"We Want STEM": Exploring Digital Toys in a Hong Kong Kindergarten

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Abstract

Limited research has examined STEM education in early childhood, or addressed how STEM is integrated into the curriculum in the kindergarten level. Teachers' conceptions of STEM appear to differ from the pedagogical theory. They may be aware of the basic subject concepts, but they lack the effective teaching approaches required to integrate the subject concepts into playful learning processes. Thus, it is important to investigate how teachers can design STEM activities that involve digital toys, in addition to the subject concepts, pedagogical approaches, and factors that affect teachers' pedagogical designs. The aims of this study were to 1) investigate the different types of STEM activities in a kindergarten in Hong Kong; 2) understand the perspectives of school management teams and teachers on implementing STEM activities, and 3) provide recommendations for STEM activities appropriate to kindergartens.

Keywords: STEM, pedagogical design, digital toys, Hong Kong kindergarten

Children are born with curiosity about the world around them. Aldemir and Kermani (2017) suggested that preschool education is critical for young children as it equips them with the skills to build knowledge in later stages of education. Young children can learn the fundamental concepts of STEM through hands-on activities in preschool years. This learning experience facilitates problem-solving, critical thinking, and interpersonal communication (McClure et al., 2017). Research has also suggested that early STEM experiences are important for young children, as their Mathematics and Science knowledge in preschool years has been associated with better academic performance in those subjects in primary education (Duncan et al., 2007).

Young children can be provided with learning opportunities by experiencing different learning materials. These can be natural items such as water, sand, and wooden blocks (Lindeman, Jabot,& Berkley, 2013). Tippett and Milford (2017) conducted classroom observations of STEM-related activities in a kindergarten. Through hands-on experience, young learners gained an understanding of STEM disciplines, for example by learning about birds and their nests as science, designing and assembling components as engineering, and learning shapes as mathematics. They were very enthusiastic about participating and sharing their ideas about the STEM subjects under discussion. In addition to natural items, robotic educational tools are increasingly used in early childhood settings, as they can combine technology and engineering. Bers, Seddighin, and Sullivan (2013) suggested that the key cognitive, motor, and social skills development of young learners can be improved through robotics. Rogers and Portsmore (2004) highlighted that robotics can excite young learners in STEM disciplines and increase their curiosity and enthusiasm for learning. Bers et al. (2013) used their robotics prototype, Kids Invent With Imagination (KIWI), to create a professional development programme for early childhood teachers. The KIWI construction set is developmentally appropriate for learners aged 5-7. The robot contains two motors, a light sensor, a sound sensor, and a distance sensor, and can be assembled and programmed to be stationary or to move. Young learners can programme the robots, which can then follow their instructions, such as performing an action when the light goes out. Bers (2008) found that 4-year-old children can understand the concepts of programming and are able to manipulate robots, thus developing technological fluency in early childhood.

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Curto and Moreno (2013) explained that the construction of robots can help young learners understand key concepts from science and engineering, and they can create and participate in learning processing while interacting with others through teamwork. Tanaka, Cicourel, and Movellan (2007) found that long-term bonding and socialisation occurred between toddlers and a humanoid robot placed in a childcare centre for over 5months. The children's interest in interacting with the robot was found to increase and they treated it more like a peer than a toy. Care-taking behaviour towards the robot was observed. Similarly, in their recent research, Crompton, Gregory, and Burke (2018) found that for young learners, interacting with a robot encouraged development in domains such as language and communication, as well as physical, cognitive, and social-emotional learning. They showed curiosity towards the robot and a willingness to interact with it. They also demonstrated taking turns and cooperating with their peers in the presence of the robot.

Messer, Thomas, Holliman, and Kucirkova, (2018) conducted research on digital toys (programming on iPads) versus non-digital toys (using paper and pencils and solving mathematical problems), and found no significant differences in children's mathematics skills, spatial awareness or working memory. The results also indicated that all three types of learning experiences increased the children's mathematics and spatial abilities. The authors therefore suggested that the content of instruction is more important than the medium. Motivation is another important aspect of learning, and toys and engaging tasks have been found to increase young learners' perseverance, motivation, and responsiveness (Highfield, 2010). The role of teachers in STEM education is central, as they can encourage students to engage in STEM subjects. However, there are challenges to implementing STEM-related activities, such as ensuring appropriate pedagogical approaches and teaching content are in place. Bagiati and Evangelou (2015) conducted their research in a pre-school in the US. They found that teachers were concerned about STEM content and practical constraints such as time, scheduling, and attendance. Pedagogy is critical, as teachers must understand how to develop their students' understanding and skills via activities. The pedagogical approaches teachers take must be responsive to their students' needs (McClure et al., 2017). Project-based learning and inquiry-based instruction are central to STEM education. Project-based learning promotes meaningful learning experiences, and it has been empirically demonstrated that if students feel positive about project-based learning in STEM, it can influence their attitudes when planning their careers(Tseng, Chang, Lou,& Chen, 2013). Inquiry-based instruction is considered the signature pedagogy of STEM education, as it provides students with a comprehensive structure that can engage and develop their scientific thinking and outlook (Crippen & Archambault, 2012).

Methodology

A case study approach was applied to investigate the application of digital toys in a Hong Kong kindergarten, and to explore and evaluate STEM activities in Hong Kong early childhood education. This approach enables an issue to be investigated using one or multiple cases for illustration (Creswell & Poth, 2017). The case study design can accommodate multiple sources of data and methods of data analysis, to provide a detailed description of a complex issue (Creswell & Poth, 2017; Merriam & Tisdell, 2016; Yin, 2017). A single case study was the focus of this project. Data we recollected from multiple sources, including observations, interviews and questionnaires. Both quantitative and qualitative methods were used. In terms of research purpose, three types of case studies can be defined: exploratory, descriptive, or explanatory (Yin, 2012, 2017).Descriptive case studies aim to provide a holistic description of an issue within areal-world context, with the focus on the perspectives of the participants. The case study in this research involved the implementation of STEM activities in a Hong Kong kindergarten and assessment of the perspectives of the principal and teachers, providing evidence for curriculum design and evaluation.

Participants

The participants in the study were from a kindergarten situated in one of three newly developed towns in a Hong Kong region. This was ranked the fourth fastest-growing of 12 new towns in terms of population in the 2018 Hong Kong Census. The district surrounded by private and both public housings and most of the parents were employed. The kindergarten was a non-profit-making school and participated in the Hong Kong government's voucher scheme. It offered half-day classes (3hours) in the mornings and afternoons for 3- to 6-year-old children (K.1-K.3). The children attended these classes 5 days a week. The class was made up of 30 children and three kindergarten teachers and the ratio was thus 1:10, which is smaller than the government's suggested ratio of 1:11. The head teachers delivered a daily story approach curriculum, which included a high scope and project approach, whilst other subject teachers delivered a curriculum consisting of visual arts, religion, STEM, and "Zippy Friends" on Fridays.

This study contributes to the discussion of STEM activities in Hong Kong early childhood education by presenting the case of a Hong Kong kindergarten. Three questions are addressed:

1) What types of STEM activities occur in Hong Kong kindergartens?
2) What perspectives do principals and teachers have on implementing STEM in Hong Kong?
3) How do teachers implement STEM activities in Hong Kong?

The school team profile

The principal had over 30 years of teaching experience and had been in the role for 20 years. She had founded the school in 2001. Thirty qualified teachers were employed at the school, with backgrounds in early childhood education, music, art, and physical education (Table 1). They varied in the duration of their teaching experience (Table 2).

Table 1 Teachers' (Including Principal's) Educational Qualifications

Qualification	Master of Early Childhood Education	Postgraduate Diploma of Education	Bachelor of Early Childhood Education	Bachelor of Visual Art/Music	High Diploma in Early Childhood Education	Other
No. of Teachers	5	3	11	2	8	1
Percentage	16.7	10	36.7	6.6	26.7	3.3

Table 2 Duration of Teachers' Teaching Experience

Years of Teaching Experience	0-3	4-6	7-10	>11
Number of Teachers	13	4	2	10
Percentage	44.8	13.8	6.9	34.5

The school-based curriculum

The school applied the Kindergarten Education Curriculum Guide (2017) developed by the Education Bureau of Hong Kong, which emphasizes the promotion of learning through play and strengthening the elements of free exploration in play. It also recognises the strengths of the current school-based curriculum. The Guide includes the six learning areas of physical and health education, language, self and society, early mathematics, arts, and science and technology. The children attended half-day classes from Mondays to Thursdays, which had a mainly school-based story approach and also incorporated a HighScope curriculum, and project-based approach. In addition, the school took a free play approach on Fridays and included other co-curricular activities such as visual art, religious study, additionally STEM activities have been involved from 2018.

Procedures

The data collected were quantitative data from the teachers 'responses to a survey of their perspectives and practices regarding the implementation of STEM activities (see Appendix 1), and qualitative data from interviews with the principal and three teachers. The varying lengths of their teaching careers enabled an in-depth investigation of their readiness, attitudes, and teaching experiences regarding STEM activities. A self-assessment questionnaire produced by the WGBH Educational Foundation for the Massachusetts Department of Early Education and Care, developed using federal funds from The Race to the Top: Early Learning Challenge Grant, was revised and used for the teacher survey (Engaging Children in STEM, 2014). The survey items were scored on a 5-point Likert scale (1= *strongly dissatisfied*, 2=*dissatisfied*, 3=*neutral*, 4=*satisfied*, and 5=*very satisfied*). In addition to the 13 survey items, three open-ended questions examined teachers' beliefs about STEM education in terms of children's growth and the challenges and difficulties teachers may encounter in teaching STEM, and invited their suggestions concerning the STEM curriculum. The questionnaires were distributed to 20 teachers from the school. A total of 19 were completed as requested (return rate=95%). The returned questionnaires were coded and were processed by statistical means. To collect qualitative data, semi-structured interviews were conducted with the principal (P) and three teachers with different levels of teaching experience (Teacher A=experienced, Teacher B= medium, and Teacher C=least experienced) to investigate their perspectives and teaching practices regarding STEM activities. The semi-structured interviews took around 30 minutes each, was conducted in the school and were audio-recorded for data analysis. The

interview data was coded using interrelated themes, such as the teachers' perspectives on STEM education in early childhood and the implementation of STEM, and their reflections on teaching and children's STEM learning.

The main interview data were also coded by themes including perspectives on STEM in education, the development of the STEM curriculum at the school, teachers' attitudes towards STEM teaching, children's learning through STEM activities, and parents' views of the STEM curriculum.

Results

Perspectives on STEM Education in Early Childhood

The principal

In addition to the main emphasis on "learning by doing" and "free play exploration" in the Hong Kong Kindergarten Curriculum Guide, the principal developed the STEM curriculum as one of the regular Friday co-curricular activities. She believed that the children's exploration skills, creativity, collaboration, and problem-solving skills were enhanced through free play exploration using STEM learning materials. She designed the school-based STEM curriculum herself and explained that: I notice that the children were very interested in playing with new blocks purchased at the beginning of the school term. I attended a learning exhibition and was introduced to some STEM toys there. I believe that the children may be interested in playing with these STEM toys, just like the blocks. I believe that children learn through exploration, creativity, collaboration, and problem-solving from STEM toys. I also want to let children play with the STEM toys under a free play approach as free play toys. Without integration into the story approach curriculum, teachers find it less stressful planning the STEM curriculum. Teachers are not required to evaluate the STEM curriculum formally, so they enjoy the STEM activities freely with children. (P-1.1)

The teachers

In the teacher survey, 74% agreed that STEM education was meaningful to children's growth and believed that parents supported their children in learning STEM. All of the teachers interviewed gave positive feedback on STEM in early childhood education. They believed that the STEM toys were interesting to children as they could be manipulated, and as the children worked on STEM activities in small groups, they could collaborate to solve problems. They worked by themselves, which had not been observed with traditional learning materials. For example, the teachers said: My sons are in Grades 3 and 4 of primary school, I learned from them that STEM education is a broad subject. It is much more than just "STEM toys". I learnt from my sons that there are life sciences and more, not only STEM robots, which can be integrated into different curriculum approaches, such as the story approach. I hadn't learned about STEM before, I only knew simple science concepts. However, I know kids like robots very much. There is no harm in just letting children play with them as toys. (Teacher A) The STEM curriculum is a world trend. Children enjoy learning by doing and free play. Children have more fun when the activities are scheduled on co-curricular days and when they are not assessed in the activities. It is stress free for both children and teachers (Teacher B). I have never taught STEM activities and actually I am not quite sure what it [STEM] is. I only know there are Mathematics, Science, and Technology subjects that can be learned from the STEM toys. We just follow what the principal designed and shared with the school at the end of each term. However, as class teachers, we shared our experiences every Friday (Teacher C). Children look forward to every Friday as they can play with the STEM robots. Teachers observed that children enjoy playing together with their classmates. Some of the children had experienced STEM toys at home, and they showed greater interest, especially the boys were emphasized.

The Development of the STEM Curriculum and Learning Settings

The STEM curriculum was developed by the principal and vice principal in 2018. Their aim was to foster children's exploration, creativity, collaboration and problem-solving skills that enable them to enjoy explorative free play with the STEM learning materials. Parents were briefed about the goals of the STEM curriculum at the beginning of the school year. The learning materials were STEM toys from the commercial market and digital robots were the main type. Before the new school year commenced, the principal and vice principal assessed STEM toys at exhibitions of learning products, where they were able to manipulate the toys before purchasing them for the school. After purchasing, the principal invited the toy distributors to demonstrate the STEM toys to the teachers. The principal then developed the STEM curriculum with the above learning goals. She explained that: I attend the learning exhibition every year to explore new learning materials for children. Last year, I was introduced to many STEM toys, especially a robot. I found that this STEM toy was a good one to start our STEM curriculum.

I treated this as one of the toys in the school that could encourage problem-solving skills, creativity, collaboration skills, and exploration skills under the free play approach(P-1.2).

On the staff development day at the beginning of the new school term, I organized a workshop in which teachers could play with the STEM toys. It is important that teachers know how robots work, just like traditional learning materials. I reminded the teachers that the free play approach was adopted in STEM activities. Teachers should not intervene during the STEM activities and should just support the children to solve problems on their own. (P-1.3)

The principal stressed that the school-based story approach underpinned the free play approach in the STEM curriculum, and allowed the children to play with one selected STEM robot as part of the co-curricular activities that took place every Friday. She observed that the children enjoyed playing with the STEM robots. Although she had limited professional knowledge of how to integrate STEM into either the school-based story approach or the six learning areas, her reference to the learning areas of early mathematics and science and technology obviously alluded to STEM.

The Teaching of the STEM Curriculum

The STEM activities setting

Teachers followed the STEM curriculum designed by the principal and the learning goals of each STEM activity. The children played with a STEM robot for 40 minutes to 1 hour every Friday in one school term. The children organised themselves into groups of three in their own classroom. The teachers supported the free play exploration of the children and did not interrupt them during their free playtime. Hu (2015; 2017) divided teaching activities into the three categories of teacher-initiated and teacher-directed (TI-TD), teacher-initiated and children-directed (TI-CD), and children-initiated and children-directed (CI-CD). She also developed four analytical steps to distinguish these three types of activities: (1) initiator of activity; (2) specificity of teachers' intended learning outcome; (3) intensity of children's participation; and (4) children's playful experience. The following flowchart (Figure 1) presents the categories and process used to identify teaching and learning activities.
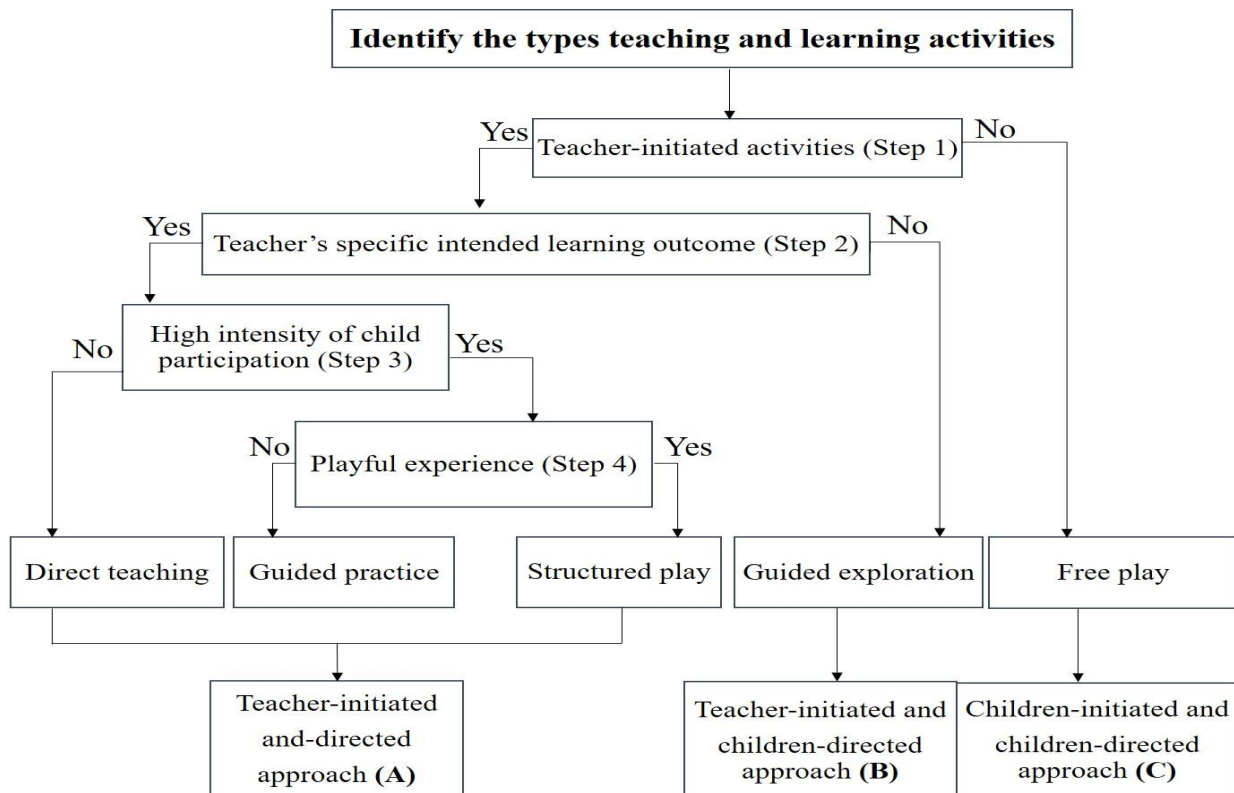
Figure 1. Flowchart for identifying teaching and learning activities (Hu, 2015). This figure describes the process and categories used to identify teaching and learning activities

In this study, 63 teaching plans we recollected after digital toys were used at the Hong Kong kindergarten for the entire academic year. Each age group provided 21 lesson plans. The research target classes spanned stages K1 to K3, and the five digital toys used were coded. This analytical framework was used to classify and collate the research data, and the following findings were obtained. **Activity type distribution.** The research team examined and analysed the data on the three age groups. The results are shown in Figure 2.

TI-TD   Teacher-Initiated and Teacher-Directed
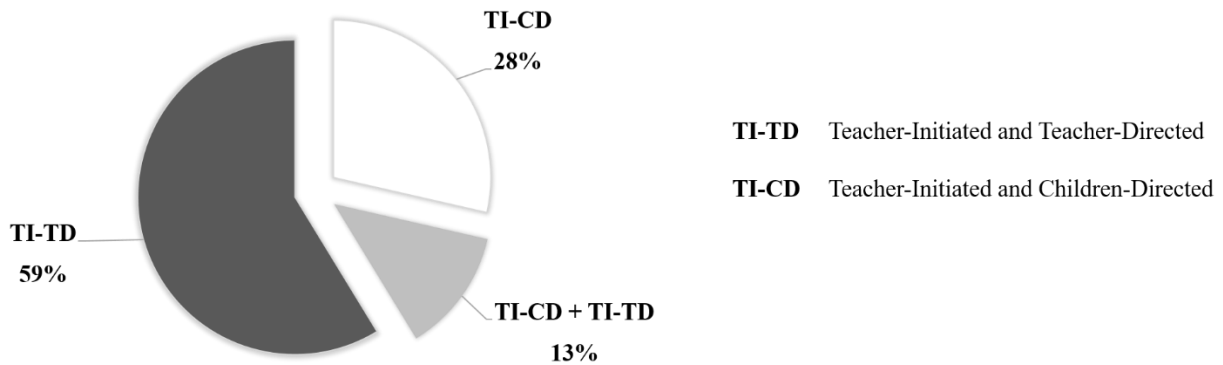
TI-CD   Teacher-Initiated and Children-Directed

Figure 2. Activity type distribution. This figure shows the distribution of activity type among the three age groups

In all 63 classes, 37 activities (59%) were TI-TD (initiated and directed by the teacher), 18 (28%) were TI-CD (initiated and directed by the children), and eight(13%) were TI-CD and TI-TD (mixed). Thus, when using the digital toys, the teachers mainly used TI-TD activities in the classrooms. **Activity type distribution by age.** Figure 3 illustrates the three activity types used in the63 lesson plans for the different age groups. With an increase in the age of the children, the data on the TI-TD and TI-CD activity types form an X-shaped interaction, demonstrating that the teachers who used digital toys gradually increased the frequency of the TI-TD activity type during the teaching process. Thus, the frequency of TI-CD activities was reduced daily for the children across their fixed school time. The use of the TI-CD + TI-TD mixed activity type also slightly increased with the children's age.
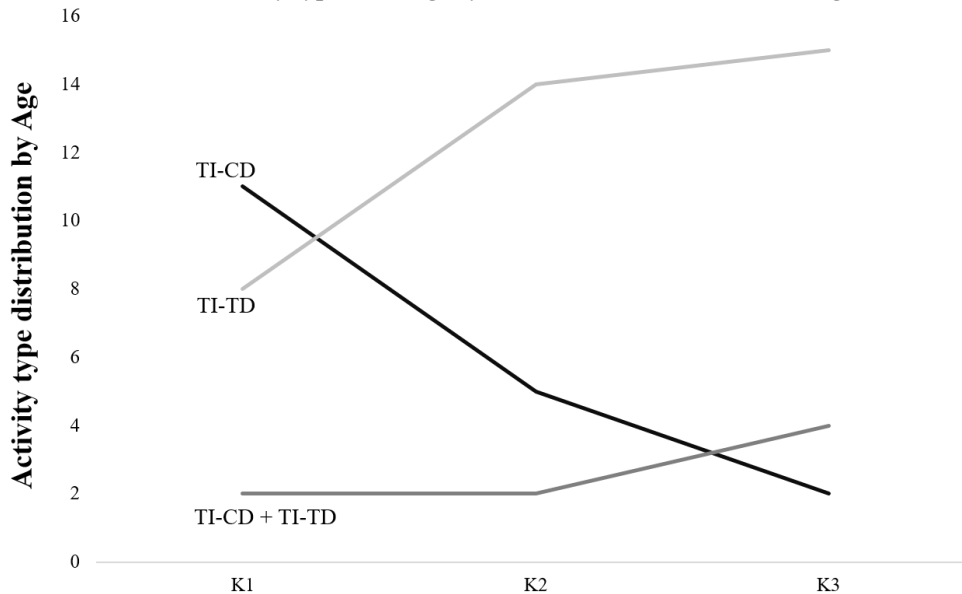

Figure 3.Activity type distribution by age. This figure provides a graph showing the distribution of activity type by the children's age.

In this study, teachers prepared digital toys for the children in all of the teaching and learning activities, and so the children's learning and development were gradually encouraged and stimulated. Thus, all of the teaching activities in this study could be identified as TI-TD or TI-CD. TI-TD was further refined into the three distinct types of direct teaching, guided practice, and structured play, whilst TI-CD had only one type, guided exploration.

The research team conducted a detailed examination of the specific data on the three TI-TD pedagogical approaches and compared and analysed the integrated data. Of the 45 TI-TD activity type classes and the eight TI-TD+TI-CD mixed activity type classes, 35 classes (66%) chose structured play, 18 (34%) chose guided practice, and no classes chose direct teaching. The analysis results are given in Figure 4.
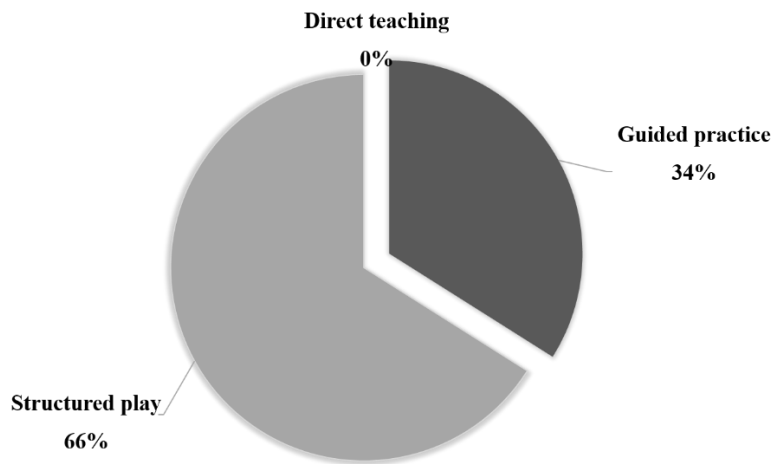

*Figure 4.*Pedagogical approach distribution. This pie chart shows the distribution of pedagogical approaches across the classes.

Teachers' beliefs about teaching influence their interpretations of what they have learnt from their training and professional development, their actual classroom practices (Breffni, 2011; Polly, Neale,& Pugalee, 2014) and their pedagogical decision-making and attitudes(Nathan, Tran, Atwood, Prevost,& Phelps, 2010). The survey assessed the teachers' views on the effectiveness of using learning centres to engage children in STEM (Table 3).

Table 3 Teachers'Self-Assessment of Use of Learning Centres to Engage Children in STEM

Use of Learning Centres to Engage Children in STEM	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied
Using existing learning centres to engage children in collaboration, planning, investigating, designing and problem-solving.	0%	2%	47%	42%	0%
Planning for and creating additional learning centres that invite children to use STEM.	0%	37%	47%	16%	0%
Asking open-ended questions that prompt children to think deeply about STEM and integrate STEM language into their vocabulary.	0%	21%	42%	32%	5%

The results revealed that the teachers felt less comfortable about integrating STEM learning in learning centres and guiding children to gain different skills from STEM experiences. The STEM curriculum was not integrated into the school-based story approach and was only conducted in the classroom as one co-curricular activity. We didn't evaluate the STEM curriculum formally, which was good, unlike the formal curriculum from Monday to Thursday. We encouraged children to solve problems in groups. For example, the children found that the robots were affected by other tablets when the robots were too close to other groups. I asked the children how to solve this problem, they suggested moving one group outside of the classroom. We shared our evaluation informally every week and revised the learning goals for the next week, especially when we found that a few children encountered difficulties in manipulating the robots. We didn't feel any stress about the STEM curriculum even though there were challenges to children and ourselves (Teacher B).

In addition, the teachers did not receive any formal STEM training before the implementation of the STEM curriculum. The school invited teachers to share their experiences at the teacher development day at the end of the term. In the interviews, the teachers said that: This was the first year of the STEM curriculum in our school. We only had one introduction workshop by the STEM toys distributors. They only introduced how to manipulate the toys using the manual. They didn't train us in any teaching methods with children and there's no sustainable training throughout the year.

The principal designed the STEM curriculum and we found that some learning goals were difficult for children to achieve as she didn't implement the STEM activities. She invited us to share our experiences in the middle of the year with other teachers in the staff development days. We suggested that the learning goals should be revised to meet the children's abilities. Our teacher role was to support children's free play, not to be teacher-directed. The STEM activities are still attractive to K.3 children as they used them as one of the free play sessions on Fridays and they had no classwork or homework(Teacher B). At the beginning, applying STEM toys were new learning experience to the K.2 children. There were only a few children who had used these kinds of toys at home. Teachers observed that some children encountered problems manipulating the robots after many trials. Two children came to teachers and said they wanted to play with other toys. After discussing, the teacher changed the group size to five and paired children with STEM experience with the children who had the least experience. This encouraged them to support their peers with less ability and experience. The teachers also responded in the survey to questions about the teaching strategies they used to help children reflect on and articulate the knowledge they gained through STEM. The results revealed that they were generally satisfied with their guiding skills and the strategies they used (Table 4).

Table 4 Teacher Self-Assessment on Guiding Children to Reflect on New Understanding

Approach to Guiding Children to Reflect on New Understanding	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied
Prompting children to reflect on and summarise their learning by looking back at a prediction and comparing it with what happened.	0%	2%	32%	63%	0%
Prompting children to reflect upon and summarise their learning by reviewing their experiences and observations and coming to a conclusion or providing an explanation.	0%	0%	48%	47%	5%
Prompting children to reflect upon and summarise their learning by looking at related experiences and making connections with their own.	0%	26%	63%	11%	0%

Children's Learning in the STEM Curriculum

Children can develop fine motor skills, eye-hand coordination, and collaboration skills through teamwork (Lee, Sullivan,& Bers, 2013). Robotic manipulation allows children to become not only engineers, by playing with motors and sensors, but also storytellers, by creating and sharing their projects (Bers, 2008). In this study, the children in all of the age groups regarded the STEM activities positively. The STEM toys were appropriate to most of the children's developmental stages and were more appropriate when there were more learning aids in the design that supported children's exploration in the free play. Individual differences were observed among the children, and those with a greater interest directed the activities while those with less interest or less experience were more passive. Most of the children looked forward to the STEM activities on Fridays but few demonstrated that they solved problems with peers in groups. Some applied the skills they used in playing with blocks to solve the problems. For example, the teachers said: The children helped each other when playing with the STEM toys. They displayed collaboration and problem-solving skills. They showed how to manipulate the robots after a few weeks. We then asked the children to share any "new" ways to manipulate the robots to motivate them to find new experiences. Or else, we grouped children so those with higher ability could support the lower ability children (Teacher B). Some of my children felt a bit frustrated when they couldn't manipulate the robot at the beginning of the term. This robot required concepts of direction but the children hadn't learned these concepts at the beginning of term. They just kept pressing the buttons to try to make it move. They also found that the robots were affected by other remotes because they were too close. They then formed a bigger group to reduce the number of robots in the class. However, in the second term, the children played with another robot, "Cubetto."This one had more picture cards as aids to support the children's play.

I observed that the children were more confident, maybe because they gained some manipulation skills in last term. Unlike playing with blocks, the robots can be coded when the children have obtained the required concepts and coding skills. Children just played with the blocks freely in their own ways (Teacher C).

The children were not assessed in the STEM activities, but the school evaluated the STEM curriculum after one term in a teachers 'curriculum meeting. They were not required to evaluate the activities formally, but after each week the teachers discussed whether and how they should revise the learning goals for the following week.

I think the K.1 children were a bit young to play with STEM robots, which required lots of rules to play. The K.1 children had no Mathematics or other concepts enabling them to do the coding for the STEM robots. Some of them kept pressing the buttons to make the robots move, and the robot nearly fell off the tables. Some children looked frustrated when the robots did not move, they gave up trying. At the beginning, three of us monitored the groups but left them alone, but we found that we needed to support one small group of children. Then, we demonstrated some basic operational skills to this group and changed the group size to five children so they had more peer support. Then, some children regained their confidence and played with their classmates (Teacher A).

The Views of Parents and Children of the STEM Curriculum

The principal collected feedback from parents and children on the STEM curriculum, as this was the first year that it had been implemented in the school, using a parent questionnaire at the end of the school year. They were asked whether they thought STEM could encourage children's interest in learning, creativity, problem-solving, and collaboration, and if they agreed that STEM should be implemented in the school. In the interview, the principal said: I am so pleased to see that the parents are very positive about the STEM curriculum. As it was the first year of this curriculum, I was a bit worried about the feedback from parents. The results of the survey were very encouraging, and over 95% of the parents agreed that [the STEM curriculum promotes] children's learning, creativity skills, problem-solving, and collaboration. They strongly agreed that the school should continue to implement the STEM curriculum (P). The principal also collected the children's views of the STEM curriculum at the end of the school year, along with the other co-curricular activities that took place every Friday. She said in the interview: The children also enjoyed the STEM activities. Over 90% of them enjoyed playing with the STEM robots. The children shared in the open-ended questions that as they liked the STEM robots because they found them funny, they can control the robots and make them move, either by themselves or with others. I think children experienced how to manipulate the STEM robots after a few weeks of the term. They gained the confidence to control the STEM robots as they said and they enjoyed play in groups rather than by themselves (P).

Teachers' Attitudes to STEM Teaching and Challenges

Vartuli (2005)suggested that teachers' beliefs are at the heart of teaching, and guide their behaviour and decisions in classrooms. Although the teachers agreed that STEM was a trend in early childhood education, the key results from the survey revealed that they were not generally positive in their self-assessment of STEM education(Table 5).

Table 5 Teacher Self-Assessment of STEM Education

Aspect of Self-Assessment	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied
I understand what STEM is	0%	16%	42%	42%	0%
I recognize the opportunities of STEM exploration that already exist in my programme	0%	5%	37%	58%	0%
I can engage children in all aspects of STEM	0%	21%	53%	26%	0%

In addition, a teacher shared concerns about STEM teaching in the interviews: We didn't receive any training in teaching the K.1 children to play with STEM. We were only briefed once on how to manipulate the STEM robots. We believe that there should be some teaching techniques such as questioning skills and supporting skills. Therefore, when we observed that the children didn't know how to play with the STEM robots, we hesitated to get involved in the STEM activities, but we knew that otherwise, the children may have lost interest due to their disappointment. Importantly, we don't know much about STEM, so it is not easy for us to teach the terms of STEM. We only taught simple science activities but I believe there should be more in the STEM curriculum (Teacher A).

Although the teachers supported the STEM curriculum in schools to encourage children's interest in learning and potential, they shared their difficulties in implementing the STEM activities at the beginning of the school term. This was consistent with the finding that early childhood teachers are less confident in implementing nature/science activities than other activities in other curricular domains (Torquati, Cutler, Gilkerson, & Sarver, 2013). The STEM robots were a bit complicated for the K.1 and K.2 children. The teacher-child ratio should be smaller than 1:10, so we can better support the children. The space in the classrooms was too small to play with about 10 STEM robots. We were not told that the STEM robots might be affected if they were too close to each other. The children noticed that their STEM robots were disturbed by the other remotes of other groups because they were too close.

We then moved a few groups to play outside the classroom to allow more space (Teacher A and Teacher B). In the first few weeks of the new STEM curriculum, teachers observed that some children became frustrated when they found difficulties in exploring the robots by themselves. Teachers reflected and decided to demonstrate some basic skills for manipulating the robots. However, some designs of robots were not user-friendly and were without any learning aids to support children's explorations, such as picture cards.

Discussion and Next Steps

STEM integration depends on a clear understanding of the STEM curriculum. This project revealed that teachers may lack the STEM-related knowledge and pedagogical approaches needed to provide the appropriate instruction and support for children when they explore digital toys. The child participants, the principal, and the teachers are really new to STEM integration, and as this was a new experience, the teachers lacked the professional development to equip children with the relevant concepts, particularly those related to STEM curriculum design for young children. The teachers experienced difficulties in answering the children's questions and providing child-directed STEM activities. The teachers may not be familiar with the scientific and mathematical concepts of digital toys, which may lead to problems integrating technology and engineering in early childhood education. The one-off demonstrations from the toy manufacturers did not provide sufficient information for the educators to design age-appropriate activities. Generally, teachers had positive attitudes towards learning STEM, but they expected on-site professional development so they could apply it in classrooms. For the younger group in particular, guidance in operating the digital toys was required, and so the teachers needed to provide the children with the initial steps to explore the STEM-related functions.

Digital toys can be considered as cognitive tools for teachers and involve multiple learning experiences. Through the exploration play process, teachers can guide students to apply mathematical concepts and problem-solving processes when exploring spatial concepts, measurement, structures, numbers, and representation. For example, the operational keys on the back of the robot can control its directional movement, which can provide children with self-directed learning opportunities. In this project, children positively engaged in operating the remote controls to learn the basic coding strategies. To programme the robot to carry out actions, young learners put coding blocks on the control board and combine them to create a sequence of movement. They could explore this method in books, which provide an educational background that shows these young learners that they can use coding to perform different tasks. The programming language was a visual drag-and-drop coding tool aimed at making coding interactive and fun. As English (2016) emphasized in her study, teacher input concerning new engineering design concepts is required when implementing STEM education. Her research reveals the lack of inclusion of engineering experiences in primary grades, due to the view of engineering as being too complex to teach and learn. Digital toys are hands-on, technology-based tools used in STEM activities. The toys for kindergarten learners are unplugged and interactive. The integration of robotic toys in teaching and learning provides children with opportunities to not only learn coding, mathematical and spatial concepts, but also develop high-level cognitive skills such as creative thinking and problem solving while they actively engage in learning (Alimisis, 2013).

Conclusion

The aim of this study was to investigate the different types of STEM activities in a kindergarten in Hong Kong, examining the perspectives of the school management team and teachers on implementing STEM activities, and provide recommendations for appropriate STEM activities in kindergartens. Three activity types were found to be used to analyse the collected STEM activities with STEM robots. The teacher-initiated and teacher-directed types were mainly used in the classroom. This confirmed that failing to integrate STEM in the early childhood curriculum can lead to missed opportunities in practicing and mastering the knowledge and skills required to implement an effective STEM curriculum.

Although the participants in the study valued the role STEM can play in early childhood in this rapidly changing world, their teaching beliefs influenced their classroom practices and pedagogical considerations. From the survey and interviews, it emerged that the participants were aware of the importance of learning STEM knowledge in early childhood, but they were not aware that STEM could be a valuable component in other learning areas. Significantly, teachers lacked sustainable professional training in STEM integration and the necessary subject knowledge and skills. These were barriers to implementing the STEM curriculum effectively alongside their school-based curriculum. In summary, this study provides implications for school management teams and teachers, and it can assist them in implementing STEM activities within a school-based curriculum.

The acceptance of STEM learning and the teachers' beliefs are more likely to be the major factors in successful STEM integration, and it can help maximise the children's potential learning and STEM-related skills. As an exploratory experience, STEM learning can help stimulate children's authentic learning. However, the methods used to prepare teachers are important so they can offer appropriate activities. Additionally, we suggest that on-site school-based curriculum development plans should be designed to help teachers identify playful learning strategies according to children's learning needs. Research teams could also follow up on the initial experiences and analyse how children reflect on their learning processes by developing observational tools that can assess children's physical, emotional, and cognitive engagement in STEM activities, particularly when combined with the school curriculum.

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