could associate this and said fulcrum, load and… it was nice to see him express his understanding in a different setting." (Cara, excerpt from the Parent forum interviews)

It was important for the research team to design intervention not only from the perspective of the child who is participating in the session but have a broader scope were siblings and parents could play together. Another participant shared that even when children were not in the same physical setting, they were able to align with eachother's motive and sometimes create new learning demands. Lexi's mother Chloe shared that "Imaginative play is Lexi's thing and introducing this new science narrative is really working for her. She has got a new vocabulary now and making connections. There was a bit an extension of the farm. The other day one of the farm dogs in our farm was stealing the eggs from the henhouse and Lexi was so excited by that. She made connection that dog is like fox. She learnt the concept of predators. Dogs were chasing hen but they were safe in the henhouse. Now every chicken is Rosie, she enjoys acting out the role play. She was initially intimated by the challenge of making get home machine, lever fulcrum… She wouldn't attempt it. Next session when others shared. Lexi could see that others could do it… it showed to her it was possible, her fears went away by seeing what other kids and parents have made… I could play with her and my toddler together in the PlayWorld." (Chloe, excerpt from the Parent forum interviews)

Component 8: Research team's feedback sessions

After every Conceptual PlayWorld session the research team which included researcher, instructional design consultant and storyteller met for a short debrief. These sessions were to reflect on what worked well and what didn't work well. Discussion about each child's participation and storyteller's experience were considered to refine the plan for the next session. The storyteller in the final feedback session shared that "We did a detailed planning. A number of ways to engage families. It all came down how it will make sense to the families. How we can make it really fun, interesting and playful for children. We planned for clear and direct messages. We were also thinking are parents familiar of these concepts etc and how to support them. I was also worried about how to make their learning visible for data collection."

The research team in this kind of methodological approach has a dual citizenship. On the one hand, it has to align with the aims of academic inquiry (i.e. the purpose of research to understand science concept formation in children) and on the other hand, be responsive to the needs and demands of the participants. Recognition of these distinct demands by the researcher are central to educational experiment design.

7. Discussion

The components of educational experiment presented above were not done in sequential stages but they were happening in an interconnected manner. Our educational experiment created a motivating condition for children's STEM learning as evidenced through parents' statement mentioned in the previous section. The collective imaginary situation created through the story of Rosie's walk offered an authentic problem to solve for children. Parents and children contributed to the collective fiction of the PlayWorld by bringing in elements from their home setting. It is worth highlighting that these emotionally engaging and amplified dramatic situations were created through following three aspects of educational experiment methodology:

i) Potentiality

The data on the social situation and everyday practices of the child was collected with a perspective not only to understand the child as s/he already is i.e. the "present person" but to think more carefully about the "potential person". Participation in these sessions also led to the development of a new consciousness in parents. Development of this new consciousness as evidenced through parents and children's participation in the bi-weekly sessions amplified some of the already existing play practices in the home setting. Various components of the educational experiment design shared in the previous section also shows that the new pedagogical practice informed by Conceptual PlayWorld multiple activity settings. These activity settings are the cultural-material conditions that participants inhabit within an institution. As children, parents and researchers together created the joint educational activity their perspectives and motive goals became visible in these activity settings.

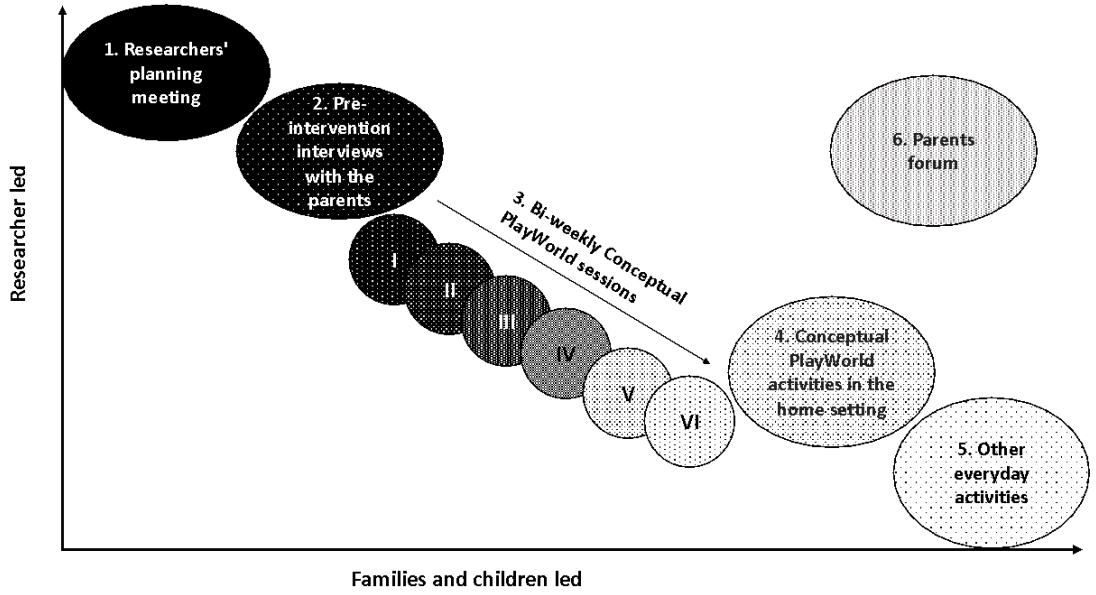


Figure 04- Figure representing various activity settings that were created or influenced by the Conceptual PlayWorld intervention

The figure 04 shows that both researcher and participants had a possibility to lead and create new practices. Research team's planning meeting, their reflective sessions and pre-intervention interviews were led by the researcher. These activities helped in developing an open-ended design for intervention. It also created an opportunity for participants to share their subjective experiences and understanding with the researcher thus making it a legitimate object of research inquiry. The methodological approach also became visible to parents in the first two activity settings. They were prepared for the bi-weekly sessions where we saw full dynamic unfolding of the Conceptual PlayWorld model that informed pedagogic practice. The collective narrative of the story and problem-solving scenario offered parents and children tools to explore zones of potential development. As mentioned in the previous section one of the mother shared that she did not expect her two and half year old to engage in science. It is central to the educational experiment methodology following Vygotsky (1997) that ""we had to actually give the subject the external means with which he could solve the problem presented to him." (p.78)

The artificially amplified learning space created using Conceptual PlayWorld model offered possibilities for parents to see their children's potentials in science. Vygotsky highlights this

methodological aspect on how it creates a social situation that in turn makes new demands on participants.

> "Man introduces artificial stimuli, signifies behaviour, and with signs, acting externally, creates new connections in the brain. Together with assuming this, we shall tentatively introduce into our research a new regulatory principle of behaviour, a new concept of determinacy of human reaction which consists of the fact that man creates connections in the brain from outside, controls the brain and through it, his own body." (p.55)

Creation of these activity settings, a new cultural-material conditions in the child's social situation was not guided by a formulaic approach but a relational approach was taken. Close ties between the method and everyday practices of the family shaped these activity settings. The theoretical underpinnings of the study and evidenced based model of practice (i.e. Conceptual PlayWorld) offered possible developmental trajectories that could emerge from the study. These anticipations guided by the theoretical knowledge to a certain degree helped in holistic understanding of the practice in the home setting.

ii) Theoretical-dialectical knowledge

The theoretical-dialectical knowledge as Davydov (2008) explained is developed in the process of idealisation of the practical, object-oriented activity. He argued that "the thing's idealized form (its concept) chronologically precedes the actual, sensibly perceived, particular thing" (Davydov, 2008, p.92). The theoretical knowledge from the cultural-historical theory is used to purposefully create human activity that offers opportunity for particular empirical manifestations, in this science concept learning. The activities in multiple activity setting as represented in the figure above were not insular units of the educational experiment design but they were interconnected with the whole and had dependence on the whole. This interdependence on the pedagogical model (Conceptual PlayWorld) mediated researcher and researched persons activities in the activity settings thus keeping them aligned to the purpose of the practice. "The sources of theoretical thinking lie in the very process of productive labour" (Davydov, 2008, p.94), the object-oriented activity makes the motive goal visible. To follow "Davydov's ideas one should follow the transformation in the relation between central concepts in a core model of children's learning and development" (Hedegaard, 2008, p.186). The storyteller in each of her sessions highlighted the core model guiding the Conceptual PlayWorld. Her effort was to develop a

learning process using Conceptual PlayWorld so that children's prior knowledge is transformed into the new knowledge of the concept of lever and ascend to their everyday practices. The demand of solving the problem task together was informed by children's everyday practices and interest. This facilitated a shared intentionality which was used to introduce them to the educational goal of concept learning. Marx wrote, "It is the work of science to resolve the visible, merely external moment into the true intrinsic movement..." (Marx, 1894/1959, p.214).

iii) Relationality

Very similar to 'three-quarter approach', a neologism developed by Chaiklin (2006) in the context of practice developing research the effort was to develop a collaborative relationship with the research participants. The researcher had a motive to establish a particular theoretical-pedagogic model of Conceptual PlayWorld in children's home setting that could amplify their play and STEM concept learning. The research team did not have a complete picture or concrete formulation of practice in advance. This is in contrast to the mainstream experimental approach in psychology where researcher has a pre-defined path and final protocol before entering the research setting. Another effort in the mainstream psychology is to remain objective or neutral. In contrast in an educational experiment the researcher has a theoretical commitment and a research interest which s/he shares with the participants and their collaborators. Educational experiment from this perspective demands relational agency (Edwards, 2005, 2010) i.e. mutual alignment of motives that develops a capacity to offer support and ask for support from others (Rai, 2017, 2019). Relational agency argues for fluidity of relationship "not encouraging dependency…encouraging a capacity to both seek and give help when engaging with the world" (Edwards & Mackenzie, 2005).

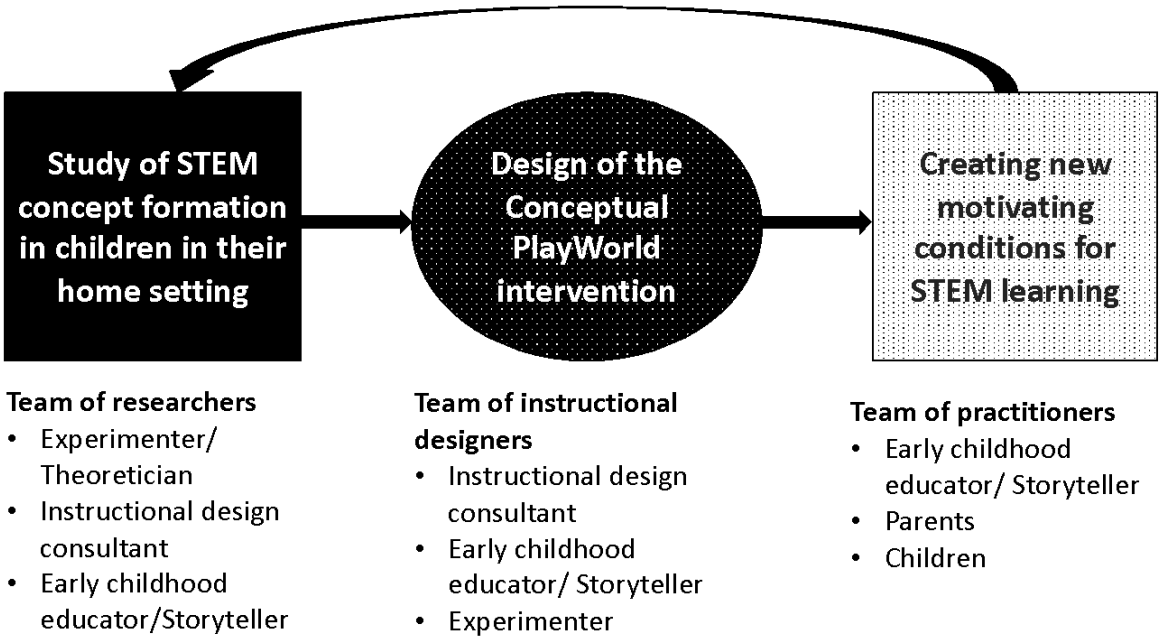


Figure 05: Figure representing the multi-agency collaboration and a bootstrapping model of developing practice

As expressed in the figure above that multi-agency collaboration was at play. The research team comprising of experimenter, instructional design consultant and early childhood educator had core expertise in designing research study. The instructional design team was well-equipped to use Conceptual PlayWorld for intervention while parents brought their core expertise on working with children and ensuring their wellbeing. This relationality demands being responsive to other people's strengths and needs. Recognising this relationship was central to using an experimental education methodology to understand children's development.

The purposeful interactions with the families also led to a bootstrapping model of practice (see figure 04) where results and protocols were not frozen but negotiated between the participants. It is worth noting that redesigning does not mean correcting errors in the design. Every iteration of the work offers new theoretical insights which were not available earlier. Thus, each iteration offers new insights which replaces fuzziness, hunches and probable theoretical answers. Thus, the purpose is not to arrive at reproducibility but to a newer understanding and an iteration to further illuminate the construct under study. Through this relational position researcher's perspective, educator's perspective and families' perspective were brought together to create a joint educational activity of science concept learning.

8. Conclusions

Educational experiment is not merely an intervention model but studying development of a transformative and dynamic practice across social situation. Central to this methodological work is the theory of children's development inspired by Vygtosky, (1987, 1997), Davydov (1972/1990, 2008) and Hedegaard (2008). Fleer's (2017a, 2018) Conceptual PlayWorld guided the pedagogic inventiveness to create an emotionally engaging learning environment that amplifies children's play. The methodological focus stayed on what is meaningful from children's perspective in relation to their social situation and everyday practices they participate in. The hallmark of educational experiment lies in working with the potentialities of the researched person; developing relational and collaborative approach to research inquiry; and drawing on theoretical-dialectical knowledge to guide practice. These ideas could be further synthesised as follows:

i) Instead of replicating the pre-decided structure the educational experiment methodology constructs or generate a practice within child's social situation and makes it a legitimate object of study as it develops. Thus, the methodological approach is generative in its nature creating new motivating conditions for children's learning.
ii) Individual perspectives were valued to create a collective nature of activity, thus instead of individual subject and its activities the analysis drew meaning from the collective action.
iii) Conceptual PlayWorld- an evidence based developmental model informed pedagogical thinking for the methodology. The design of this model facilitated joint collaboration taking a responsive and practical approach to make complex concept learning accessible to children in their play settings.
iv) As reported in previous sections the research activity was at the same time had pedagogic purpose and playfulness, thus it was in control of the researcher but demanded coordination and agentic participation from parents, children and researchers. It developed in participants a sense of subjectness that they were keen to contribute to the purpose of research. One of the central features of the educational experiment methodology is research and praxis are weaved together.

The focus of the educational experiment methodology in this study was the "production of the viable unheard of, or the potential to overcome restrictions of reality by devising new possibilities for the future." (Liberali, Fuga and Lopes, 2021, p.86).

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