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Can Preschool Teachers' Accurate Analysis of the Development Trajectories of Children's Preconceptions Ensure Their Effective Response? Evidence from Situational Judgement Tests

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Abstract: In early childhood science education, analyzing and responding to children's preconceptions are essential professional skills possessed by preschool teachers. This study aims to evaluate the level of preschool teachers' skills of analyzing and responding to the development trajectories of children's preconceptions (DTCP) and explores the relationship between them in different science disciplines as well as between teachers with different teaching experiences from a Chinese teachers perspective. A newly developed and validated instrument, the Situational Judgement Tests of Preschool Teachers' Skills to Analyze and Respond (SJTs-PTSAR), is adopted. Altogether, 1084 Chinese teachers from three cities in China were surveyed, and analysis of the psychometric properties indicated that SJTs-PTSAR was a reliable and valid scale. The means and standard deviations of preschool teachers' analysis skills were 1.04 and 0.31, and those for responding were 1.02 and 0.26. There was no significant difference between the scores of the two skills ($t = -1.842$, $p > 0.01$, Cohen's d = 0.068). Correlation analysis showed that the preschool teachers' analysis skills were positively related to their responding ($r = 0.353$, $p < 0.001$), and there was a significant correlation between the skills of teachers of different teaching ages. These results showed that preschool teachers' skills to analyze and respond to the DTCP were at a medium level, and an accurate analysis could not guarantee a high-level response based on the DTCP. The correlation coefficient between these two skills with teachers of different teaching experience was nonlinear. A number of suggestions for teacher training and professional development are provided to promote the sustainable development of teachers' analysis and response skills.

Keywords: preconceptions; conceptual development trajectory; teacher analyzing; teacher responding; situational judgment tests (SJTs); sustainability

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1. Introduction

The sustainable development of preschool teachers plays an important role in sustainability education and has attracted increasing attention in matters related to promoting the sustainability of teachers [1,2]. Researchers have generally put forward some suggestions to promote the sustainable development of teachers by analyzing their knowledge, understanding, skills, and values in relation to education for sustainable development [3,4]. In particular, professional skills are one of the essential components of teachers' sustainable development, in which the skills in analyzing and responding to the development trajectories of children's preconceptions (DTCP) are particularly important in early childhood science education.

It is important to note that preschool teachers' skills in analyzing and responding are essential for children's scientific thinking. It has been acknowledged that children have a propensity to hold preconceptions in scientific activities before learning scientific concepts due to their limited cognitive development [5–7]. Under such circumstances, preschool teachers' skills in analyzing the DTCP and responding accordingly play an important role in helping children's transition from preconceptions to scientific concepts. Specifically, preschool teachers' accurate analysis of the DTCP and effective responses can help children develop scientific thinking, cultivate their spirit of scientific inquiry and, finally, promote a sustainable development of scientific achievements in the future [8,9]. Therefore, preschool teachers' skills of analyzing and responding to the DTCP are becoming increasingly important in early childhood science education, which is also consistent with the requirement that teachers should understand children's learning experiences, observe children's play and provide appropriate support in guided play [10,11]. Meanwhile, it is important to explore the relationship between the two skills, since some targeted professional development projects can be provided to promote the sustainable development of teachers.

More and more scholars directed their attention to reveal the relationship between the skills of analyzing and responding [8,12,13]. The empirical studies have shown that the relationship between these two abilities is complex and non-linear due to the different teaching ages of teachers in different situations. Specifically, teachers' comprehensive or accurate analyses of children's thinking cannot guarantee that they will make a response that promotes the development of children's thinking and vice versa [12–15]. On one hand, it is difficult for preschool teachers to make an appropriate response to support children's development if they cannot analyze children's thinking or preconceptions exactly [6,7,16]. Surprisingly, some research findings show that preschool teachers can make appropriate responses even though they cannot analyze the development level of preconceptions accurately [17,18]. However, it is understandable that such appropriate response cannot last continuously and consistently in different situations [19].

The hitherto existing studies on analyzing and responding largely focus on primary, secondary or pre-service teachers in the areas of mathematics and science by video-based assessment [15,20], but there is lack of research on the relationship between the two skills of in-service preschool teachers. Providing specific evidence with respect to pre-school teachers is even more important since their working conditions differ substantially from those of primary and secondary teachers. While these teachers work in formal, often highly structured classroom environments, pre-school teachers work in a more informal setting where they need to make use of unstructured situations if they want to foster children's development [21]. These children are also much younger than primary or secondary students and need different forms of support for their scientific learning processes.

To fill this gap, we explore the relationship between preschool teacher's skill in analyzing and responding of preconceptions development presented via the Situational Judgment Tests (SJTs). Referring to the models, which are constructed based on the theories of zone of proximal development (ZPD), concept progressive development, cognitivism, constructivism and cultural-history, SJTs for preschool teachers' skills of analyzing and responding are developed. Providing such evidence is not only important from a methodological point of view, as it would support the validity of the SJTs used, but it is also relevant for policy makers because they can then draw conclusions about what type of opportunities for learning have to be provided during pre-school teacher training. In these cases, such opportunities would be those that support pre-school teachers' professional ability and sustainable development.

2. Relationship between Preschool Teachers' Skills in Analyzing and Responding

Recent studies have shown that the relationship between the skills of analyzing and responding is complex. Jacobs et al. [22] found that only when teachers analyze children's understanding can they decide how to respond based on children's understanding. Similarly, Barnhart and van Es [13] have also found that a high level of analyzing students' scientific thinking tends to co-occur with a high level of response, and a low level of analyzing co-occurs with a low level of responding. However, Seo et al. [15] found that although science teachers in middle schools can analyze students' misconceptions about photosynthesis mainly from the process of knowledge construction, they often use content-focused strategies in teaching and pay less attention to student-focused strategies.

Some studies revealed that the attributes of teachers' content knowledge (CK), pedagogical content knowledge (PCK), beliefs, working context, or teaching experience are related to their analysis and response. Dunekacke et al. [14] showed that mathematics content knowledge and mathematics pedagogical content knowledge are predictors of pre-school teachers' analysis of children's thinking and of their planning of action. Similarly, other studies revealed a strong interrelation of teachers' teaching decisions or situated reaction-competency and CK, PCK and beliefs [12,23]. Two studies also reported that a school climate of trust or the context in which teachers work and other professional communities in which they engage also serve as influence factors for analyzing and responding [12,24]. Moreover, experienced or expert teachers tended to show higher levels of analyzing and responding to children's thinking than novice or pre-service teachers [25–28]. Ho and Tan [29] found that a researcher's and a teacher's ways of analyzing classroom events were different. Colestock and Sherin [30] provided evidence that different teaching experience teachers used rather similar sense-making strategies when viewing videos of classroom situations.

3. Using Situational Judgment Tests to Evaluate Teachers' Attributes

In the selection of personnel in the international community, SJTs are becoming more and more popular [31]. SJTs ask candidates to evaluate the possibility or effect of each action by presenting the situation they encounter in the workplace and their associated response options [32]. SJTs are mainly used to evaluate different structures related to job performance, such as knowledge, ability, other characteristics, etc., which is different from the structure measured by cognitive ability tests or personality questionnaires. More specifically, a recent meta-analysis shows that SJTs can be divided into four categories: knowledge and skills, applied social skills (e.g., leadership), basic personality tendencies (e.g., integrity) and heterogeneous composites [31]. As a situation-based evaluation method, SJTs are becoming more and more used to measure the implicit traits and attributes of individuals in complex and situational work environments [33–36]. Meanwhile, the participants in the SJTs are presented with their familiar job situations and their related response to the situation. Therefore, when they are required to make judgments, they need to engage in a meaningful conversation with the situations and the possible responses, which can promote the participants to pursue self-reflection and achieve continuous sustainable development [37].

In recent years, in the field of education, researchers have developed SJTs to measure teachers' implicit knowledge [32], preschool teachers' science PCK [38], observation ability [39], children's care and educational ability [40] and effective teaching attributes [41].

These studies have created both video-based and text-based SJTs, in which single-choice questions and multiple-choice questions are both presented, and these SJTs can assess various kinds of teachers' abilities. For example, Alexander [38] presented SJTs, including both a video-based and several text-based scenarios, in which single-choice questions and multiple-choice questions were presented to identify preschool teachers' science PCK. Guo et al. [39] developed 20 single-choice questions in line with children's ZPD focused on identifying preschool teachers' skill to observe in 20 text-based scenarios in the fields of mathematics and science and so on. Referring to existing research, this study developed a valid SJT tool to assess preschool teachers' skills of analyzing and responding to children's preconceptions development in science.

4. The Current Study

The relationships have been investigated between prospective preschool teachers' analyzing and responding and their mathematics-related knowledge, beliefs and teaching experience. However, not only has less attention been paid to in-service pre-school teachers, but the comparison of these two skills between teachers with different teaching experiences is also lacking. Providing specific evidence with respect to pre-school in-service teachers is even more important, since the two skills can best promote children's learning [8]. Pre-school children come to the science situations with a wide range of preconceptions about how the world works [42], which requires pre-school teachers to analyze the DTCP adequately and then offer appropriate response strategies through the ZPD. Meanwhile, it is not the case that the more teaching experience one has, the stronger the teacher's beliefs and the higher level of the teacher's analyzing and responding on the basis of children's understanding [43,44]. Thus, identifying the level and relationship between these skills of teachers with different teaching experience is also very important for improving in-service teachers' analysis and response skills through teacher training [45–47].

In this study, SJTs for preschool teachers' analysis and response skills are developed, a descriptive analysis is performed and the relationship between the two skills in different scientific disciplines and that between teachers of different teaching experiences are discussed. The conclusions of these studies can provide a practical basis for carrying out more targeted teacher training and improving the sustainable development of teachers' analyzing and responding.

Overall, the current study aims to: a. identify the basic status of the two skills; b. explore the relationship between the two skills in different scientific disciplines and between teachers with different teaching experience. The following research questions will guide this survey:

1. What is the overall level of preschool teachers' skills of analyzing and responding to the DTCP?
2. What is the relationship between preschool teachers' skills of analyzing and responding in different science disciplines?
3. What is the relationship between the analyzing and responding skills of preschool teachers with different teaching ages?

5. Materials and Methods

5.1. Participants

The survey was conducted through four stages, and each stage had different participants (Figure 1 presented the basic information of participants at different stages). In stage I, utilizing the purposive sampling method, 10 preschool teachers from two cities in Jiangsu and Anhui provinces in China were targeted for interviews, and 6 experts in the field of early childhood education were invited to assess the theoretical model. These 10 preschool teachers had rich experiences in science teaching, and some worked kindergartens where teachers are carrying out science curriculum reform projects. The six experts are all famous professors, hold PhD degrees and have high-ranking journal publications in the field of early childhood education. The participants in stage II were mainly employed to determine the situations in which preconceptions occurred and improve the behavioral response items. In total, 20 children and 6 teachers in a city in Jiangsu province were selected on the principle of convenience and voluntary sampling for face-to-face situational interviews, while 39 teachers from three cities in Jiangsu, Anhui and Hebei provinces were randomly interviewed through both telephone and face-to-face about the response items. Stage III is a pilot test, and 278 preschool teachers from Jiangsu and Zhejiang provinces were randomly selected as participants. A total of 21 questionnaires were excluded from the sample because of some stereotyping answers. Therefore, in this stage, the final sample consisted of 257 preschool teachers (mean age = 33.9, SD = 8.186).

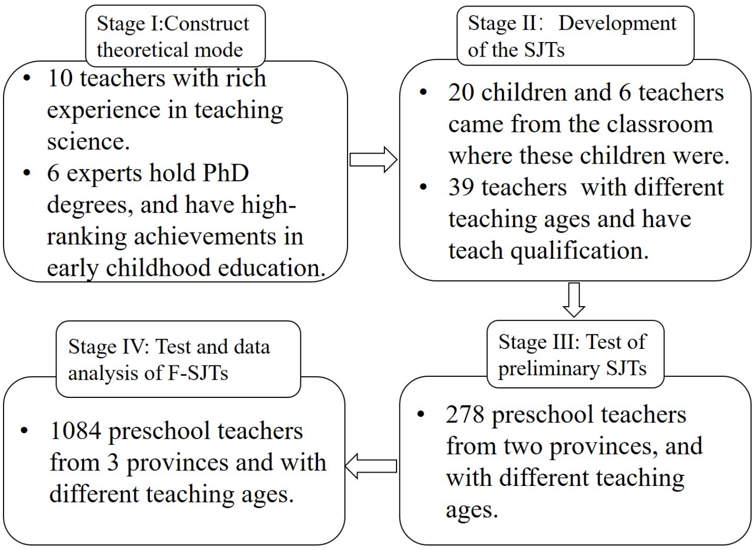

Figure 1. Participants' characteristics in different stages.

Stage IV is the formal test. In selecting participants, the cluster sampling method was adopted with the region and economic development level being two important parameters. A total of 1084 preschool teachers in Jiangsu province, Guangdong province and Hebei province were selected as samples, out of which 125 were eliminated as the stereotyping answers. Therefore, the final samples included 945 preschool teachers (mean age = 31.53, SD = 8.161). Among them, there were 322 teachers in Jiangsu province, 306 teachers in Guangdong province and 317 teachers in Hebei province. A total of 44 kindergartens were selected, including 30 public kindergartens and 14 private kindergartens. As shown in Table 1, 174 teachers (18.4%) had more than 16 years of teaching experience. A majority (77.4%) of the teachers had an associated degree or lower, and 22.4% of them had a bachelor's degree or above. A majority (70.9%) of the teachers specialized in preschool education, while around a quarter (25.4%) had no teaching qualification.

Table 1. Participant characteristics (N = 945).

Demographic Characteristics	Frequency (%)
Education level	
High school and below	246 (26.0)
Associated degree	486 (51.4)
Bachelor's degree and above	213 (22.5)
Teaching qualification	
Yes	705 (74.6)
No	240 (25.4)
Degree education major	
Preschool education	670 (70.9)
Non-preschool education	275 (29.1)
Years teaching experience	
0–1 Years	115 (12.2)
2–5 Years	239 (25.3)
6–10 Years	269 (28.5)
11–15 Years	148 (15.7)
16 Years and above	174 (18.4)

5.2. Procedures

5.2.1. Stage I: Constructing the Theoretical Model

In this stage, the theoretical model of teachers' analyzing and responding skills was determined through literature analysis, teacher interviews and expert discussions. A preliminary theoretical model was established via clarifying the theoretical basis and the structures of analyzing and responding. Then, an interview with teachers was made to obtain their analysis and response to the preconceptions, and the preliminary theoretical model was improved according to the interview results. Finally, a face-to-face discussion with the experts about the theoretical basis; the rationality, hierarchy, discrimination and model presentation of the structural elements of teachers' analyzing and responding skills was organized; and the formal theoretical analyzing and responding model of this study was eventually determined, as shown in Figure 2.

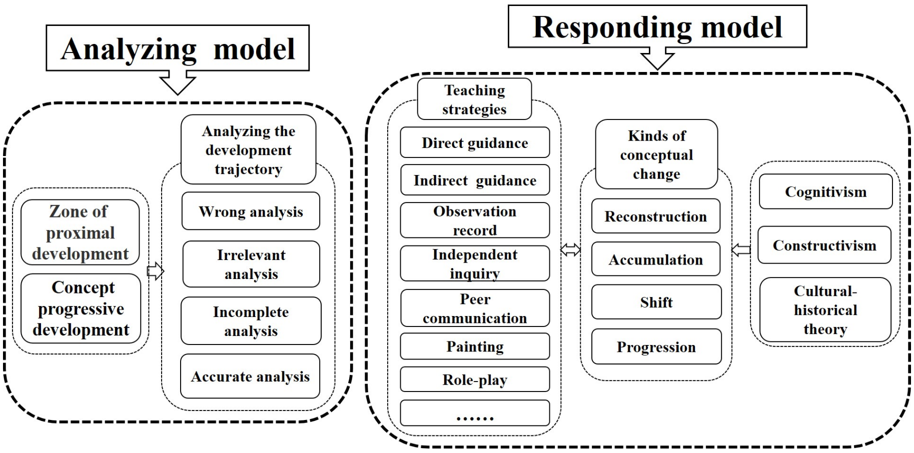

Figure 2. Formal theoretical analyzing and responding model.

The formal analyzing model presents the constituent elements of teachers' skills in analyzing the DTCP, which is proposed based on the theory of the ZPD and progressive concept development. The modern construction theory emphasizes that there are two levels of children's development, one is the current level of children, the other is the possible development level of children, and the difference between these two levels is the level of children's ZPD [48]. Children's learning of scientific concepts is based on the stable life experience of each child, and they use everyday experience, interaction with peers or supports from teachers to develop their scientific concepts which then divides into smaller 'sub-concepts'. That is, the development level of different preconceptions make them less abstract and more specific and restrictive [7,49]. The notion of progressive concept development states that in the process of forming scientific concepts, preconceptions will experience a series of small and continuous enabling concepts, which are very important for complete understanding [50]. In other words, the development of preconceptions is progressive and presents some specific development trajectories [51–54].

Based on the theory of ZPD and progressive concept development, teachers' skills to analyze are divided into four levels: wrong analysis, irrelevant analysis, incomplete analysis and accurate analysis. Wrong analysis means that a teacher's interpretation and judgment of the development of children's existing level is higher than that of the ZPD, or close to scientific concepts. Irrelevant analysis means that a teacher's interpretation or judgment of the development of children's current level (preconceptions) is at the level of other directions. For example, a child's preconception of a shadow can be: 'even if there is no light, the shadow still exists'. Then, the preconception should develop in the direction of how the shadow is formed, and the teacher's analysis should also follow this direction. However, some teachers tend to let children understand the changes in shadow size, color and so on. Incomplete analysis means that a teacher's interpretation and judgment of the development of children's existing level is at a slightly higher level than that of the ZPD. Accurate analysis means that a teacher's interpretation or judgment of the development of children's existing level is consistent with the level of the ZPD.

The formal responding model shows that the teaching strategies and kinds of conceptual change, which are proposed on the theory of cognitivism, constructivism and cultural-historical theory. The conceptual teaching strategies based on cognitivism and classical constructivism are used various ways, such as teachers' direct or indirect guidance, observation and exploration, observation record and so on, to trigger cognitive conflict and obtain conceptual change [17,55]. However, conceptual teaching strategies drawing their theoretical foundations from social constructivism and cultural-historical theory [56,57] emphasize that the conceptual change in children is obtained mainly through the interaction with more knowledgeable and experienced individuals (e.g., teachers) or peers or by means of mediating cultural tools [58], such as painting, role-playing and so on [59,60].

For conceptual change, Posner et al. [61] (p. 223) first put forward the theory of conceptual change, which suggested that changing a learner's current way of thinking about a scientific theory was not a simple thing, as they first need to consciously express their dissatisfaction with the theory. Any new replacement theory will only be accepted if it is intelligible, plausible and fruitful. Empirical research has found that it is very difficult to really obtain conceptual change [62]. Considering this, many researchers have made various descriptions of the degree of conceptual change [63]. On closer examination of these descriptions, a dichotomy of two levels emerges, that is, addition and revision, and the later kind of conceptual change is divided into strong revision and weak or lesser revision by most theorists [64].

According to the degree of conceptual change, we divide the purpose of teaching strategies in response to preconceptions into reconstruction, accumulation, shifting and progression. Conceptual reconstruction means that teachers use strategies to enable children to obtain a higher level or closer to scientific concepts. Conceptual accumulation means that teachers use strategies to accumulate children's experience, which may help children reach the level of the ZPD, or higher-level concepts and may also form other concepts or more serious misconceptions. Conceptual shifting means that teachers use strategies to enable children to explore concepts unrelated to the development trajectory of their preconceptions. Conceptual progression means that teachers use strategies to help children reach the level of the ZPD.

5.2.2. Stage II: Development of the SJTs

Firstly, 20 scenarios were preliminarily planned by consulting the scientific activities in the *kindergarten teacher guidance books* and arranging the common preconceptions and the associated situations. These scenarios include 10 scenarios in the field of physical science, 6 scenarios in the field of life science and 4 scenarios in the field of earth and space science, and mainly occurring in children aged 4–6. Then, these situational interviews were conducted with the second group of participants to further determine the preconceptions and the contexts in which they occur.

Secondly, the question mode is determined as the forced choice. Each situation contains two questions: question 1 asks the participants to select the best strategy, which mainly examines teachers' skill to respond. Question 2 asks the participants to choose the reason for the best strategy according to the preconception development level that children will soon reach, which mainly examines teachers' skills of analysis.

Thirdly, the behavioral response items are determined. Referring to the formal analyzing and responding model, the researchers first prepared the teacher's behavioral response in each situation and determined four response items, as shown in Table 2. Then, 39 teachers in the second group were interviewed to modify and improve the behavioral response items. Each interview lasted from 30 to 90 min, and the whole interview process lasted four months.

Table 2. Behavior response model of teachers' analyzing and responding skills.

		Four Reaction Terms			
Mode 1	Responding	Conceptual progression strategies	Conceptual reconstruction strategies	Conceptual accumulation strategies	Conceptual shift strategies
	Analyzing	Accurate analysis the ZPD	Wrong analysis of the ZPD	Incomplete analysis of the ZPD	Irrelevant CPD
Mode 2	Responding	Conceptual progression strategies	Conceptual reconstruction strategies	Conceptual accumulation strategies	Conceptual accumulation strategies
	Analyzing	Accurate analysis of the ZPD	Wrong analysis of the ZPD	Incomplete analysis of the ZPD	Incomplete analysis of the ZPD

5.2.3. Stage III: Test of Preliminary SJTs

SJTs were distributed online using www.wjx.cn, accessed on 23 March 2022 (setting skip question function), China's leading online survey platform. The evaluation tool of the pilot test is named preliminary SJTs (P-SJTs). First, we determine the scoring method. In this study, the strategies of conceptual progression are determined as the best response strategy, and 2 points will be obtained if this item is selected. The strategy of conceptual reconstruction is determined as the worst strategy. If the participant chooses this strategy, 0 points will be obtained. The other two strategies are classified as medium strategies. If these options are selected, 1 point will be given. Accordingly, the option for teachers to analyze the ZPD accurately is set as the correct answer, and 2 points will be given if this option is selected. The option for teachers to analyze the ZPD mistakenly is set as the wrong answer, and 0 points will be obtained if this item is selected and 1 point for other options. Therefore, in terms of teachers' analysis and response, three grades of 0, 1 and 2 are adopted. After that, seven experts in the field of preschool education were invited to score the behavioral response items independently, and the Kendall harmony coefficients were 0.688 and 0.725, respectively, $p = 0.000$, indicating that there was significant consistency between the scores of experts on questions 1 and 2.

Second, examining the quality of P-SJTs. The fourth group of participants were investigated. Cronbach's alpha coefficient was 0.710 for the P-SJTs. The formation of situational and behavioral response items strictly abide by the development procedure of SJTs, which ensures that the test items can fully reflect the formal analyzing and responding model and that the final SJTs have good construct validity. There are three items with low discrimination under the classical test theory (CTT), namely: s10q1 (situation 10, question 1, and so forth) ($t = -0.599, p = 0.550$), s19q1 ($t = -1.252, p = 0.213$), s19q2 ($t = -1.000, p = 0.319$). The difficulty value is between 0.3 and 0.8. Under the item response theory (IRT), there are 4 items with poor discrimination and difficulty: s3q1 ($a = -0.04$, $b = -17.10 \sim 12.27$), s10q1 ($a = -0.05, b = -15.35 \sim 16.99$), s18q1 ($a = 0.008$, $b = -109.371 \sim 41.99$), s19q1 ($a = -0.04, b = 10.07 \sim -9.38$) and s19q2 ($a = 0.03$, $b = -18.04 \sim 32.30$). Comprehensively comparing the item quality under CTT and IRT, four situations were deleted, namely: situation 3, situation 10, situation 18 and situation 19. Finally, the formal SJTs (F-SJTs) have 16 situations in which preconceptions occur.

5.2.4. Stage IV: Test and Data Analysis of F-SJTs

The fifth group of participants were investigated in the survey of F-SJTs. Cronbach's alpha coefficient was 0.733 for the F-SJTs. Under the CTT, the discrimination of all items is good, and the difficulty value is between 0.31 and 0.84. Under the IRT, the discrimination calculated by using the graded response model is between 0.23 and 1.05, and the average discrimination is 0.63. The difficulty value $b1$ is $-5.55 \sim 1.02$, $b2$ is $-1.41 \sim 7.08$ and the average difficulty is −2.29 ∼ 2.05. F-SJTs have good reliability and validity, and the item quality is within the acceptable range.

6. Results

6.1. Teachers' Skill to Analyze and Respond

The means, standard deviations and paired-samples *t*-test results of preschool teachers' skill to analyze and respond are presented in Tables 3 and 4. Preschool teachers' analyzing ($M = 1.04, SD = 0.31$) and responding ($M = 1.02, SD = 0.26$) are within 1 standard deviation compared with the median, so the two skills are at the medium level, and there was no significant difference between the scores of the two skills ($t = -1.842, p > 0.01$, Cohen's d = 0.068). Specifically, in the field of physical science, preschool teachers' analyzing skills ($M = 0.88, SD = 0.38$) are lower than responding ($M = 1.03, SD = 0.28$). The paired samples *t*-test found that the difference between the two skills was statistically significant ($p < 0.001$, Cohen's d = 0.459). In the other two fields of science, preschool teachers' analyzing skills are higher than responding. The paired samples *t*-test found that the difference between the two skills in the two fields was statistically significant ($p < 0.001$, Cohen's d > 0.4).

Table 3. Means, standard deviations of teachers' analyzing and responding skills.

Fields	Analyzing M (SD)	Responding M (SD)
Physical science	0.88 (0.38)	1.03 (0.28)
Life science	1.20 (0.32)	1.04 (0.42)
Earth and space science	1.16 (0.56)	0.88 (0.48)
Total	1.04 (0.31)	1.02 (0.26)

Table 4. The paired samples *t*-test of differences between scores of teachers' analyzing and responding skills.

	MD	CL (95%)		t	*p*	Conhen's d
		LCL	UCL			
A-R	0.019	−0.001	0.040	−1.842	0.066	0.068
APS-RPS	−0.155	−0.181	−0.128	−11.251	0.000	0.459
ALS-RLS	0.163	0.134	0.192	−11.030	0.000	0.438
AESS-RESS	0.284	0.244	0.324	−13.868	0.000	0.550
APS-ALS	−0.327	−0.350	−0.304	−27.799	0.000	0.921
ALS-AESS	0.044	0.010	0.078	2.536	0.011	0.097
APS-AESS	−0.283	−0.381	−0.248	−15.851	0.000	0.593
RPS-RLS	−0.009	−0.036	0.017	−0.667	0.505	0.018
RLS-RESS	0.165	0.127	0.203	8.583	0.000	0.369
RPS-RESS	0.156	0.123	0.188	9.409	0.000	0.405

A, Analyzing; R, Responding; APS, Analyzing in physical science; RPS, Responding in physical science; ALS, Analyzing in life science; RLS, Responding in life science; AESS, Analyzing in earth and space science; RESS, Responding in earth and space science (hereinafter same).

As for analyzing, results showed that the level of analysis in physical science ($M = 0.88$, $SD = 0.38$) is lower than that in the other two fields. The paired samples *t*-test found that statistically significant differences exist between each pair of factors ($p < 0.001$). As for responding, the results showed that the level of response in earth and space science ($M = 0.88, SD = 0.48$) is lower than that in the other two fields. The paired samples *t*-test found statistically significant differences between each pair of factors ($p < 0.001$), except responding in life science and in physical science ($p = 0.505$).

6.2. Correlation Analysis

6.2.1. Relationship between the Skills of Analyzing and Responding

Table 5 reports the Pearson correlation coefficient between skills of analyzing and responding. Overall, preschool teachers' skill in analyzing was positively related to their responding ($r = 0.353, p < 0.001$). Specifically, in each science discipline, analyzing was also positively related to teachers' skill in responding, but the Pearson correlation coefficient is lower than 0.30. Therefore, there is a weak correlation between preschool teachers' analyzing and responding skills. The results indicate that a high level of analyzing children's DTCP cannot guarantee that teachers will respond appropriately, and vice versa.

Table 5. Interrelations of differences between scores of teachers' analyzing and responding skills.

	A	R	APS	RPS	ALS	RLS	AESS	RESS
A	1							
R	0.353 ***	1						
APS	0.898 **	0.266 **	1					
RPS	0.266 **	0.782 **	0.225 ***	1				
ALS	0.773 **	0.299 **	0.481 **	0.213 **	1			
RLS	0.270 **	0.811 **	0.190 **	0.334 **	0.264 ***	1		
AESS	0.592 **	0.400 **	0.363 **	0.174 **	0.351 **	0.208 **	1	
RESS	0.187 **	0.307 **	0.133 **	0.226 **	0.113 **	0.131 **	0.261 ***	1

** $p < 0.01$; *** $p < 0.001$.

6.2.2. Relationship between Analyzing and Responding of Teachers with Different Teaching Ages

The mean values, standard deviations and inter-correlations between analyzing and responding skills of teachers with different teaching ages are presented in Table 6. The results show that with the increase in teaching age, the scores of analyzing and responding first rise and then decline. Teachers with teaching experience of 11–15 years have the highest scores on the two skills. In terms of analyzing, the scores of teachers with teaching ages of 16 years and above ($M = 1.01, SD = 0.27$) are lower than that of teachers with teaching ages of 0–1 years ($M = 1.02, SD = 0.30$).

Table 6. Means, standard deviations and interrelations of differences between scores of teachers' analyzing and responding skills.

	M (SD)	1	2	3	4	5	6	7	8	9	10
1. A1	1.02 (0.30)	1									
2. R1	0.97 (0.26)	0.421 ***	1								
3. A2	1.02 (0.32)	0.162	0.068	1							
4. R2	0.99 (0.28)	−0.002	−0.023	0.344 **	1						
5. A3	1.04 (0.31)	0.033	0.037	0.104	0.130 *	1					
6. R3	1.01 (0.26)	0.109	0.057	0.053	0.118	0.397 ***	1				
7. A4	1.10 (0.30)	−0.107	−0.012	−0.013	0.008	−0.034	−0.159	1			
8. R4	1.07 (0.26)	−0.067	−0.095	0.098	−0.058	0.097	−0.186 *	0.371 ***	1		
9. A5	1.01 (0.27)	0.213 *	0.203 *	−0.026	−0.047	0.009	−0.029	0.024	−0.007	1	
10. R5	1.05 (0.24)	0.026	0.081	−0.108	−0.051	0.061	−0.025	0.021	−0.122	0.195 **	1

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; A1, Analyzing skill of teachers with 0–1 teaching age; R1, Responding skill of teachers with 0–1 teaching age; A2, Analyzing skill of teachers with 2–5 teaching age; R2, Responding skill of teachers with 2–5 teaching age; A3, Analyzing skill of teachers with 6–10 teaching age; R3, Responding skill of teachers with 6–10 teaching age; A4, Analyzing skill of teachers with 11–15 teaching age; R4, Responding skill of teachers with 11–15 teaching age; A5, Analyzing skill of teachers with 16 teaching ages and above; R5, Responding skill of teachers with 16 teaching ages and above.

In addition, there is a significant correlation between the two skills of teachers with different teaching ages. Among them, the correlation between the two skills of teachers with a teaching age of 0–1 years is high ($r = 0.421, p < 0.001$), while the correlation between the others is weak; the correlation between teaching ages of 16 years and above especially is very small ($r = 0.195$, $p < 0.01$). According to the correlation coefficient, it can be seen that with the increase in teaching experience, the correlation between analyzing and responding skills shows a trend of decreasing first, then increasing and then gradually decreasing. The results indicate that the relationship between the analyzing and responding skills of teachers with different teaching experience is non-linear.

7. Discussion

7.1. The Level of Preschool Teachers' Skills to Analyze and Respond

This study found that preschool teachers' analyzing and responding are within 1 standard deviation compared with the median, showing that the teachers' two skills were at a medium level. Interestingly, the previous studies found that pre-service teachers have a lower and moderate skill in analyzing and responding to children's thinking [13,21]. The possible explanation for such a new finding is that in-service preschool teachers are more familiar with children's thinking or preconceptions and scientific activities than pre-service teachers, and therefore, they have significantly higher skill to analyze and respond to children's thinking than pre-service teachers [22]. In the field of physical science, our study also found that preschool teachers' level of analyzing is significantly lower than that in other fields. One reason is that it is more difficult for preschool teachers to master the formal scientific concepts in physical science compared to the other two fields, due to preschool teachers having poor scientific knowledge and even having similar preconceptions as children in some physical science activities [18,65,66]. For example, in buoyancy activities, young children and even their teachers regularly recognize that objects float or sink either due to their size or to their weight: heavy or big objects will sink while light or small objects will float [67]. On the other hand, preschool teachers are more familiar with the contents in the field of life science, and they tend to focus on, and feel confident in, teaching life-science-related concepts more than physical science concepts in kindergarten classrooms [68,69].

7.2. The Relationship between Analyzing and Responding in Different Scientific Disciplines

Our second research question concerns the relationship between the two skills in different scientific disciplines. This study found that the Pearson correlation coefficient between analyzing and responding skills was lower than 0.4, indicating that the high level of analysis of the DTCP does not guarantee a high level of responding to those preconceptions in different scientific disciplines, which is consistent with other studies [13,70]. The distribution of preschool teachers' correlation coefficient and scores in different fields of science between the two skills indicates that accurate analysis and appropriate response to the DTCP may be successively difficult. It may be that preschool teachers' mastery of science content knowledge in different scientific disciplines is different, and their use of response strategies is also different when facing children's preconceptions in various situations. Our study also found that in the fields of life science and earth and space science, preschool teachers tend to analyze the DTCP accurately but lack appropriate response strategies to promote the development of preconceptions. For example, in the activity of exploring the formation of rain in situation 8, the preconception of two young children is that water vapor will turn into rain when it meets heat. Then, the development trajectory of this preconception should be as follows: a. discover that water vapor turns into small water droplets when it meets cold; b. understand the change process of small water droplets from water vapor to rain and then to snow; c. have a more scientific understanding of the formation process of rain; d. understand the conditions of the three-state change of water. We found that preschool teachers prefer to judge the development level that children will reach quickly in the next period of time as a / b / c, and a few of them select d. However, in terms of responding strategies, preschool teachers incline to choose the strategy of conceptual reconstruction, such as 'leading them to recall the scenes of little water drop journey, and guiding them to understand the three forms of water and the conditions for their mutual transformation.' This example shows that preschool teachers are not good at the strategies of social construction, such as cooperation and communication between children, painting and singing, so the teachers' responding skills in the field of earth and space science are significantly lower than those in the other two scientific disciplines.

7.3. The Relationship between Analyzing and Responding of Teachers with Different Teaching Age

As for the third research question, our study found that with the increase in teaching experience, the scores of preschool teachers' analyzing and responding skills first increase and then begin to decline after 16 years of teaching. Moreover, the correlation between the two skills first decreased, then increased and then gradually decreased; especially after 16 years of teaching, the correlation between the two skills is very small. These findings show that teachers' expertise in analyzing children's understandings and responding to them does not simple growth with the increase in teaching experience. Teachers who have been teaching for more than 16 years have rich teaching experience and have a comprehensive understanding of the characteristics of children's development [71]. However, in the interview of the formation of the SJTs, it was found that these teachers' analyses of the DTCP are also solidified, and their response strategies for preconceptions in different situations are characterized by fluctuations. The solidification of these teachers' analyses of the DTCP shows that they have a disposition to consider the general characteristics of children's development, but they ignore the individual differences of preconceptions. Simultaneously, these teachers will respond to preconceptions based on the general characteristics of children's development, the availability of materials or the purpose and time of scientific inquiry, etc. Therefore, there is no fixed model for their response strategies in different situations, which leads to a certain degree of disconnection between their analysis and response behavior. Moreover, previous studies have found that teachers often ignore understanding children's preconceptions when they teach science activities [72], so even teachers with rich teaching experience are not familiar with the DTCP, unless they participate in the professional development related to children's thinking [22].

8. Conclusions

Our study found that preschool teachers' skills of analyzing and responding to the the DTCP is at the medium level, and there are differences between the scores of the two skills in different scientific disciplines. In the field of physical science, analyzing is significantly lower than in life science and earth and space science, while in the field of earth and space science, responding is significantly lower than that in the other two fields. Based on these results, we can carry out targeted teacher training or teacher professional development projects to promote the sustainable development of teachers' analyzing and responding skills. For example, for physical science, we should help teachers strengthen their learning of buoyancy, light and shadow, etc., so as to help them acquire science content knowledge and become familiar with common preconceptions of children and acquire DTCP knowledge. As for earth and space science, teachers' responding skills are weak. In the process of professional development, teachers need to deeply understand the characteristics of children's scientific learning and comprehend how to use response strategies such as painting, singing and drama-playing to promote CPD. Meanwhile, teachers themselves also need to consciously apply these strategies to interact with children and gradually become familiar with the strategies of social construction.

In different science disciplines, preschool teachers' accurate analysis cannot ensure an appropriate response based on the DTCP. In teacher training or professional development, teachers should not only strengthen the analysis of the DTCP in different areas, but should also reflect on the response strategies based on the DTCP. With the increase in teaching experience, the scores of preschool teachers' analyzing and responding skills also increased, but they began to show a downward trend after 16 years of work, and the correlation coefficient between the two skills showed characteristics of fluctuation; especially after 16 years of teaching, the correlation between the two skills was very small. Therefore, in their professional development, teachers should reinforce their learning of children's scientific thinking, identify preconceptions in daily science teaching actively and consider how to carry out science lessons based on the DTCP. For those teachers with 16 years or more of teaching experience, we should help them realize the relationship between individual differences and generality in children's preconceptions development.

9. Limitations

This study has some limitations. First, F-SJTs have 16 situations, which are limited to physical science, life science and earth and space science and lack preconceptions in the field of engineering and technology science. It is because of that there is less research on the DTCP in this discipline when consulting the literature in the early stage. Second, at present, the sample is limited to preschool teachers in one urban area with medium and high economic development levels in each province of East, South and North China. In addition, only preschool teachers from urban areas were included in the sample.

10. Future Directions

First, it is necessary to expand the situations in which preconceptions occur in the field of engineering and technology science. Second, there is a large gap in the economic development level of different cities, which will lead to a certain gap in the ability level of teachers. Meanwhile, there is a certain gap in the quality of preschool teachers between urban and rural areas in China. Therefore, in future research, we need to consider the samples with a balanced urban economic development level and urban–rural ratio.

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