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STEM Education in Early Years: Challenges and Opportunities in Changing Teachers' Pedagogical Strategies

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Abstract: In recent years, there have been growing calls to include STEM education in early childhood (EC). This has created new challenges for EC teachers as they try to find ways to integrate STEM content and pedagogical strategies into school-based curricula. This study interviewed 24 EC teachers to understand their roles in implementing STEM education in preschool classrooms. The qualitative interviews explored changes in teachers' roles and challenges before and after integrating STEM-related activities. The study revealed that the STEM education process is a dynamic one, and that the role of EC teachers is changing from one delivering teacher-centered knowledge to one fostering STEM-related learning in children. The research findings indicate that EC teachers face various challenges when implementing STEM education. The transformation of the teacher's role during STEM classroom practices when encountering a range of challenges is discussed.

Keywords: early childhood education; pedagogical strategy; STEM education; teachers' role

1. Introduction

In the past two decades, STEM (Science, Technology, Engineering, and Mathematics) education has gained dramatic and larger-scale interest among educators and researchers all over the world [1–3]. Researchers and educators have called for national awareness of the significance of engaging in STEM education in the general education system as early as possible [4,5]. STEM education in the early childhood education field has been considered an "effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" [6]. Yelland [7] further defined STEM in the instruction aspect: "STEM education in the early years provides a context for designing active learning ecologies that connect with children's natural curiosity about their world. It engages children in authentic investigations, using critical and creative thinking in systematic ways to build knowledge, acquire skills and cultivate confident dispositions for learning (p. 5)".

Early childhood education (ECE) prepares children with the skills they need to build knowledge in the later stages of education [8]. The period between infancy and the third grade is critical to developing STEM-related thinking dispositions such as curiosity, inquiry, assessment, and analysis. STEM education provides children with contextualized and authentic real-life contexts to observe, investigate, and collaborate with others to solve meaningful real-world problems [9]. As such early STEM education will also help to give children a learning mindset and confidence in the face of challenges [10]. The most critical factors of STEM success are brain structures cultivated from an early age through children's early experiences; these will be the foundation for developing children's lifelong thinking skills and learning methods [11].

Research has also shown that STEM education being started early could benefit children in multiple aspects. On the cognitive aspect, early STEM education enables children to develop various kinds of STEM-related knowledge and skills [12], nurture STEM-related thinking [13], improve their understanding of abstract concepts [14,15], apply their existing

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life experiences and expand on new experiences during the learning process [16], and develop agency of learning scientific knowledge [17]. On the affective aspect, children gain opportunities to enhance STEM-related learning interest and motivation [15,16], participate in active learning [15], and enhance their engagement in exploring and learning [14,18,19] and their STEM dispositions and feelings [12]. On the skills aspect, early STEM education can also support children in developing their problem-solving skills [12,14,20], collaboration and creation [15], imagination [14], science-related questioning skills [13], science process skills [16], and digital skills [17].

1.1. Early STEM Education in Hong Kong

The Hong Kong Government's Policies of 2015 and 2016 highlighted the promotion of STEM education in primary and secondary schools in Hong Kong. These policies aimed to give students an innovative mindset as well as strengthen their soft skills [21,22]. In the STEM education report published in 2016, the government disbursed a one-off grant to each school to promote STEM in the primary sector. In 2022, the government policy address highlighted the promotion of STEM education "for all", "for fun" and "for diversity" in primary and secondary schools [23].

However, despite all this, early years STEM education was not mentioned or promoted by the Education Bureau, although Mathematics, Science, and Technology were separately introduced in the Guide to Pre-primary Curriculum in 2006 as "Early Mathematics" and "Science and Technology" [24]. STEM education was still absent in the 2017 kindergarten curriculum guide; the learning area "Science and Technology" was replaced by "Nature and Living" with the aim of nurturing curiosity and motivating students to explore the world around them. It emphasized that the kindergarten curriculum was transdisciplinary and was tightly connected with young learners' daily lives. Yet technology was only vaguely mentioned. It suggested that teachers could guide students to make good use of technological products to assist them in daily tasks [25].

Countries with stronger STEM development were found to share several similarities, including teacher satisfaction and support, professional development in disciplinary contents, curriculum guidelines, national STEM policy frameworks, etc. [26]. Considering the lack of support in early years STEM education and limited welfare policies for kindergarten teachers in Hong Kong, it comes as no surprise that the development of STEM education in early-year settings in Hong Kong lags behind that of other regions.

1.2. EC Teachers' Challenges of Implementing STEM Education

Teachers' beliefs about pedagogy can promote student engagement and motivation [27]. Although more than 90% of subject teachers have undergraduate or higher degrees beyond the subjects they teach, according to Gao [28], they often lack sufficient professional training in teaching methods. This pedagogical deficit can lead to a lack of confidence in their ability to improve their teaching skills and understanding of STEM education, making it difficult for them to align with curriculum reforms, stimulate students, and engage effectively with students in STEM classrooms [28]. This deficit also poses a barrier to the implementation of STEM education. Cheng [29] states that STEM education requires teachers to be familiar with scientific principles so that they can explain them to young learners with examples and arouse students' interest in exploring the world.

Hu and Yelland [30] point out that preschool teachers are expected to be independent in terms of the usage of technology and teaching content related to STEM. However, even though primary and secondary schools now have more governmental support than before, Hong Kong Federation of Education Workers [31] indicates that over three quarters of surveyed teachers feel that they face huge challenges when conducting STEM education. In 2018, 68.8% of teachers stated that a lack of sufficient STEM-related knowledge and skills caused difficulties in carrying out STEM education activities, and among 65% of school management staff, the principals agreed that inadequate teacher training made it difficult to implement STEM [32].

Teachers' beliefs impact the classroom in numerous ways. Being able to organize and carry out high-quality teaching and address children's issues might be helped or hindered by teachers' perceptions of their knowledge base and the quality of their resources [33,34]. One study on the influence of teachers' beliefs on understanding and supporting STEM education revealed that preschool teachers will spend less time in class on specific content when they believe they lack the necessary teaching skills or have low self-efficacy in that content area [35,36].

1.3. Pedagogical Strategies in Early Childhood STEM Education

Pedagogical strategies are crucial to being able to create meaningful STEM education activities. One of the fundamental pedagogical strategies for teaching STEM in the early years is using real-life experience and hands-on exploration in a child-centered learning process. Research indicates that exploratory play [37] provides children with a better understanding of STEM content and practical problem-solving in our society. Incorporating real-life experiences, such as in design and making activities [38], enables teachers to make STEM education more relevant and meaningful to children.

This approach also encourages children to ask questions, explore, make, and share. Bagiati and Evangelou [12] invited 15 children to gain STEM knowledge and learn skills related to construction through a STEM activity themed 'Let's build a city', aiming to teach skills such as counting and simple calculation, material selection, shape, structure, etc. In the activity, a puppet ('Sam') asked the children for help to solve an urgent problem: building a bigger house to store his large number of birthday gifts. The children designed and created new, bigger houses for Sam by communicating and negotiating with peers and using hands-on activities. The research showed that the children developed STEM knowledge and skills in this dynamic process. Their STEM dispositions and feelings were enhanced through peer cooperation and the buildings they designed and constructed.

Some EC teachers also use story books or picture books to arouse children's interests in STEM education. 'The authenticity of a problem is largely determined by the contextual information in which the problem is situated (p.59)' [39]. A teacher can use a story to guide children to ask science-related questions, such as how apples grow [13]. The above study showed that storytelling increases interest in STEM education, science-related questioning skills, and STEM-related thinking skills. Fleer [14] found that using the story of a Robin Hood treasure hunt could motivate children to solve an engineering-related problem. In that study, children gained an understanding of engineering principles and concepts, enhanced their engineering thinking, and developed engineering-related skills such as design and prototyping.

Another crucial pedagogy strategy in EC STEM education is to design a continuous and long-term learning process jointly constructed by teachers and children such as inquiry-based learning. EC teachers think that inquiry-based learning is an effective way to enable children to explore STEM concepts in open-ended learning. This dynamic learning process engages children, fosters their curiosity, develops their problem-solving skills, and guides them to interact with STEM resources to build age-appropriate STEM concepts [20].

Dİlek et al. [16] explored the impacts of inquiry-based learning on children's science motivation and process skills. Fourteen children aged 5–6 years were invited to investigate the scientific concept of 'force' through inquiry-based STEM education. The teacher used a story about force to arouse the children's curiosity. The children then took the lead in using different objects in group activities to conduct sink and float experiments in water. Through summarizing and reasoning about the phenomena and data obtained from the experiments, the children found the types of objects that floated or the methods for helping them float. The children applied their existing life experiences and expanded on new experiences during the learning process.

Flexible learning resources [40] are essential in transitioning from a knowledge-based learning culture to developing a dynamic STEM education process. Teachers can improve their role as co-creators and knowledge co-constructors in STEM activities by providing the necessary resources and support. In a study by Schaen et al. [15], a teacher and a group of older children used a free web app named 'TinyTap' to design a new app for younger children's mathematics learning. The teacher demonstrated the way to use 'TinyTap', illustrated younger children's learning needs, and provided technical support when the children asked for help. The participating children enhanced their understanding of mathematical concepts, active learning, STEM-related learning motivation, collaboration, and creation.

Johnston [17] provides another useful example. Two EC teachers and their children used both digital and physical resources to explore outer space and the solar system; they used an app related to outer space and the solar system, and confetti to represent stardust. The study found that both physical and digital resources supported children's hands-on learning opportunities and a joint scientific information base. Additionally, digital technologies supported EC teachers and children as they attempted to co-investigate. The utilized learning process enabled them to share their understanding and seek new knowledge about space by transitioning between the roles of apprentice and expert. Using physical and digital resources appropriately, and balancing processes of making and remaking, provides children with opportunities for sensory play and explorations of their world, broadening children's STEM education opportunities in their daily lives [41].

In the context of early childhood education in Hong Kong, it is crucial to investigate challenges that may arise during the implementation of STEM education and the role of EC teachers in this process. By exploring the following research questions, a deeper understanding can be gained of the opportunities and challenges of incorporating STEM approaches in an early childhood setting.

1. What challenges do EC teachers encounter during the process of implementing STEM education in Hong Kong?
2. What has changed in EC teachers' considerations of curriculum and pedagogy before and after implementing STEM education?

2. Methodology

This interview-based study draws on the reported experiences of early childhood (EC) teachers in Hong Kong. The findings reported in the present study belong to a large continuous project examining different aspects of STEM education in Hong Kong's early childhood education. The aim of this study was to understand the needs, challenges, and limitations of early childhood teachers to implement STEM activities in their current curriculum context. A designed reflective STEM classroom practice approach was introduced to the participating teachers. The approach required the teachers' STEM classroom practice interact with their teaching reflection frequently.

The EC teachers were provided a 26-h professional development program including school-based STEM activity design, practicing classroom observation and discussion, and on-site support. Each teacher designed STEM activities according to their school-based curriculum and context. For example, one teacher designed an outdoor STEM activity since her school was near a park. The teachers were asked to design STEM education activities through two typical local preschool curriculum types, including 'Thematic' and 'Project' approaches. During the process, the teachers had to reflect on their real STEM education practices and adjust their STEM activity designs or pedagogical strategies according to the development and changes observed in children during the teaching process, then record the changes in their teaching practices.

The study involved interviewing 24 EC teachers before and after implementing STEM education in their classrooms. The STEM activities were organized into four categories—nature, community, family, and school—with themes that were close to children's real-life experiences. For example, under the community category, activities included designing caring bus stops for vision-impaired people, creating a fun theme park for children, and designing a traffic-safe city for everyone.

During the interviews, the EC teachers shared their challenges and limitations in both the phases of preparing and implementing STEM activities and described their curriculum designs and pedagogical approaches. Through their descriptions, this paper provides a rich and detailed understanding of the challenges faced by EC teachers when implementing STEM education in early childhood settings as well as the strategies they use to overcome these challenges and promote effective learning outcomes. EC teachers reported their challenges and limitations in the two phases. They also elaborated that different curriculum designs and pedagogies were applied in the two stages of preparing and implementing STEM activities by reflecting classroom practices.

2.1. Participants

24 EC teachers from 6 project schools participated in the pre- and post-interviews. Two types of early childhood settings were used: kindergartens (half-day and whole-day service) and kindergarten-cum-childcare centers (whole-day service). They were privately run by voluntary agencies as non-profit-making institutions. Four kindergartens provided half and whole-day services and two kindergarten-cum-childcare centers provided whole-day service. Before this study, STEM activities were not integrated into the school-based curricula.

All participants in the study reported that they had not received formal STEM professional development programs or training. The interview participants were some teachers in the above-mentioned project. Considering the progress requirements of this study, the participants were purposefully selected to have formal early childhood teaching qualification certificates (Bachelor's degree: 54%; Higher Diploma/Certificate in Early Childhood Education: 33%; Postgraduate Diploma in Education: 8%; Master of Education: 4%), and years of teaching experience (2 to 20 years: 46% had 5–10 years of working experience, 33% had less than five years of working experience, and 21% had more than ten years of working experience) from the participating kindergartens. Moreover, the 24 teachers also included people who taught all three young children's age groups in kindergartens: K1 (3–4 years old, 21%), K2 (4–5 years old, 42%), and K3 (5–6 years old, 38%). This diversity in the teachers was used to help understand how the 26-h of professional development program would affect STEM education for teachers of all early childhood ages in kindergartens (see Table 1).

Table 1. Background information of the participants.

Participant	Groups	N (%)
Gender	Female	24 (100)
	Male	0 (0)
School type	Kindergarten-cum-child care center	2 (33)
	Kindergarten	4 (67)
Educational level	Bachelor Degree	13 (54)
	Higher Diploma/Certificate in Early Childhood Education (CE(ECE)/HD(ECE))	8 (33)
	Postgraduate Diploma in Education Qualification (PGDE)	2 (8)
	Master of Education Degree	1 (4)
Teaching experience	11–20 Years	5 (21)
	5–10 years	11(46)
	<5 Years	8 (33)
Teaching class level	K1 (3–4 years old)	5 (21)
	K2 (4–5 years old)	10 (42)
	K3 (5–6 years old)	9 (38)

To protect the privacy of the interviewees and their schools, each interviewee, and their kindergarten, were represented by a code such as 'LT3, GT1'. This ensured that the interviewees were able to share their honest opinions without fear of any repercussions. The code name of each interviewed teacher is composed of two capital letters and one number. The first capital letter represents the first letter of the interviewed teacher's school's name.

The second capital letter is the initial letter of the word 'Teacher' because the interviewees in the whole project included not only the teacher team but also others. The number represents the age group of the children taught in the interviewed teacher's class (e.g., K1, K2, and K3).

2.2. Teacher Interview

The research team used in-depth interviews [42] for the present study. This method was used to gain insight into participants' experiences, perceptions, opinions, feelings, and knowledge through open-ended questions and follow-up probes [42,43]. The 24 EC teachers were individually invited to pre- and post-STEM education interviews following the implementation stage. The researcher conducted thorough interviews with the participants over ZOOM and recorded the entire process to gather detailed, first-hand information. The semi-structured interviews were conducted in an interactive way, allowing the interviewees to share their experiences and insights on the challenges and opportunities of implementing STEM education in the kindergartens. To protect the privacy of the interviewees and their schools, each interviewee and their kindergarten were represented by a code. This ensured that the interviewees were able to share their honest opinions without fear of any repercussions. The interview questions have been attached as examples in Appendix A.

There were four sections in the list of interview questions, including:

(1) six questions about school or class information;
(2) nine questions about curriculum, pedagogy, resources, and STEM habits of mind;
(3) seven questions about different stakeholders' conditions and situations, such as schools' policies and resources, teachers' qualifications and beliefs, children's interests and abilities, and government's policies;
(4) eight questions about explanatory indicators, such as teachers' self-reported competence, challenges and limitations, impacts on teachers and children, the vision of STEM education, professional development, and teachers' expectations.

2.3. Data Analysis Process

The study was framed using grounded theory, which helped to explain the interconnectedness of curriculum design, pedagogical approaches, and teacher preparedness in the context of STEM education [44]. Ground theory refers to a systematic methodological approach that allows the researchers to design and implement a new research project without a specific theory or preconceived ideas about outcomes and to derive or construct a theory from practical collected data [45,46]. As such, the approach taken involved the ideas that children are active constructors of their own knowledge, and that deep learning occurs [47] through active engagement with ideas. Teachers' professional development in STEM education and their pedagogical beliefs are closely linked to their activity design and implementation [48]. By coding interviews with teachers, grounded theory techniques were applied to begin data analysis, and an open mind was used to identify patterns and changes through content analysis [49]. The research team members reviewed and reread the transcripts of interviews from texts to specific STEM learning contexts to obtain a comprehensive understanding of the data.

We used a qualitative content analysis framework proposed by Vaismoradi et al. [50] to analyze the data. We used four steps to go through the data analysis based on the theory of the theme development process, including initialization, construction, rectification, and finalization [50,51]. Three data coders and one researcher were involved in the whole data analysis process.

Qualitative content analysis is mixed-methods analysis that combines a qualitative step and a quantitative step (analyzing category frequencies). It provides a range of specific techniques (summarization, inductive category formation, interpretation, deductive category assignment, mixing techniques) for different research questions approaching a given text. Qualitative content analysis supports the systematic analysis of textual material in educational research. Researchers or educators can explore and reflect on the internal processes of learning and development through open-ended data collection methods used on transcripts. The core elements of qualitative content analysis are its rigor, an understanding of the precise unit of analysis, the step model of the technique, and the final check of the coding protocol. This systematic qualitative content analysis meets scientific quality standards [52].

The first step in the study was initialization. The target data group was selected from the whole data pool for this study based on the content of the data resources bank in different aspects by this study's data analysis group after discussion. The data were focused on the interviewed EC teachers' reflections about their challenges and limitations, and their pedagogical strategies in pre-and post-interviews.

The second step was construction. Two turns of data coding were conducted by two different data coders. Two data coders first summarized sub-titles based on the evidence from the teachers' pre- and post-interviews and generated the indicators by combining similar terms and revising the meanings given by the sub-titles, which were shortened and individual-specific. Then the two data coders generated consensus indicators by comparing and discussing the differences and similarities in their coding.

The third step involved two other research members checking and examining the data coding to refine and confirm the indicators after discussion.

Finally, the research members reflected on the findings and engaged in dialogue with literature and theory. Then, the limitations and implications of this study were reviewed. Through this rigorous process, the study provided valuable insights into the challenges and opportunities of implementing STEM education in early childhood settings.

3. Findings

RQ1: What challenges do EC teachers encounter during the process of implementing STEM education in Hong Kong?

EC teachers encountered challenges and limitations in three aspects during the teaching process: (1) curriculum and pedagogy, (2) STEM education context preparation, and (3) teachers' individual STEM preparation. After STEM implementation, the challenges and limitations on the aspect of curriculum and pedagogy that had been reported by EC teachers reduced from 95.8% to 83.3%, and the aspect of teachers' individual STEM preparation decreased from 29.2% to 20.8. However, more teachers reported challenges and limitations in the aspect of STEM education context preparation, which increased from 20.8% to 29.2%. (See Table 2).

Table 2. Teacher ratios changes in three STEM education challenge aspects.

Aspects	Pre-Interview		Post-Interview	
	f	%	*f*	%
Curriculum and pedagogy aspect	23	95.8	20	83.3
Teacher's individual STEM preparation aspect	7	29.2	5	20.8
STEM education context preparation aspect	5	20.8	7	29.2

3.1. Curriculum and Pedagogy

The curriculum and pedagogy included the challenges and limitations that EC teachers were most concerned about in both phases of the interviews. 'Lack of STEM content knowledge' was the biggest challenge that teachers identified for their curriculum preparation and teaching implementation, and this led them hard to incorporate STEM-related abstract concepts or STEM interdisciplinary knowledge into activity designs. The following excerpts were examples from teachers LT3 and KT3.

> *"I am not familiar with engineering area, so I prefer to choose mathematics and science. It may cause problems in balancing other STEM-related disciplines of learning"*
>
> (by teacher LT3 in pre-interview)

"The concepts (STEM) were complicated for me. I don't know how to simplify the concepts or present them to the children in the activity, and I don't know what I want to do"

(by teacher KT3 in post-interview)

Some teachers also reported that due to the 'lack of STEM content knowledge', there had been negative impacts of their pedagogical strategies, such as leading them to choose a superficial or single pedagogical strategy to deliver STEM knowledge, interfering with implementing strategies and reducing teaching-positive effects during STEM education. Moreover, it is important that EC teachers obtain STEM education training in their teacher education program to prepare their STEM education in the future. The following are sample descriptions from teachers GT1, DT2, and KT3.

"Teachers need specific knowledge, whether it is about science, technology, or other fields. It may be challenging to design activities when we have no such knowledge as references. The activity design would be relatively simple"

(by teacher GTI in pre-interview)

"If the children ask some questions I didn't prepare during the STEM education, I may not be able to answer them. This is a difficulty for me"

(by teacher DT2 in pre-interview)

" ... in making water filters, the most important thing was to let the children know how to arrange the materials so that the clean water could be filtered out. But sometimes, we found that the filtered water was clearer when we placed the materials messed up. I don't know how to explain it to the children"

(by teacher KT3 in post-interview)

The second most mentioned challenge in curriculum and pedagogy was the 'lack of guiding strategy'. Teachers found it hard to implement STEM activities in classroom practice and predict the effectiveness of the teaching and children's STEM education. For instance, teacher CT2 predicted she would have difficulty with guiding strategies in her pre-interview, and she reflected on the impact of the difficulty after the activity implementation.

"I never had experience teaching STEM. It is all new to me. So I will have difficulties in activity design or guiding strategies"

(by teacher CT2 in pre-interview)

"Implementing the first STEM activity by myself was hard because I didn't master guiding strategies. So most of the time, I just let the children play freely. Later I found that the children need to be demonstrated first and guided to do the work once, and then let them try freely. That was much better"

(by teacher CT2 in post-interview)

The EC teachers also reported challenges related to children's STEM education needs for their 'curriculum and pedagogical strategy'. They sought to understand children's age-appropriate STEM education. For example, teacher CT1 mentioned that children need to prepare their 'knowledge' or 'ability' for STEM education.

"K1 children don't have enough knowledge and ability for STEM education. They may not be able to complete the work in the making process. In the end, the teacher has to finish the rest part for the children"

(by teacher CT1 in pre-interview)

Moreover, teacher LT3 was concerned about the depth of children's STEM education as she described in the post-interview: "the STEM areas are too broad. Even one theme also has too many learning areas. What kind of learning design works for children? How deep should children learn STEM?"

3.2. Teacher's Individual STEM Preparation

The category 'Teacher's Individual STEM preparation' referred to the challenges and limitations that EC teachers paid attention to before STEM implementation. Two indicators used from the interviews included 'lack of classroom practical experience' and 'lack of confidence'. Teachers' confidence in STEM education was enhanced whereas no teacher reported a 'lack of confidence' after STEM activity implementation. The following example is from teacher GT1, who has eight years of teaching experience. She described the change in her confidence in STEM education before and after STEM education.

"When the teacher doesn't know what to do, then they will have no confidence to teach the children well. Before STEM education, I constantly doubt myself what to do and how to design activities to achieve the STEM level"

(from pre-interview)

"Now I feel much more confident in designing STEM activities than before because I gained some experiences in different types of STEM activities, STEM-related learning content, and related information. I feel confident. Of course, I think there is still a lot to learn and enrich myself"

(from post-interview)

3.3. STEM Education Context Preparation Aspect

'STEM education context preparation' was the only aspect of challenges and limitations that received more teachers' comments after the STEM activity implementation. Before the implementation of STEM education, teachers believed that 'lack of resources' was the only challenge and limitation that hindered them from constructing appropriate STEM education contexts, as described by teacher ET2 in the following quote.

"There are no suitable resources to support my STEM activity designs. Sometimes STEM activities require teaching outdoor, which requires us to prepare suitable and related learning resources"

(by teacher ET2 in pre-interview)

After STEM education, the EC teachers' attention on the challenges of 'STEM education context preparation' turned to solutions that they thought would effectively promote children's STEM education, such as 'lack of experience in using STEM digital resources' and 'lack of technical support from professionals'. Overall, pedagogical strategies were the EC teachers' greatest concern. The teachers reported diverse challenges and limitations in 'delivering STEM knowledge' or 'illustrating abstract concepts', 'guiding strategies during STEM activity', 'caring for children needed diverse learning', etc.

RQ2: What has been changed in EC teachers' consideration of pedagogy strategies before and after implementing STEM education?

3.4. Pedagogy Strategies Applied in the STEM Activities

Sixteen pedagogy strategies were identified in the EC teachers' interviews. Some teachers reported multiple pedagogy strategies in their STEM activity designs or implementations. The pedagogy strategies were categorized into the teacher-children-cooperation, children-centered, and teacher-centered types.

The teacher-children-cooperation type referred to teachers and children being one learning community during STEM education. The design of STEM education activities under this teaching strategy was flexible and dynamic. The learning design was adjusted based on the children's learning progress. EC teachers provided support according to the children's learning progresses and needs, such as through guiding, demonstration, discussion, information searching, experimentation, etc. The seven pedagogical strategies of the teacher-children-cooperation type included experimentation, inquiry-based learning, asking questions, picture-book-based learning, project-based learning, outdoor exploration, and tools scaffolding.

The child-centered type referred to children being the leaders in STEM activities. The learning activities were promoted and developed according to the children's interests, thoughts, and intentions. Teachers gave guidance or prompts when children ask for help or went off the learning track. The six child-centered pedagogy strategies were children-centered, group learning, hands-on activity, multi-sensory exploration/experiential learning, children's interest-driven learning, free exploration, and collecting materials.

The teacher-centered type referred to the teacher leading the learning progress in STEM activities. The learning activities were promoted and developed based on teachers' teaching plans. Teachers mainly used elaboration and demonstration to deliver the learning content to children. The three teacher-centered pedagogy strategies were observation, demonstration, and direct teaching.

3.5. The Changes in Pedagogy Strategies

The EC teachers interviewed changed their application and consideration of pedagogy strategies in the phases of preparation and implementation of STEM activities, making changes in the number, types of selection, and implementation processes of pedagogy strategies.

The first change was that the EC teachers' pedagogy strategies, applied in their STEM activities, were enriched and enhanced through classroom practices. The number of pedagogy strategies applied was increased from 10 at the preparation stage to 12 at the implementation stage.

Additionally, more EC teachers (58.3%) applied composite pedagogical strategies rather than individual ones during classroom practice compared to during the preparation stage (20.8%) (see Table 3). The following example was from teacher FT1, who considered an individual pedagogical strategy before the STEM activity but applied composite types after.

Table 3. Selection of pedagogy strategies applied in the STEM activities.

Selection of Pedagogy Strategy	**Pre-Interview**		**Post-Interview**	
	f	%	*f*	%
Composite to apply more than one types of pedagogy in the activity design	5	20.8	14	58.3
Individual to apply one type of pedagogy in the activity design	19	79.2	10	41.7

> "... *experimentation, like cooking. It provides children with an opportunity to watch the whole process and changes. I believe more chances for observation and asking questions can inspire children to think*"
>
> (by teacher FT1 in pre-interview)
>
> "*In fact, I tried many strategies, such as exploration, direct operation, experimentation, group learning, and collecting data*"
>
> (by teacher FT1 in post-interview)

The second change was that the EC teachers were more willing to 'provide opportunities for children to be more engaged in STEM education'. The selection of teacher-children-cooperation-type and child-centered-type pedagogy strategies increased from 4 types at the preparation stage to 6 types and 5 types respectively after STEM activity implementation. The selection of the teacher-centered type decreased to one teacher. For instance, teacher HT3 chose the pedagogical strategy of inquiry-based learning for both of her sections of STEM activity design. However, she took the lead and authority to enforce the STEM activity during the process with this principle: "teacher poses a task—teacher guides children to design/make a solution—teacher guides children to test—teacher asks children to discuss or summarize/sharing based on the provided resources". The following excerpt is from her pre-interview:

"In order to explore how to make a boat move, I let the children make a model with play dough, and test it. I will also provide some pictures of different transportation in sea, land, or air to let the children compare the structures. Then I will ask the children to discuss the structure of the boats"

(from pre-interview)

After implementing the STEM activity, EC teacher HT3 gave authority to the children and allowed them to engage in the activity more through free exploration and cooperation with adults, including teachers and parents, using this principle: "invite children to collect theme-related materials/search theme-related information—discuss with children about the solutions/ideas—hands-on operation". The following excerpt is from her post-interview.

" . . . I leave a question or a worksheet that invites my children to collect resources or information. They can work together with their parents when they go home or they can search for information by using the iPad in the classroom. Then we discuss everyone's plan together and choose suitable plans. After the process, we test the selected methods to see whether they work or not"

(from post-interview)

The third significant change was that the EC teachers preferred choosing pedagogical strategies based on their children's diverse learning needs, focusing on children's deep learning and organizing the long-term learning process rather than making the process superficial and individually fragmented. In the preparation stage, the top three popular pedagogy strategies that teachers mentioned were experimentation (45.8%), inquiry-based learning (20.8%), and multi-sensory exploration/experiential learning (16.7%). After implementing the STEM activities, the two pedagogy strategies that were among the top three during the preparation stage dramatically dropped: experimentation, proposed by 45.8% of teachers, dropped to being proposed by 8.3%, and multi-sensory exploration/experiential learning strategy from being proposed by 16.7% to being proposed by 8.3% of teachers. Inquiry-based learning (54.2%) became the most popular choice of pedagogical strategy, group learning (41.7%) became the second, and hands-on activity (25%) replaced multi-sensory exploration/experiential learning (8.3%) to be the third priority choice. (See Table 4).

Table 4. Pedagogy strategies applied in STEM activities, pre-and post-interview.

Pedagogy Strategies	Pre-Interview		Post-Interview	
	f	%	*f*	%
Teacher-Children Cooperation Pedagogical strategies				
Experimentation	11	45.8	2	8.3
Inquiry-based learning	5	20.8	13	54.2
Ask questions	1	4.2	2	8.3
Picture book-based learning	2	8.3	0	0
Project-based learning	0	0	1	4.2
Outdoor exploration	0	0	1	4.2
Tools scaffolding	0	0	1	4.2
Children-centered Pedagogical strategies				
Group learning	2	8.3	10	41.7
Hands-on activity	2	8.3	6	25.0
Multi-sensory exploration/Experiential learning	4	16.7	2	8.3
Children interest-driven learning	1	4.2	0	0
Free exploration	0	0	4	16.7
Collect materials	0	0	1	4.2
Teacher-centered Pedagogical strategies				
Observation	1	4.2	0	0
Demonstration	1	4.2	0	0
Direct teaching	0	0	1	4.2

The following exemplifies teacher BT3′s changes in applying pedagogy strategies in her STEM activity themed 'My Community: Caring Bus Station'. Her activity design invited children to design and make barrier-free bus stop models for visually-impaired people. At the preparation stage, she chose experimentation to allow children to understand that STEM existed in daily life by letting them observe phenomena. The following excerpt was from her pre-interview.

"I chose experimentation . . . let them find out the phenomena in the experimentation that can also be found in their daily life"

(by teacher BT3 in pre-interview)

After the STEM activity implementation, she changed to use combined inquiry-based learning and group learning for children's STEM education. The following excerpt is from her post-interview:

"I used inquiry-based learning and group learning in my STEM education. These strategies can enable children to experience hands-on experiments, observe phenomena and changes, and discover new things in the process of inquiry. When the children present their learning, I can provide suggestions or comments when their understanding was different from the concepts or knowledge taught"

(by teacher BT3 in post-interview)

The example from teacher AT3 illustrated that she adjusted and refined the experimentation implementation process to be simpler when she considered her children's abilities. Before the STEM activity, she designed the experimentation process thus: "asking children to predict the test result based on their real-life experience—making a plan—hands-on operation/testing and data recording—discussion and review/summarize". The following excerpt is from her pre-interview:

" . . . the process can be a group discussion, then do experiments to test, planning, practice, and review"

(from pre-interview)

After the STEM activity, she reflected that the experimentation strategy process was simplified to "asking children to hands-on operation/test—multi-sensory experience—hands-on operation/re-test". The following excerpt is from her post-interview:

" . . . when we were learning to make a tank with an aquaponics system, I extended my children's learning about the concept of ecosystems by inviting them to collect rainwater, and then with them explore energy resources and make ecological bottles. Children had a better understanding of how the aquaponics system was a self-sufficient system through the ecological bottles they made"

(from post-interview)

4. Discussion

In this study, the EC teachers interviewed were from different regions of Hong Kong, with different backgrounds such as in terms of teaching hours, different classes, different numbers of children in their classes, and different qualifications and years of teaching experience. The sample we used is representative, and the results are credible. The number of participating teachers was extensive, with 24 EC teachers, and the study was conducted around four types of STEM themes—nature, community, family, and school—which covered most of the popular themes and children's life experiences in Hong Kong kindergartens. The study directly collected teachers' first-hand feelings and views in the pre-interviews as information, allowing us to get close to the actual situation of early childhood education and teaching. In addition, the pre-interviews also collected the needs and limitations of front-line EC teachers before implementing STEM education, and this was favorable to help EC teachers solve specific practical difficulties and to promote the further professional development of STEM early childhood education in Hong Kong.

4.1. Reflective STEM Classroom Practice

From the findings of the study, it is evident that Hong Kong's EC teachers urgently need appropriate STEM education-related professional development to support them in obtaining new related content knowledge and skills. The EC teachers in the study believed that the lack of STEM content knowledge and related teaching experience would make it challenging to design pedagogical strategies for children to participate in meaningful STEM activities or to apply multiple strategies in their STEM activity designs comprehensively. For example, teacher GT1 reflected that she could only apply a simple pedagogical strategy in her activity design due to a lack of relevant content knowledge when she designed a STEM activity that invited children to explore with coding toys to make multipurpose cleaning tools. Some teachers also felt that the lack of STEM-related teaching experience made them lack guiding strategies to implement STEM activities. For example, teacher CT2 reported difficulties with guiding strategies when she designed or implemented a STEM activity. This is consistent with what was reflected in the findings of a previous study [29]. So far, neither EC teachers nor kindergartens in Hong Kong have had the opportunity to obtain formal and systematic STEM-related professional development from the education system. Jamil et al. [53] suggested that when STEM education is officially integrated into the local standards-based early childhood curriculum, EC teachers can develop diverse and effective pedagogical strategies according to children's STEM education needs.

After understanding EC teachers' challenges and limitations on STEM practices, the teachers' reflections under the specific interview question regarding pedagogical strategies were carefully checked and analyzed. New and exciting findings emerged: the EC teachers' pedagogical strategies had strengthened after their reflective STEM classroom practices. One essential impact considered was that reflective STEM classroom practices had encouraged EC teachers to engage in dynamic teaching and learning processes rather than fixed and pre-designed activity designs. They had allowed EC teachers to flexibly adjust or revise their pedagogical strategies or learning tasks according to their children's changing learning needs and abilities in the process of STEM education. A dynamic learning process occurs in activities in which children actively engage, interact, and communicate with other people [54]. Ayre and Nettle [55] argue that a dynamic learning process can support the production of new knowledge for changing practice by effectively integrating diverse perspectives and knowledge from other disciplines in solving complex problems of sustainability. As such, EC teachers have opportunities to take care of different children's learning progress to a greater extent, and enable age-appropriate pedagogical strategies or activity designs for the STEM education of children, than others. For example, one teacher (AT3), in implementing a STEM activity of making an aquaponics system, simplified the complex experiment implementation process in her previous design and provided a direct hands-on and multi-sensory activity based on her children's abilities.

Additionally, reflective classroom practice also inspired the EC teachers to create more practical and innovative school-based pedagogical strategies based on the children's abilities and the teaching environment through continuous reflection and timely practice. Zwozdiak-Myers [56] states that reflective practice is an enquiry-oriented teaching-research process that allows teachers to enhance their classroom practices in nine dimensions:

- to study their teaching for personal improvement,
- to systematically evaluate their teaching through classroom research procedures,
- to link theory with their practice,
- to question their theories and beliefs,
- to consider alternative perspectives and possibilities,
- to try out new strategies and ideas
- to maximize the learning potential of all their students,
- to enhance the quality of their teaching,
- to continue to improve their teaching (p. 5)

The findings of this study also evidenced that teachers' STEM-related knowledge or capabilities are complementary to their practices in STEM education. Hamre et al. [57]

states that new knowledge leads to changes in teachers' practices and that the outcomes of new practices lead to the further refinement of their knowledge continuously and cyclically. This interactive cycle might enhance the reflective level of EC teachers' STEM education. Children solve real-life problems in learning activities designed by teachers [58], while teachers simultaneously solve the problems of pedagogical strategy application in real classroom practice. Reflective STEM classroom practice may be an effective way for EC teachers who lack relevant professional development to develop or enhance STEM pedagogical strategies.

4.2. Opportunity of Transforming Teacher's Role in Children's STEM Education

Another finding in this study was that EC teachers are more willing to provide opportunities for children to participate in child-centered learning after implementing STEM activities. This has been reflected in the decline of the types of teacher-centered pedagogical strategies and the increase in the types of child-centered and teacher-children-cooperation strategies. The traditional method of teaching science, which relies on demonstration and explanation [59], is gradually being replaced by more engaging and interactive approaches [60]. EC teachers recognize the importance of incorporating real-life experiences and classroom practice of STEM concepts to achieve learning outcomes. This helps children develop a better understanding of STEM content knowledge [30] and fosters their curiosity and wonder [61], improving their problem-solving skills in daily activities [62].

This change leads to EC teachers transforming from their roles as knowledge delivers or skill trainers to more open scaffolders that meet the diverse learning needs of children, becoming collaborators that co-create learning activities or co-construct new knowledge or facilitators that provide the necessary support when children ask for help. Significantly, this involves creating STEM education experiences that cater to different learning styles, incorporate STEM resources to improve children's engagement, and apply hands-on exploration to inspire children to understand STEM concepts and build up their own knowledge throughout the process. In previous studies, the changing of teachers' roles in STEM activities engaged children more to promote their STEM education interests [63,64] and active learning [65], and deeply engraved STEM thinking in their learning DNA to ensure their continued successes in STEM in future education [19].

For example, children are curious. They prefer and are better suited to hands-on lessons [2]. Children are encouraged to use their existing resources to explore STEM-related concepts and activities actively, and they can also exchange information with peers to help each other. At the same time, the involvement of teachers as collaborators can better promote children's imagination, creativity, and ability to work with others. The high degree of warmth and open communication in the teacher-child relationship [66] has positive and long-term effects on children's cognitive development, self-regulation, and social skills (e.g., assertion, communication, cooperation, empathy, engagement, responsibility, and self-control [67]) [68]. As teacher HT3 explained, she provided children with more opportunities to freely explore and cooperate instead of worrying about how to lead the activities.

5. Implication and Limitation

The pre- and post-experimental interviews with EC teachers implementing STEM education in this study revealed that more EC teachers chose composite pedagogical strategies for curriculum design than individual strategies and created more innovative strategies according to the needs of their children's STEM education and development. The three most frequent pedagogical strategies during STEM classroom practices were hands-on activities, group learning, and inquiry-based learning opportunities. In addition, more EC teachers considered providing engaged opportunities for children's STEM education through transforming teacher-centered pedagogy to teacher-child cooperation or child-centered pedagogy. Regarding difficulties faced by EC teachers: teachers felt less pressure regarding curriculum preparation, pedagogical strategies, and individual teacher preparation for

STEM education after the professional development training before the implementation of STEM education.

However, the EC teachers also reported that integrating STEM content and pedagogical strategies into school-based curricula presents new challenges for them, especially when schools adopt teaching materials from the market. One of these key challenges is the need to change their roles from traditional educators to learning facilitators. This is particularly important for early childhood educators who may have limited knowledge of STEM disciplines, such as those involving science and engineering concepts, during learning activities. To address this challenge, educators can integrate real-life inquiry that gradually develops their understanding of STEM content knowledge to prepare and design STEM activities. In this study, school-based reflective STEM classroom practices were useful to teachers and offered multiple practical opportunities to understand and explore STEM resources prior to conducting classroom activities. These preparations improved EC teachers' understanding of the incorporated concepts and helped them connect age-appropriate activities to STEM content.

Moreover, it is essential to note that building up content knowledge is just one aspect of STEM education. Educators also play a crucial role in fostering a meaningful STEM environment that encourages curiosity [61] and problem-solving skills [62]. Creating a constructive and collaborative learning environment gives EC teachers more motivation and confidence to co-learn STEM content knowledge with children. Nevertheless, flexible learning resources, an appropriate timetable, and team support are essential factors in achieving this shift in the learning culture. As co-learners and co-creators in STEM activities, EC teachers act as guides and facilitators in the learning process, providing structured knowledge while encouraging curiosity and critical thinking. By providing on-site professional support, STEM-activity-teaching observation by professional teams, and practical opportunities for reviewing, teachers can shift their roles to foster STEM thinking with children and create a supportive and collaborative learning environment.

6. Conclusions

In conclusion, the integration of age-appropriate STEM content and pedagogical strategies into school-based contexts has presented new challenges for EC teachers in STEM education. An effective professional development program for preparing STEM learning involves not only providing content knowledge, but also co-developing an integrated STEM curriculum with schools to meet the learning needs of young children. In addition, the changing teacher-centered roles of EC teachers result in building meaningful learning with children in authentic and appropriate STEM education contexts. When EC teachers are supported with school-based professional development and STEM education training, in which they help to create more child-centered and effective learning environments that promote co-learning and co-creating knowledge with children, the methods of demonstration and reflective practice are meaningful for teachers to build up pedagogical beliefs and broaden their pedagogical repertoire to adjust their roles in guiding activities. As a result, the role of teachers has changed, particularly in the early childhood education field, where there has been a limitation of STEM knowledge for both educators and students. This shift in learning calls for a change in the culture of learning, wherein practice-based problem solving (STEM education, e.g., design and application) becomes a key component of the real-life learning experience. By doing, rather than just delivering or via direct teaching about STEM content knowledge, it can help children build STEM content knowledge and critical thinking during the learning process. These children develop problem-solving skills and become creative makers by understanding STEM phenomena in real life.

To conclude, future research directions will further explore effective and generalize pedagogical strategies for implementing STEM education in Hong Kong's early childhood education, develop and implement STEM resource packages as references that help EC teachers address the constraints and dilemmas of implementing STEM education in the curriculum, and further promote the appropriate implementation of STEM education in

Hong Kong's early childhood education system. In addition, this study also provides valuable references for EC educators on issues such as the challenges and difficulties in the implementation of STEM education, learning STEM at the early childhood education level, multiple pedagogical applications, types of teaching strategies, and positive impacts on children.

Institutional Review Board Statement: This study was conducted in accordance with the policy of 'Human Research Ethics Committee' of The Education University of Hong Kong (Reference no. 2019-2020-0354 and date of approval: 28 May 2020) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the participants to publish this paper.

Data Availability Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Interview questions samples at STEM activity pre-implementation stage.

(A). School/Class Information: Basic Background Information about schools and class

1. How many class teachers are there in your class? Do you have any teaching assistants?
2. How many children are there in your class?
3. How many children are in each group when you have theme/small group activities?
4. What pedagogy did your school apply?
5. For how many years have you been teaching in early childhood education?
6. What is your early childhood education qualification?

(B). Core Indicators: Curriculum, Pedagogy, Resources, Habits of Mind

1. What STEM-related themes/activities do you have in your school's curriculum? Any examples?
2. What learning theme or activity do you recommend?
3. What are the specific STEM-related learning objectives in the theme/activity you selected just now?
4. What activities will you design to achieve these learning objectives?
5. What pedagogy do you usually use when carrying out STEM-related activities?
6. What pedagogy do you think is most effective?
7. Why do you think this pedagogy is most effective?
8. Did you try any STEM-related resources in your school before?
9. Can you give some examples? (If yes)
10. Are there settings related to STEM in your school environment? (If so, ask the teacher to describe what they are and how to apply them)
11. Can your classroom allow you to establish a regular STEM corner for children?
12. What STEM resources do you want to try?
13. Do you have an interest in exploring some new technology products?

(C). Supplementary Indicators: School Factors, Teacher Factors, Children Factors, System Factors

1. What necessary support for implementing STEM activities do teachers need from school?
2. Is the current school timetable and curriculum suitable for STEM curriculum implementation? If not, how to improve it?
3. Have you participated in any training about STEM (science, technology, engineering, or mathematics) in your early childhood teacher professional development?
4. (If not) Have you taken any relevant courses in secondary school? Were they enough to prepare you for STEM teaching now?

5. Which area of learning do you have the most confidence in within STEM (science, technology, mathematics, and engineering)?
6. Which area of learning do you have the least confidence in within STEM (science, technology, mathematics, and engineering)?
7. Why implement STEM education in kindergarten?
8. What area(s) of STEM are your children most interested in, during STEM activities?
9. Do your children have enough knowledge and ability to complete STEM activities?
10. Why do your children have different abilities in each area of S-T-E-M?
11. What expectations do parents have for developing children's scientific skills and knowledge? How do these expectations affect your teaching?

(D). Explanatory Indicators: Teachers' Self-reported Competence, Challenges and Limitations, Impacts on Teachers and Children, Vision of STEM Education, Professional Development, Teachers' Expectations

1. What difficulties do you predict you will have in designing and implementing STEM activities?
2. What difficulties will your children encounter in STEM learning with examples?
3. How can the government education policy strengthen the support of STEM education in early childhood education?
4. What training can universities provide to improve the quality of early childhood STEM education?
5. Which aspect(s) of training about STEM education is most needed? Any examples?
6. How do you expect this teaching package to enrich children's STEM learning experience?
7. What is STEM?
8. How to describe your mood and confidence about the STEM activities you will plan and implement?

Interview questions samples at STEM activity post-implementation stage.

(A). School/Class Information: Basic Background Information about schools

1. How many class teachers were there in your class? Did you have any teaching assistants?
2. How many children were there in your class?
3. How many children were in each group when you had theme/small group activities?

(B). Core Indicators: Curriculum, Pedagogy, Resources, Habits of Mind

1. What STEM-related themes/activities did you have in your school's curriculum? Any examples?
2. What learning theme or activity do you recommend?
3. What were the specific STEM-related learning objectives in the theme/activity you selected?
4. What activities did you design to achieve the learning objectives?
5. What STEM-related resources did you apply in the STEM activities?
6. What pedagogy did you apply when carrying out STEM-related activities?
7. What pedagogy was most effective?
8. Why was this pedagogy most effective?
9. What STEM-related resources did you use in your teaching activities?
10. Did your school environment add any STEM-related settings? (If so, ask teacher to describe what they and how they were applied)
11. Can your classroom allow you to establish a regular STEM corner for children?
12. Did you apply or test any STEM resources that you want to try before the plan starts?

13. Do you have interest in continuing to explore some new technology products?

(C). Supplementary Indicators: School Factors, Teacher Factors, Children Factors, System Factors

1. What necessary support for implementing STEM activities did teachers need from school?
2. Were the current school timetable and curriculum suitable for STEM curriculum implementation? If not, how to improve it?
3. Have you participated in any training about STEM (science, technology, engineering, or mathematics) in your early childhood teacher professional development?
4. (If not) Have you taken any relevant courses in secondary school? Were they enough to prepare you for STEM teaching now?
5. Which area of learning did you have the most confidence in within STEM (science, technology, mathematics, and engineering) after the STEM activity implementation?
6. Which area of learning did you have the least confidence in within STEM (science, technology, mathematics, and engineering) after the STEM activity implementation?
7. After implementing the STEM activities, why do you think we should implement STEM education in kindergarten?
8. In what area(s) of STEM were your children most interested in during the STEM activities?
9. Did your children have enough knowledge and ability to complete STEM activities?
10. Why did your children have different abilities in each area of S-T-E-M?
11. What expectations did parents have for developing their children's scientific skills and knowledge? How did these expectations affect your teaching?

(D). Explanatory Indicators: Teachers' Self-reported Competence, Challenges and Limitations, Impacts on Teachers and Children, Vision of STEM Education, Professional Development, Teachers' Expectations

1. What difficulties did you meet when you designed and implemented STEM activities?
2. What difficulties did your children encounter in STEM learning, with examples?
3. How can the government education policy strengthen the support of STEM education in early childhood education?
4. What training can universities provide to improve the quality of early childhood STEM education?
5. After implementing STEM activities, which aspect(s) of training about STEM education is/are most needed? Any examples?
6. What suggestions for further improvement do you have regarding the experience of co-developing the teaching package with the research team?
7. Can this co-developed teaching package enrich young children's STEM learning experiences? Which aspect(s)?
8. What is STEM?
9. How do you describe your mood and confidence about the STEM activities after implementing the STEM activities?

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References

1. Bybee, R.W. *The Case for STEM Education Challenges and Opportunities*; National STEM Teachers Association: Washington, DC, USA, 2013.
2. Simoncini, K.; Lasen, M. Ideas About STEM Among Australian Early Childhood Professionals: How Important is STEM in Early Childhood Education? *Int. J. Early Child.* **2018**, *50*, 353–369. [CrossRef]

3. Yakman, G.; Lee, H. Exploring the exemplary STEAM education in the US as a practical educational framework for Korea. *J. Korean Assoc. Sci. Educ.* **2012**, *32*, 1072–1086. [CrossRef]
4. Ata Aktürk, A.; Demircan, H.Ö. A review of studies on STEM and STEAM education in early childhood. *Ahi Evran Üniv. Kırşehir Eğitim Fakültesi Derg.* **2017**, *18*, 757–776. Available online: https://www.researchgate.net/publication/319702309_A_Review_of_Studies_on_STEM_and_STEAM_Education_in_Early_Childhood (accessed on 7 April 2023).
5. Dejarnette, N.K. America's Children: Providing Early Exposure to Stem (Science, Technology, Engineering and Math) Initiatives. *Read. Improv.* **2016**, *53*, 181–187. Available online: https://eric.ed.gov/?id=EJ996974 (accessed on 7 April 2023).
6. Moore, T.; Stohlmann, M.; Wang, H.; Tank, K.; Glancy, A.; Roehrig, G. Implementation and integration of engineering in K-12 STEM education. In *Engineering in Pre-College Settings: Synthesizing Research, Policy, and Practices*; Purzer, S., Strobel, J., Cardella, M., Eds.; Purdue University Press: West Lafayette, ID, USA, 2014; pp. 35–60. Available online: https://experts.umn.edu/en/publications/implementation-and-integration-of-engineering-in-k-12-stem-educat (accessed on 27 February 2023).
7. Yelland, N. STEM Learning Ecologies: Productive Partnerships Supporting Transitions from Preschool to School Growing a Generation of New Learners. In *Embedding STEAM in Early Childhood Education and Care*; Springer International Publishing: Berlin/Heidelberg, Germany, 2021; pp. 237–260. [CrossRef]
8. Aldemir, J.; Kermani, H. Integrated STEM curriculum: Improving educational outcomes for Head Start children. *Early Child Dev. Care* **2017**, *187*, 1694–1706. [CrossRef]
9. Lindeman, K.W.; Jabot, M.; Berkley, M.T. The Role of STEM (or STEAM) in the Early Childhood Setting. In *Learning Across the Early Childhood Curriculum*; Emerald Group Publishing Limited: Bentley, UK, 2013; Volume 17, pp. 95–114. [CrossRef]
10. McClure, E.R.; Guernsey, L.; Clements, D.H.; Bales, S.N.; Nichols, J.; Kendall-Taylor, N.; Levine, M.H. *STEM Starts Early: Grounding Science, Technology, Engineering, and Math Education in Early Childhood*; Joan Ganz Cooney Center at Sesame Workshop: New York, NY. USA, 2017. Available online: https://files.eric.ed.gov/fulltext/ED574402.pdf (accessed on 13 April 2023).
11. National Scientific Council on the Developing Child. *The Science of Early Childhood Development: Closing the Gap between What We Know and What We Do*; The Council: Cambridge, MA, USA, 2007; Available online: https://developingchild.harvard.edu/wp-content/uploads/2015/05/Science_Early_Childhood_Development.pdf (accessed on 13 April 2023).
12. Bagiati, A.; Evangelou, D. Starting young: Learning outcomes of a developmentally appropriate PreK engineering curriculum. In *Research in Engineering Education Symposium*; Hernandez, W., Ed.; Universidad Politécnica de Madrid: Madrid, Spain, 2011; pp. 644–651. Available online: http://rees2009.pbworks.com/w/file/fetch/63149087/REES%202011%20proceedings.pdf (accessed on 16 April 2023)Available online: .
13. Zhang, M.; Parker, J.; Eberhardt, J.; Passalacqua, S. "What's So Terrible About Swallowing an Apple Seed?" Problem-Based Learning in Kindergarten. *J. Sci. Educ. Technol.* **2011**, *20*, 468–481. [CrossRef]
14. Fleer, M. Engineering PlayWorld: A Model of Practice to Support Children to Collectively Design, Imagine and Think Using Engineering Concepts. *Res. Sci. Educ.* **2022**, *52*, 583–598. [CrossRef]
15. Schaen, R.J.; Hayden, G.; Zydney, J.M. Now we have an app for that. *Teach. Child. Math.* **2016**, *22*, 506–509. [CrossRef]
16. Dİlek, H.; Taşdemİr, A.; Konca, A.S.; Baltaci, S. Preschool Children's Science Motivation and Process Skills during Inquiry-Based STEM Activities. *J. Educ. Sci. Environ. Health* **2020**, *6*, 92–104. [CrossRef]
17. Johnston, K. Digital technology as a tool to support children and educators as co-learners. *Glob. Stud. Child.* **2019**, *9*, 306–317. [CrossRef]
18. Dorouka, P.; Papadakis, S.; Kalogiannakis, M. Tablets and apps for promoting robotics, mathematics, STEM education and literacy in early childhood education. *Int. J. Mob. Learn. Organ.* **2020**, *14*, 255. [CrossRef]
19. Tippett, C.D.; Milford, T.M. Findings from a Pre-kindergarten Classroom: Making the Case for STEM in Early Childhood Education. *Int. J. Sci. Math. Educ.* **2017**, *15*, 67–86. [CrossRef]
20. Krogh, S.; Morehouse, P. *The Early Childhood Curriculum: Inquiry Learning through Integration*, 3rd ed.; Routledge: London, UK, 2020.
21. The Government of the Hong Kong Special Administrative Region (HKSAR). Policy Address. 2015. Available online: http://www.policyaddress.gov.hk/2015/eng/p150.html (accessed on 13 February 2023).
22. The Government of the Hong Kong Special Administrative Region (HKSAR). Policy Address. 2016. Available online: http://www.policyaddress.gov.hk/2016/eng/p67.html (accessed on 13 February 2023).
23. Panel on Education, Legislative Council of The Hong Kong Special Administrative Region of The People's Republic of China. The Chief Executive's 2022 Policy Address. Hong Kong, China. 2022. Available online: https://www.legco.gov.hk/yr2022/chinese/panels/ed/papers/ed20221104cb4-917-1-c.pdf (accessed on 13 February 2023).
24. Curriculum Development Council. *Guide to the Pre-Primary Curriculum*; The Education Bureau HKSAR: Hong Kong, China, 2006. Available online: https://www.edb.gov.hk/attachment/en/curriculum-development/major-level-of-edu/preprimary/pre-primaryguide-net_en.pdf (accessed on 23 February 2023).
25. Curriculum Development Council. *Kindergarten Education Curriculum Guide*; The Education Bureau HKSAR: Hong Kong, China, 2017. Available online: https://www.edb.gov.hk/attachment/en/curriculum-development/major-level-of-edu/preprimary/ENG_KGECG_2017.pdf (accessed on 23 February 2023).
26. Marginson, S.; Tytler, R.; Freeman, B.; Roberts, K. *STEM: Country Comparisons: International Comparisons of Science, Technology, Engineering and Mathematics (STEM) Education*, 1st ed.; Australian Council of Learned Academies: Melbourne, Australia, 2013; Available online: http://hdl.handle.net/10536/DRO/DU:30059041 (accessed on 23 February 2023).

27. Cornelius-White, J.H.; Harbaugh, A.P. *Learner-Centered Instruction: Building Relationships for Student Success*; Sage Publications: Thousand Oaks, CA, USA, 2010.
28. Gao, Y. An Emerging Giant of Science: Achievements and Challenges of STEM Education in China. In *The Age of STEM*; Freeman, B., Marginson, S., Tytler, R., Eds.; Routledge: Milton Park, UK, 2014; pp. 69–88. Available online: https://www.taylorfrancis.com/chapters/edit/10.4324/9781315767512-4/emerging-giant-science-yuan-gao (accessed on 28 February 2023).
29. Cheng, T. A preliminary study on the challenges of implementing STEM (Science, Technology, Engineering and Mathematics) education in Hong Kong's kindergartens. *J. Hong Kong Teach.* **2018**, *17*, 223–239. Available online: https://www.edb.org.hk/irooms/eservices/T-surf/Content/Documents/HKTC%20Volume%2017.pdf (accessed on 28 February 2023).
30. Hu, X.; Yelland, N. Changing Learning Ecologies in Early Childhood Teacher Education: From Technology to STEM Learning. *Future Teach.* **2019**, *2*, 236–254. [CrossRef]
31. Hong Kong Federation of Education Workers. Research Report of STEM Teacher Support Policy in Hong Kong. 2017. Available online: https://hkfew.org.hk/images/content_file/hkfew_stem.pdf (accessed on 3 March 2023).
32. Cheng, T.; Li, X.; Ng, J.; Zhou, Y. *Current Situation of Early STEM Education in Hong Kong*; Survey report of Vocational Training Council (VTC); VTC: Hong Kong, China, 2018.
33. Kallery, M. Early years teachers' late concerns and perceived needs in science: An exploratory study. *Eur. J. Teach. Educ.* **2004**, *27*, 147–165. [CrossRef]
34. Watters, J.J.; Diezmann, C.M.; Grieshaber, S.J.; Davis, J.M. Enhancing science education for young children: A contemporary initiative. *Australas. J. Early Child.* **2001**, *26*, 1–7. [CrossRef]
35. Greenfield, D.B.; Jirout, J.; Dominguez, X.; Greenberg, A.; Maier, M.; Fuccillo, J. Science in the preschool classroom: A programmatic research agenda to improve science readiness. *Early Educ. Dev.* **2009**, *20*, 238–264. [CrossRef]
36. Tschannen-Moran, M.; Woolfok Hoy, A.; Hoy, W.K. Teacher efficacy: Its meaning and measure. *Rev. Educ. Res.* **1998**, *68*, 202–248. [CrossRef]
37. Bairaktarova, D.; Evangelou, D.; Brophy, S. Early engineering in young children' s exploratory play with tangible materials. *Child. Youth Environ.* **2011**, *21*, 212–235.
38. English, L.D. Learning while designing in a fourth-grade integrated STEM problem. *Int. J. Technol. Des. Educ.* **2018**, *29*, 1011–1032. [CrossRef]
39. Hung, W. The 3C3R Model: A Conceptual Framework for Designing Problems in PBL. *Interdiscip. J. Probl.-Based Learn.* **2006**, *1*, 50–67. [CrossRef]
40. Scutter, S.; Stupans, I.; Sawyer, T.; King, S. How do students use podcasts to support learning? *Australas. J. Educ. Technol.* **2010**, *26*, 180–191. [CrossRef]
41. Johnston, K.; Kervin, L.; Wyeth, P. STEM, STEAM and Makerspaces in Early Childhood: A Scoping Review. *Sustainability* **2022**, *14*, 13533. [CrossRef]
42. Patton, M.Q. *Qualitative Research & Evaluation Methods: Integrating Theory and Practice*, 4th ed.; SAGE Publications, Inc.: Thousand Oaks, CA, USA, 2015.
43. Rosenthal, M. Qualitative research methods: Why, when, and how to conduct interviews and focus groups in pharmacy research. *Curr. Pharm. Teach. Learn.* **2016**, *8*, 509–516. [CrossRef]
44. Hayes, J.C.; Kraemer, D.J.M. Grounded understanding of abstract concepts: The case of STEM learning. *Cogn. Res. Princ. Implic.* **2017**, *2*, 7. [CrossRef] [PubMed]
45. Glaser, B.G.; Strauss, A.L. *The Discovery of Grounded Theory: Strategies for Qualitative Research*; Aldine de Gruyter: New York, NY. USA, 1967.
46. Stough, L.M.; Lee, S. Grounded Theory Approaches Used in Educational Research Journals. *Int. J. Qual. Methods* **2021**, *20*, 160940692110522. [CrossRef]
47. Fullan, M.; Langworthy, M. *A Rich Seam. How Pedagogies Find Deep Learning*; Pearson: London, UK, 2014.
48. Kirchhoff, A.; Lawrenz, F. The Use of Grounded Theory to Investigate the Role of Teacher Education on STEM Teachers' Career Paths in High-Need Schools. *J. Teach. Educ.* **2011**, *62*, 246–259. [CrossRef]
49. Krippendorff, K. *Content Analysis*; Sage: Thousand Oaks, CA, USA, 2012.
50. Vaismoradi, M.; Jones, J.; Turunen, H.; Snelgrove, S. Theme development in qualitative content analysis and thematic analysis. *J. Nurs. Educ. Pract.* **2016**, *6*, 100–110. [CrossRef]
51. Stolp, E.; Moate, J.; Saarikallio, S.; Pakarinen, E.; Lerkkanen, M.-K. Exploring agency and entrainment in joint music-making through the reported experiences of students and teachers. *Front. Psychol.* **2022**, *13*, 964286. [CrossRef]
52. Mayring, P.A.E. Qualitative content analysis. In *International Encyclopedia of Education*, 4th ed.; Elsevier: Amsterdam, The Netherlands, 2023; pp. 314–322. [CrossRef]
53. Jamil, F.M.; Linder, S.M.; Stegelin, D.A. Early Childhood Teacher Beliefs About STEAM Education After a Professional Development Conference. *Early Child. Educ. J.* **2018**, *46*, 409–417. [CrossRef]
54. Broström, S. A dynamic learning concept in early years' education: A possible way to prevent schoolifcation. *Int. J. Early Years Educ.* **2017**, *25*, 3–15. Available online: https://www.tandfonline.com/doi/full/10.1080/09669760.2016.1270196 (accessed on 7 April 2023). [CrossRef]
55. Ayre, M.; Nettle, R. Doing integration in catchment management research: Insights into a dynamic learning process. *Environ. Sci. Policy* **2015**, *47*, 18–31. [CrossRef]

56. Zwozdiak-Myers, P. *The Teacher's Reflective Practice Handbook: Becoming an Extended Professional through Capturing Evidence-Informed Practice*; Routledge: London, UK, 2018. [CrossRef]
57. Hamre, B.K.; Pianta, R.C.; Burchinal, M.; Field, S.; LoCasale-Crouch, J.; Downer, J.T.; Howes, C.; LaParo, K.; Scott-Lttle, C. A Course on Effective Teacher-Child Interactions: Effects on Teacher Beliefs, Knowledge, and Observed Practice. *Am. Educ. Res. J.* **2012**, *49*, 88–123. [CrossRef]
58. Yelland, N. A pedagogy of multiliteracies: Young children and multimodal learning with tablets. *Br. J. Educ. Technol.* **2018**, *49*, 847–858. [CrossRef]
59. Rutten, N.; van Joolingen, W.R.; van der Veen, J.T. The learning effects of computer simulations in science education. *Comput. Educ.* **2012**, *58*, 136–153. [CrossRef]
60. Sinatra, G.M.; Heddy, B.C.; Lombardi, D. The Challenges of Defining and Measuring Student Engagement in Science. *Educ. Psychol.* **2015**, *50*, 1–13. [CrossRef]
61. Reighard, C.; Torres-Crespo, M.N.; Vogel, J. STEM Curiosity Academy: Building the Engineers of Tomorrow. *Child. Libr.* **2016**, *14*, 32–35. [CrossRef]
62. Torres-Crespo, M.N.; Kraatz, E.; Pallansch, L. From fearing STEM to playing with it: The natural integration of STEM into the preschool classroom. *SRATE J.* **2014**, *23*, 8–16. Available online: https://files.eric.ed.gov/fulltext/EJ1044758.pdf (accessed on 9 April 2023).
63. Nugent, G.; Barker, B.; Grandgenett, N.; Adamchuk, V.I. Impact of Robotics and Geospatial Technology Interventions on Youth STEM Learning and Attitudes. *J. Res. Technol. Educ.* **2010**, *42*, 391–408. [CrossRef]
64. Nugent, G.; Barker, B.; Welch, G.; Grandgenett, N.; Wu, C.; Nelson, C. A Model of Factors Contributing to STEM Learning and Career Orientation. *Int. J. Sci. Educ.* **2015**, *37*, 1067–1088. [CrossRef]
65. Freeman, S.; Eddy, S.L.; McDonough, M.; Smith, M.K.; Okoroafor, N.; Jordt, H.; Wenderoth, M.P. Active learning increases student performance in science, engineering, and mathematics. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 8410–8415. [CrossRef] [PubMed]
66. Buyse, E.; Verschueren, K.; Doumen, S. Preschoolers' attachment to mother and risk for adjustment problems in kindergarten: Can teachers make a difference? *Soc. Dev.* **2011**, *20*, 33–50. [CrossRef]
67. Gresham, F.M.; Elliott, S.N. *Social Skills Improvement System Rating Scales. Social Skills Improvement System Rating Scale*; NCS Pearson: Minneapolis, MN, USA, 2008.
68. Paes, T.M.; Duncan, R.; Purpura, D.J.; Schmitt, S.A. The relations between teacher-child relationships in preschool and children's outcomes in kindergarten. *J. Appl. Dev. Psychol.* **2023**, *86*, 101534. [CrossRef]