

Enhancing Toddlers' Science Learning Through an Inquiry-Based Science Table

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Abstract

It is critical to support children's science learning starting from infancy. However, there is little research investigating introducing science to children under three years old. The current study addressed this gap by examining the effectiveness of setting up an Inquiry-Based Science Table (IBST) in a toddler classroom. A classroom in Hong Kong with 18 toddlers and two teachers was selected as the implementation site. A qualitative approach was used to collect data. Toddlers' interaction with the IBST was observed and recorded using the Science Behaviour Checklist. Two class teachers were invited for semi-structured interviews about their views on science teaching and the effectiveness of the IBST. The results indicated that the frequency, variety and complexity of toddlers' science behaviours increased after the IBST was placed. The adult's mediating role in supporting toddlers' science learning was highlighted, while concerns and challenges of implementing science teaching to toddlers were also presented and discussed. The study suggested that more rigorous research with larger sample sizes should be conducted to investigate effective science instruction for children under three and professional training on science teaching should be provided to teachers working with infants and toddlers.

Keywords : *Early Science Education, Inquiry-Based Science Table, Infants and Toddlers, Science Behaviours*

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Introduction

Young children are natural scientists who are curious about their surroundings. Early exposure to science experience improves their inquiry abilities, positive attitudes toward science, language abilities, and logical reasoning skills, which pave the way for them to learn formal science in later grades (Amsbary et al., 2023; Eshach & Fried, 2005).

In the past two decades, there has been a growing emphasis on early childhood science education with a consistent body of research addressing the necessity of teaching science to young children (Eti & Sığirtmaç, 2021; Fleeer et al., 2014; Fragkiadaki et al., 2023; French, 2004). In practice, although teachers are still reported to lack knowledge and confidence in incorporating science into early childhood curriculum (Greenfield et al., 2009; McClure et al., 2017), research in the U.S reveals that there is an increase in children's science experiences in the preschool classroom from only 4%-8% of instructional time devoted to science (Tu, 2006) to 25% of total instruction time in science learning opportunities (Piasta et al., 2014). However, most research on science learning for young children primarily focuses on preschool-aged children, with minimal studies investigating the science learning experiences of infants and toddlers (O'Connor et al., 2021). In addition, there is a lack of investigation into how teachers working with infants and toddlers think and perceive science teaching.

This study aims to address these gaps by examining the effectiveness of setting up an inquiry-based science table (IBST) in a toddler classroom. Infants and toddlers' science learning path and the effective approaches to teaching science will first be reviewed, followed by the theoretical framework of the IBST, the method, findings, discussions and conclusion.

Science Learning for Infants and Toddlers

Gopnik (2012) found that infants demonstrate scientific intelligence gained from everyday thinking and learning. Young children learn from statistics, experiments or play and from the actions of others in a way similar to the way scientists do, which lays the foundation for inquiry-based science education (Gopnik, 2012). Keil (2011) made a similar conclusion that even infants could make casual interpretations by integrating information that is similar to adults. In addition, a recent study on toddlers' spatial abilities found that toddlers have

demonstrated a wide range of spatial skills through playing with contents and containers (Uhlenberg & Geiken, 2021).

Vygotsky (1987) posited two dimensions of concept development—everyday concepts and scientific concepts, and the former lays the foundation for the latter, though the relationship is not linear. Rooted in Vygotsky's concept formation theory, Sikder and colleagues argued that infants and toddlers engage with science concepts through their everyday play experiences; they learn science through “academic concepts” and “small science concepts”, which mirror Vygotsky's “science concepts” and “everyday concepts” (Sikder & Fler, 2015, 2018). Small science was then categorised into multiple possibilities for science, discreet science concepts, embedded science and counter intuitive science (Sikder & Fler, 2015). Importantly, research highlights the critical role of adults in helping children bridge everyday and scientific concepts (Fragkiadaki et al., 2023; MacDonald et al., 2020; Sikder & Fler, 2015). Rather than emerging automatically, the development of scientific understanding requires scaffolding from caregivers and educators.

Effective Approaches to Science Learning for Toddlers

Research emphasises the need to systematically support science learning for infants and toddlers through effective pedagogical approaches (Fragkiadaki et al., 2024). However, despite a wealth of existing studies talking about science teaching pedagogy to preschool-age children (Dejonckheere et al., 2016; Edwards & Loveridge, 2011; Lin et al., 2021), there is a substantial lack of empirical evidence to give direction to teachers on how to introduce science to children under three years old (Fragkiadaki et al., 2024; O'Connor et al., 2021).

The Conceptual PlayWorld (CPW) Model is one of the few promising models to support infant and toddler science concept learning (Fler, 2024). Using a story as the imaginary context for exploration, Fler(2024) identified five pedagogical characteristics of a scientific CPW for infants and toddlers. Draw on the CPW model, Fragkiadaki et al. (2023) contended four key elements for introducing science concepts to infants and toddlers in everyday settings: 1) making meaningful interrelations between the everyday concept and the scientific concept, 2) consistently using scientific language, 3) using appropriate analogies, and 4) using early forms of a scientific method. These strategies can be utilised to support young

children's science learning even without implementing the CPW model.

Additionally, research highlighted the significance of using inquiry-based teaching and learning approaches for children aged 0-3 (Byrne et al., 2016; Bucher & Pindra, 2020; Uhlenberg, 2022; Van Meeteren & Peterson, 2022). Inquiry-based teaching is an approach that involves asking questions and systematically seeking answers based on observation and facts, aiming to unlock children's curiosity and encourage them to find answers to their questions (Eti & Sığirtmaç, 2021). An inquiry-based approach is recommended for science teaching as it enables children to comprehend scientific knowledge through hands-on experiences. However, infants and toddlers rely more on adult guidance to navigate this process (Uhlenberg, 2022). Their skills, such as wondering, experimenting, gathering evidence, and using evidence to draw conclusions, can be enhanced, with the support of adults (Byrne et al., 2016).

The Theoretic Framework of IBST

Based on the above review of literature, this study used an IBST as the intervention in the toddler classroom. An IBST is an inviting area to provoke toddlers' hands-on exploration and investigation of scientific phenomena. It typically contains a variety of open-ended objects, materials and tools that toddlers can freely manipulate and experiment with. In contrast to a traditional science centre that may simply display a collection of unrelated items without considering children's interest, an IBST follows Uhlenberg's (2022) Inquiry Teaching Model (ITM) to stimulate toddlers' active investigations that evolve with their interests, based on teachers' observation and interaction with children.

Uhlenberg (2022) proposed an infant toddler inquiry learning model (ITILM) where young children **wonder** about the materials provided by the teachers, **strategise** to discover or create problems that are interesting to them and finally **resolve** their chosen problems. In corresponding to that, teachers can follow the ITM to engage infants' and toddlers' inquiry and support their exploration of science. The ITM majorly includes three stages: "engage the learners", "provide opportunities," and "make decisions" (Uhlenberg, 2022, p.22). The model is nonlinear, and observation is woven through the three processes.

In this study, an IBST was implemented in a toddler classroom to provide toddlers with science exploration opportunities (see Table 1). The on-site researcher created an openness to inquiry when toddlers were interacting with the IBST.

Three research questions were formed:

1. What science behaviours are exhibited by toddlers?
2. What impact does the IBST have on the science behaviours of toddlers?
3. What are the perspectives of toddler teachers regarding science teaching and learning for toddlers, as well as the effectiveness of the IBST ?

Table 1. *The Inquiry Teaching Model (ITM) and the IBST Setup*

	ITM	IBST Set-up
Week 1	Observe Observe children's current interest Understand the limits of engagement	Original materials on the science shelf
Week 2	Engage Learners Provide new materials Capitalise on the learner's natural curiosity Stimulate interest	Set up a science table with open-ended materials for free exploration
Week 3	Provide Opportunities Facilitate exploration Scaffold experimentation Foster communication	Add scientific tools in addition to the open-ended materials
Week 4	Make Decisions Intentionally provide problem-solving scenarios Intervene to promote deeper thinking Document and plan for the next	A problem-solving scenario is deliberately provided in addition to the scientific tools and the open-ended natural materials

Method

This study employed a qualitative approach to understand how the IBST affected toddlers' science learning. Data were collected through observations of toddlers' science behaviours when interacting with the IBST , using the Science Behaviour Checklist (Table 3). In this study, the term "toddler" is used to describe children from 12 months to 36 months old. Semi-

structured interviews were also conducted with the two class teachers to probe into teachers' views of science learning for toddlers and the set-up of the IBST .

Context and Participants

A private international kindergarten in Hong Kong was selected as the implementation site because the second author worked there as a student teacher during the research period. The kindergarten follows the Early Years Foundation Stage (EYFS) framework and serves children from birth to age five. The kindergarten is also inspired by the Reggio Emilia Approach, which emphasises the value of the environment. 18 children aged between 24 and 36 months in the toddler classroom of this kindergarten were invited as participants on a voluntary basis, and 16 consent forms were obtained from their parents.

The two class teachers who worked in the toddler classroom agreed to be the participants for the interview as they had the best knowledge about the children and environment in the classroom. Both teachers were female and had four years and six years of teaching experience, respectively. One teacher was an English-speaking expat teacher, and another teacher spoke Mandarin to provide children with a bilingual environment.

Ethical Considerations

The study was conducted over 6 weeks (April 2023 to May 2023), with the first week for preparation, 4 weeks of intervention and observation, and one week for the interview and wrap-up. The second author was supervised by the two class teachers and worked at the site daily as the student teacher and on-site researcher. The first author was the second author's academic supervisor, met weekly to discuss the research progress. The research team developed the observation instrument and interview guidelines collaboratively, which were reviewed and proved by the class teachers.

The two classroom teachers of the research site were asked to help distribute the invitation letters to the parents. Parents could voluntarily give permission for their children to participate in this study by returning the letter with a consent form. All children in the classroom have equal access to the IBST. Children whose parents did not give consent (N=2)

could still come to the IBST to play, but their data were not used for any analysis. The two classroom teachers also gave consent to the interview. Confidentiality was ensured, with all data anonymized to protect participant privacy.

Procedure

Observation data was collected four times over four weeks (see Table 2). The observation took place when toddlers were interacting with the IBST. A fixed camera recorder was set next to the IBST and could cover all activities happening around the IBST. Observation was conducted every Friday during free choice time, and the IBST was open for all children to access. The second author served as the on-site researcher and facilitator, responsible for turning on the video camera when children gathered around the IBST, supporting their play at the table, and taking observational notes. The research team discussed the preliminary

Table 2. *The Procedure of IBST and the Researcher's (Facilitator) Role*

	ITM	IBST Set-up	The Researcher's (Facilitator) Role
Week 1	Observe	Original materials on the science shelf	○ Observe children's current interests ○ Document limitations of the current materials
Week 2	Engage Learners	Set up a science table with open-ended materials for free exploration	○ Provide open-ended materials and water ○ Capitalise on the learner's natural curiosity about the open-ended materials ○ Stimulate children's interests by describing the new materials
Week 3	Provide Opportunities	Add scientific tools in addition to the open-ended materials	○ Facilitate children's exploration by using tools to encourage children's interaction between water and materials ○ Scaffold children's initial experimentation on water. ○ Use scientific vocabulary to foster communication
Week 4	Make Decisions	A problem-solving scenario is deliberately provided in addition to the scientific tools and the open-ended natural materials	○ Intentionally provide a problem-solving scenario ○ Ask open-ended questions ○ Describe problems children have identified ○ Use scientific vocabulary to share children's findings ○ Promote children's deeper thinking through solving the problem collaboratively

findings from the video recordings after each week's observation and determined the IBST set-up for the following week. While the two classroom teachers were not directly involved in the IBST during the observation period, as they needed to engage children not participating at the table during free choice time, their opinions about the IBST set-up were regularly consulted. This collaborative approach between the research team and teaching staff ensured the IBST implementation was informed by both the empirical data collection and the practical classroom experience.

Data Collection

Observation

Observation data was collected using the Science Behaviour Checklist (Table 3). The Science Behaviour Checklist was developed based on the Engineering Preschool Children Observation Tool (Anggoro et al., 2021, EPCOT, v.1). Items were modified based on toddlers' cognitive and language development levels. The Science Behaviour Checklist included the scientific and problem-solving behaviours in five categories: "describing/recognising information", "obtaining information and asking questions", "identifying the problem", "sharing findings", and "manipulating tools". During every observation, toddlers' science behaviours were videotaped for 30 minutes. Video data enhanced the researchers' memory of events (Erickson, 1992, p.209) and enabled the researchers to analyse in detail human interactions and associated movements-the "how" of behaviour (Ratcliff, 2003). Toddler's science behaviour frequency was also calculated as an additional method for triangulation.

First Observation. The toddler classroom originally had a shelf with some science materials set up by the two class teachers, including four water bottles with coloured water inside, two sand clocks, a lamp and a plant (Figure 1). For the first observation, the researcher observed children's interaction with the original materials on the science shelf with the video recorder on and documented children's behaviour using the Science Behaviour Checklist. The researcher only intervened in children's exploration if they asked questions or sought help.

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Table 3. *The Science Behaviour Checklist*

Science Behaviours	Indicators
<i>Describing and recognising information</i>	<u>D1:</u> Repeat a statement about a scientific phenomenon <u>D2:</u> Describe materials shared by the teacher <u>D3:</u> Offer observations or examples from their own lives
<i>Obtaining information and asking questions</i>	<u>O1:</u> Independently explore (touch, play, examine) materials <u>O2:</u> Ask clarifying questions (What is/ Where is?) <u>O3:</u> Ask exploration questions (Why does/ How does?)
<i>Identifying the problem</i>	<u>I1:</u> Repeat the problem after the teacher or another child states it <u>I2:</u> Recognise and articulate the problem
<i>Sharing findings</i>	<u>S1:</u> Present a solution <u>S2:</u> Explain a choice (material, final solution) <u>S3:</u> Describes steps of the problem-solving process
<i>Manipulating tools</i>	<u>M1</u> Actively utilise tools to explore materials or to solve a problem.



Figure1. The original science shelf

Second Observation. During the first observation, toddlers showed some interest in the water bottles by shaking them. None of the toddlers touched any other materials except the water bottles. Therefore, the research team decided to provide some open-ended materials and water for the second observation so that children could have more hands-on experience in doing science experiments. Then, the researcher set up a science table with a big water container, natural materials (branches, leaves, wood pieces, stones and shells), feathers and mirrors (Figure 2). The researcher described toddlers' behaviour, introduced materials and asked questions when deemed appropriate.



Figure 2. The IBST for the second observation

Third Observation. In the second observation, children demonstrated initial interest in the open-ended materials, but the connection between materials and water was not apparent. To facilitate more active exploration of materials and water, the researcher added several scientific tools, including two spoons, a sponge, four cups and three magnifying glasses, to the IBST for the third observation (Figure 3). The researcher asked children open-ended questions, facilitated their discussions and intentionally used scientific vocabulary such as “sink”, “float”, “scoop”, and “flow” to describe children’s actions.

Fourth Observation. In past observations, the research team noticed a lack of problem-identification and problem-solving behaviours. It was assumed that toddlers might need a more overt scenario to identify and solve a problem. Therefore, for the fourth observation, a



Figure 3. The IBST for the third observation



Figure 4. The IBST for the fourth observation

problem-solving scenario was set up intentionally: a rubber duck was placed in a tall glass jar with another jar filled with water (Figure 4). The researcher facilitated toddlers who came to the IBST to “save the rubber duck”. The researcher also asked open-ended questions, described problems children identified, used scientific vocabulary to help children share their findings, and promoted their deeper thinking through solving problems collaboratively.

Interview

After the 4-week implementation of the IBST, interviews were conducted with the two

classroom teachers. This allowed the acquisition of richer data because the two teachers were familiar with the classroom environment and the children in the classroom. Their perspectives on the IBST could be used as a complementary yet essential data source besides observations. Teachers' perspectives on toddlers' science learning and development, the perceived challenges of science teaching, and their opinions on the IBST were investigated. An interview guide was developed and followed during the interview(See Appendix I). Each interview lasted for around 40 minutes.

Data Analysis

Four 30-minute videotapes were replayed for data analysis, and the toddlers' science behaviours were coded based on the Science Behaviour Checklist. The research team listened to the videotapes multiple times. Descriptions of relevant details observed in the videos were then written as field notes. To minimise investigator bias, one video was coded independently by two researchers and the result showed 88% agreement. Then the frequency and percentage of science behaviour indicators in each observation were calculated.

Thematic analysis (Braun & Clarke, 2006) was used to analyse data obtained from teacher interviews. The audio recordings of interviews were transcribed verbatim. Both authors got familiar with the data and jotted down early impressions first. Then, the transcripts were initially analysed by the first and second author independently to generate codes related to the research questions. After comparing and checking each other's codes, the research team discussed and came up with several themes that captured something significant or interesting about the data (Moirá Maguire, 2014). The themes were reviewed to make sure there were no overlap. Finally, themes were defined and triangulated with the observation data.

Results

Toddlers' Science Behaviours

The data obtained from the observation revealed that toddlers exhibited different types of

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Table 4. *Percentage of Science Behaviour in Each Observation and in total*

Science behaviour	Indicators	First Observation	Second Observation	Third Observation	Fourth Observation	Total
Describing/re cognising information	D1 Repeat a statement about a scientific phenomenon	9.5%	7.9%	9.3%	7.9%	8.5%
	D2 Describe materials shared by the teacher	33.3%	26.3%	22.2%	21.1%	23.9%
	D3 Offer observations or examples from their own lives	14.3%	13.2%	5.6%	7.9%	9.0%
Obtaining information and asking questions	O1 Ask clarifying questions (What is/ Where is?)	9.5%	7.9%	11.1%	5.3%	8.0%
	O2 Ask exploration question (Why does/ How does?)	4.8%	5.3%	3.7%	5.3%	4.8%
	O3 Independently explore (touches, plays, examines) materials	28.6%	26.3%	27.8%	23.7%	26.1%
Identifying problems	I1 Repeat the problem after the teacher or another child states it	0.0%	2.6%	0.0%	3.9%	2.1%
	I2 Recognise and articulate the problem	0.0%	2.6%	0.0%	3.9%	2.1%
Sharing findings	S1 Present a solution	0.0%	2.6%	0.0%	2.6%	1.6%
	S2 Explain a choice (material, final solution)	0.0%	2.6%	0.0%	1.3%	0.5%
	S3 Describe steps of the problem-solving process	0.0%	0.0%	0.0%	1.3%	0.5%
Manipulating tools	M1 Actively utilise tools to explore materials or to solve a problem	0.0%	2.6%	20.4%	15.8%	12.8%
Total		100%	100%	100%	100%	100%

science behaviours when science exploration opportunities were provided.

It was observed that certain science behaviours were frequently demonstrated by toddlers over the four observations, namely “describe materials shared by the teacher (D2; 23.9%)”, “independently explore (touch, play, examine) materials (O3; 26.1%)” and “actively utilise tools to solve a problem (M1;12.8%)”. Toddlers exhibited a natural inclination towards the IBST, engaging in manipulation, description, touching, and playing with the materials and tools even before the teacher provided verbal intervention. For example, during the first observation, when the IBST had limited open-ended materials and low adult involvement, a toddler told the researcher that she had seen similar bottles with water at home (D3) and described how she could shake them to make the water move (D2). The findings corroborated the answers from the teacher interviews. Two class teachers acknowledged the presence of science learning opportunities for toddlers. For example, Ms Claire stated that young children possessed a natural inclination towards science, as they exhibited a natural curiosity and

employed their senses to explore their surroundings. She further reflected that children engaged in scientific exploration more extensively than she had initially thought, and this exploration took place in children's everyday activities.

I think science exploration naturally happens in the classroom. Toddlers are naturally curious about things, and they naturally use their senses to observe the world and the problems they face, you know, whether it's in a classroom or if they're outside and playing in their everyday activities (Ms Claire, 17-05-2023).

The other class teacher, Ms Shirley, also expressed her belief in the benefits of science learning for toddlers. She mentioned that “science learning is beneficial for children's multidisciplinary development” as it “cultivates their curiosity around the world, strengthens their understanding of mathematical concepts, and stimulates their thinking and problem-solving skills” (Ms Shirley, 18-05-2023). Additionally, she noted that science learning was often hands-on, encouraging children's exploration and observation.

While toddlers demonstrated certain science behaviours naturally, it is noteworthy that behaviours associated with “identifying problems” and “sharing findings” were less frequently observed during the first three observations. Specifically, these behaviours were observed only once during the second observation. However, when the researcher intentionally introduced a problem-solving scenario during the fourth observation, science behaviours pertaining to “identifying problems” and “sharing findings” were observed with significantly greater frequency.

Sheraine (28 months) and Ian (33 months) were playing at the IBST.

Sheraine looked at the container and pointed to the duck: Why duck there?

The researcher: Yes, a duck is inside the jar. Can you get it out?

Sheraine repeated the researcher's words, "get the duck out" (11)" and tried to use her hand to get the duck out.

The researcher: Sheraine, the jar is too deep, that why you could not reach it. Can you think of another way to save the duck?

Sheraine: Let duck swim.

The researcher: What do you mean by letting duck swim?

Ian: Duck swim in water.

The researcher: Oh! Do you guys mean we can add water inside the container so the duck can swim out?

Sheraine: Yes. You pour the water in (S1) and duck swim and out (S3).

(4th Observation, 12-05-2023)

The Effectiveness of the IBST

The observation results indicated a growing trend of increased engagement in science behaviours across the four observations. 24 science behaviours exhibited by toddlers were noted and recorded in the first observation, with 37 science behaviours in the second observation, 54 science behaviours in the third observation, and 76 science behaviours in the fourth observation. Following the ITM, toddlers demonstrated more variety of science behaviours with the increasing abundance and flexibility of materials available and the progressive level of adult intervention.

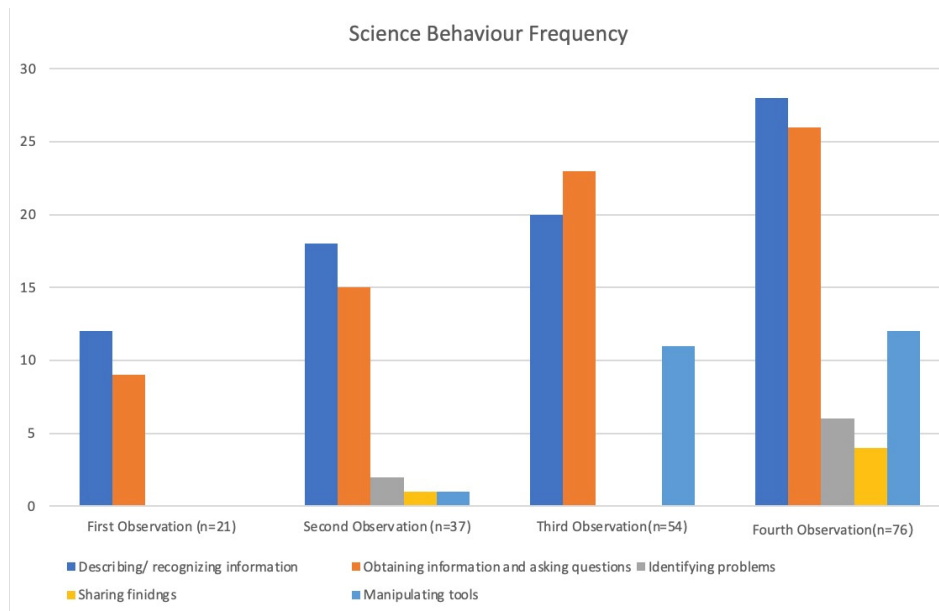


Figure 5. Science behaviour frequency over the four observations

Besides, the complexity of toddlers' play in the IBST was noted. Iris, a 30-month-old toddler, interacted with the water in the IBST during the second and fourth observation. Compared with the second observation, he demonstrated science behaviours more frequently and engaged with the materials with a higher level of sophistication, accompanied by a notable richness in his language usage during exploration in the fourth observation. Below are two excerpts of his interaction with the IBST.

Iris kept placing feathers into the container with water.

The researcher: What are you doing, Iris?

Iris: I am putting things inside the water (O3).

Iris looked at the researcher and asked: where is my hand? (O1)

The researcher: Where is your hand?

Iris: It's here! (He took his hand out from the water and shook it)

(2nd Observation, 21-04-2023)

Iris used his hand to hold the feather and placed the feather into the container with the duck.

The researcher: What are you doing, Iris?

Iris: I am getting the duck out (S1).

The researcher: You are using the feather to get the duck out.

Iris: I am helping the duck taking a shower (S2).

The researcher: How to take a shower without water?

Iris: Right!

Then, he tried to hold the container with water and asked the researcher to help.

The researcher: Do you want me to help you pour the water into the container with the duck?

Iris: Yes, and then the duck and feather go to the top(O1).

The researcher: Oh, do you mean they can float on the water?

The researcher started to pour water inside the container with the duck.

Iris: The duck is swimming...float on the water! The feather is also on the top now (D1, D3).

The researcher: Yes! We saved the duck, and now you can continue to help it take a shower.

Iris: We helped the duck float! (11)

(4th Observation, 12-05-2023)

The two class teachers who were participants in the interviews also shared positive views regarding the IBST set-up in the classroom despite not directly intervening during the observations. Firstly, they highlighted that the IBST has facilitated toddlers' engagement and enthusiasm for science by enabling them to conduct experiments and engage in hands-on learning experiences. Secondly, the teachers emphasised that the IBST created opportunities for children to acquire and practice social skills. Additionally, the teachers mentioned that the IBST played a role in enhancing children's vocabulary and language skills.

So, it (the IBST) does set the expectation that the children will be able to experiment, which is a good thing. Um, I think the children really liked it...And with that children are able to, in a small setting, talk to each other. And when one child asks questions, the other children next to him can hear it...They also have to remember our classroom agreements of how to share and how to take turns when they both want material (Ms Claire, 17-05-2023).

It provides an opportunity for our toddlers to learn more concepts by doing hands-on activities. So, of course, they are going to build more language and vocabulary while they're doing (the experiment) because you're going to ask them some questions, right? (Ms Shirley, 18-05-2023).

The class teachers provided several reflections on how to further improve the effectiveness of the IBST , including utilising outdoor spaces or shared areas, introducing the specific concepts or materials before setting up the IBST, using children's books to help toddlers understand and visualise the science concepts that they are exploring, and adding follow-up discussions and related activities to build on children's interests and curiosity.

In the final reflection, two teachers believed that the IBST set-up had increased their awareness of science teaching for toddlers and made them think more critically about how to

incorporate science in the school curriculum.

Concerns about teaching science to toddlers

The importance of science learning and the effectiveness of the IBST were discussed. However, the class teachers also shared concerns and challenges about exposing toddlers to science in the classroom.

The first concern was the insufficient provision of science materials in the classroom. Ms Claire mentioned that before the set-up of the IBST, *“there was not a lot of science available”* for children to play with (Ms Claire, 17-05-2023). Ms Shirley admitted that there were some science materials in the classroom, but she would only *“collect the relevant materials when it is required for a certain topic. But there will not be a learning station for science in the whole term”* (Ms Shirley, 18-05-2023).

The second concern discussed during the interview was the lack of science teaching guidance. Ms Claire mentioned that in the Early Years Foundation Stage (EYFS), there was *“no specific science area”* and *“no clear-cut guidance”* on how to incorporate science learning into the existing school curriculum. Both interviewees agreed that science learning was not emphasised in their school. Ms Shirley further explained that teachers might *“need to draw inspiration from the EYFS curriculum and then develop their science lesson plans”* to incorporate more science or STEAM activities into the classroom, which *“required a lot of extra effort”* (Ms Shirley, 18-05-2023).

So obviously, you didn't see that our classroom has a science area for children to explore since the set-up of the classroom and materials are regarding to our standard of curriculum. We don't see the curriculum stating that a science learning station is a must or possible to be set up in a classroom (Ms Claire, 17-05-2023).

I don't know whether STEAM is a main curriculum like EYFS, but according to what I know, it is a group of professionals writing the STEAM curriculum under a main curriculum. Therefore, implementation-wise, it requires teachers to come up with ideas to do it. I am not quite sure about it (Ms Shirley, 18-05-2023).

Both participants expressed the challenges of assessing young children's science learning. Ms Claire held the view that the limited verbal skills of toddlers made it difficult to assess their progress in science learning. Similarly, Ms Shirley also shared her puzzles about the lack of specific standards for evaluating early science learning for toddlers.

Maybe some children yet can't talk about the cause and effect of what happens around them. I think it is quite requiring for teachers to observe and understand their learning progress. But we are not quite sure about "how" (Ms Claire, 17-05-2023).

Finally, two participants regarded "safety" as a significant concern as toddlers "*frequently put materials into their mouths*" (Ms Claire, 17-05-2023). They mentioned that science learning could be messy and require additional support from other teachers to keep toddlers safe and neat. This concern prevented them from providing more science learning opportunities in the classroom.

Discussion

The purpose of this research is to inquire about the effectiveness of an IBST on toddlers' science behaviours and toddler teachers' perspectives about science learning in the classroom. The findings indicate that the science table the IBST has effectively enhanced the frequency and variety of toddlers' science behaviours and reveal the critical mediating role teachers play in toddlers' science learning and development.

Toddlers as Capable Science Learners

Although there is limited research investigating the science concepts formation and science learning trajectory for children aged 0-3, it is proved in previous studies that toddlers are capable of exploring the world around them and forming scientific concepts (Fragkiadaki et al., 2023a; Gopnik, 2012b; O'Connor et al., 2021; Sikder & Fler, 2018). The data collected in this study also suggested that toddlers were actively demonstrating science behaviours and

constructing scientific knowledge when they were interacting with science materials. Toddlers were observed to describe materials and scientific phenomena related to their own prior experience (e.g. tell the researcher that water feels cold, just like the ice cream he ate), independently explore materials and tools (e.g. use different materials and tools to transfer water from one container to the other), ask clarifying or exploration questions (e.g. ask the researcher what the sponge is used for), articulate the problem and present a solution (e.g. tell other that they will save the duck by pouring water inside), and explain the choice and the steps (e.g. tell that adding water can make the duck go to the top).

It is noteworthy that before the formal implementation of the IBST, toddlers have already exhibited certain science behaviours when interacting with less open-ended materials (e.g. the colourful water bottles), demonstrating their natural tendency to explore objects and figure out how things work. Those “unplanned” science experiences were categorised as “incidental sciencing” based on Neuman’s (1972) type of science-related activity. The beliefs surrounding the value of incidental science opportunities have contributed to a longstanding practice in early science education, where teachers provide science-related materials and leave children to “discover” objects by themselves (Gomes & Fleeer, 2020). However, this study’s findings suggest that the frequency and variety of toddlers’ science behaviours may only be enhanced when the environment is carefully prepared, and the teachers are involved with teaching intentions.

Teacher as the mediator of toddlers’ science learning and development

The IBST was structured to follow the Inquiry Teaching Model (ITM) for infants and toddlers, which consists of four processes: observe, engage learners, provide opportunities, and make decisions (Uhlenberg, 2022, p.22). Over the four interventions, the materials became more abundant and open-ended, while the facilitator’s level of involvement increased correspondingly. Consequently, the toddlers exhibited more frequent, varied, and complex science-related behaviours and language. It was evident that science behaviours related to “identifying problems” and “sharing findings” were not clearly demonstrated by toddlers until a problem-solving scenario was intentionally set by the researcher, and scientific vocabulary was purposefully used to promote deeper thinking through solving the problem

collaboratively. These findings are consistent and support previous findings in the literature that highlight the mediating role of the teacher in preparing the environment and supporting children's science learning. For instance, Gerde et al. (2018) concluded that although young children were naturally curious about the natural world and asked questions about many scientific phenomena, they would not develop deliberate scientific reasoning if teachers or adults did not provide guided inquiry related to science content, tools and process. Similarly, Fleer (2019) contended that mediation by adults was needed to support children's higher levels of problem-solving. Especially for infants and toddlers, science teaching and learning should be systematically supported as they are not verbally competent enough to express abstract ideas and thoughts. As stated by Byrne et al. (2016), even though children did not come to the classroom with a blank slate, it could not be assumed that they were able to manage inquiry-based science without progressively practising the science behaviours and skills.

On the other hand, the findings also suggest that teachers may have insufficient awareness and knowledge to capitalise on opportune moments for science teaching. During the interviews, the two participants claimed that there was limited science materials provided in the classroom setting. They also shared that they would only utilise science materials when they were specifically required to teach a relevant topic. However, in this study, most of the science materials used for the IBST set-up were collected from within the classroom environment. This suggested that the issue was not a shortage of materials per se but rather a lack of teacher awareness and intentionality in combining the available materials to create meaningful learning science opportunities for toddlers. As Gomes and Fleer (2018) pointed out, even when there were lots of science materials available in the classroom that could afford science learning, teachers might not consciously recognise the learning opportunities and miss the teachable moments. This may help explain why, prior to the intervention, the toddlers in the current study exhibited limited science behaviours related to "identifying problems" and "sharing findings" - areas where adult scaffolding was deemed highly necessary. Therefore, there is a need to explore further and address the gaps in teachers' awareness and pedagogical knowledge when it comes to effectively incorporating science learning opportunities into their daily practice. By enhancing teachers' awareness and equipping them with the necessary skills and resources, they can be better positioned to seize

the teaching opportunities and foster toddlers' curiosity, engagement, and development in the domain of science.

Limitations and Implications

The present study acknowledges several limitations that should be considered when interpreting the findings. Firstly, the small sample size in this research makes it difficult to generalise the results. Secondly, the design of the Science Behaviour Checklist used in the study requires further review and refinement. To enhance the reliability and validity of the instrument, it will be beneficial to examine its psychometric properties with a larger sample size. Employing alternative assessment tools, such as the Classroom Observation Protocol (COP) (Milford & Tippet, 2015), could provide a more rigorous criterion-based approach. Future studies should also use a robust experimental design, including a control group, to quantitatively assess the impact of the IBST intervention on toddlers' science-related behaviors and skills.

Despite these limitations, the present small-scale study still provides valuable insights into the effectiveness of the IBST in promoting toddlers' science-related behaviours. In addition, as early childhood teachers have minimal exposure to and lack understanding of the science practises and how to incorporate them into their classroom (Gerde et al., 2017), more empirical evidence on pedagogic approaches that can support the development of science concepts from infancy is needed. Teachers will only spontaneously utilise science materials effectively to engage children in scientific processes if sufficient training is provided (Edwards & Loveridge, 2011; T. Tu, 2006). Increasing teachers' sensitivity to science learning opportunities and facilitating more group inquiry experiences can foster productive dialogues and higher-order thinking skills in young children. The IBST could be a starting point for promoting science learning in Hong Kong, where the classroom space and resources are limited.

Conclusion

This study used a qualitative approach to investigate toddlers' science behaviours with the set-up of an IBST in the classroom. The observational data indicated that as the abundance and flexibility of the materials increased, along with the level of adult intervention, the toddlers demonstrated science behaviours with greater frequency, variety, and complexity in interacting with the IBST. The class teacher interview results revealed that while they recognised the importance of science learning for young children, teachers face various challenges and lack guidance in supporting toddlers' science learning. Future empirical research using a larger sample may add to what is learned in this study about supporting science learning in a toddler setting.

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Appendix I

The Interview Guide

1. What is your perspective on the nature of science learning in ECE?
2. In your opinion, do the available science materials in your classroom adequately cater to the needs of the children prior to the implementation of the IBST ? What factors contribute to your assessment?
3. How do you perceive the role of Science or STEM within the curriculum? Can you provide your justifications?
4. What notable changes or transformations have you observed in your classroom after the introduction of the IBST?
5. From your viewpoint, how do you believe the presence of IBST in a toddler classroom impacts children's science learning, including aspects such as language development and social interaction? What are the underlying reasons for your perspective?
6. What challenges do you anticipate or have you encountered when integrating science into a toddler classroom, particularly with regard to the implementation of IBST?
7. In your opinion, what additional strategies or approaches could be employed to further engage children in the process of learning science?