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Investigating PCK Among Malaysia Preschool Teachers in Early Mathematics

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Abstract--- *This paper explored the Pedagogical Content Knowledge (PCK) of preschool teachers for preparing pupils to understand mathematical concepts. The main aspect being explored is student's cognitive knowledge (SCK) and pedagogical knowledge (PK) by investigating, understanding and transforming classroom teaching practice in preschools. The design of this study was a case study with three preschool teachers who were selected as the research participants. Data were collected over five months in the form of interviews, teaching observation and document analysis. All of the interviews were in audio and video format while a checklist was used to record teaching observations. Analysis of the content of the documents produced was based on the teachers' lesson plans and results were compared with previous research. Validity and reliability were established based on the Cohen Kappa Index Scale. This study found that the research participants possessed knowledge and understanding of student's cognitive knowledge (PCK) in early mathematics. Furthermore, the research participants clearly demonstrated a good level of knowledge and understanding of pedagogical knowledge (PK) for early mathematics. It can be concluded that both PCK and PK are, therefore, important for helping preschool teachers to plan and conduct early mathematics activities that are relevant to their pupils' stage of development and for enabling them to choose the best method of teaching practice. Selecting the best teaching practice in early mathematics is, of course, vital for making students' learning activities fun and meaningful for preschoolers.*

Keywords--- *Student's Cognitive Knowledge (SCK), Pedagogical Knowledge (PK), Preschool Teachers, Early Mathematics, Best Practice.*

I. INTRODUCTION

Improving the quality of mathematics education is an important issue for any country. Various transformation processes are taking place in the mathematics education system in Malaysia as part of the MOE's drive to make national education more relevant in the international arena. This starts with preschool education. Based on the mission and vision of mathematics education in the National Vision 2020, it is the priority of the MOE to produce a Malaysian community which is knowledgeable and skilled in applying mathematical knowledge, as well as in cultivating mathematical knowledge in line with developed countries (Masniza, 2011). The responsibility of improving the quality of education rests on the shoulders of any teacher, as the quality of learning and teaching requires a fresh, practical, fun approach that is able to attract preschoolers to learn. It is evident that in recent decades, research findings have shown that there is a very significant relationship between the quality of learning taking place in the classroom and the learning

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opportunities created by teachers which directly influence students' learning and motivation to learn (Hattie, 2009; McCaffrey et al., 2004). According to Arbaa et al. (2010), a creative and innovative learning approach helps the delivery of knowledge to be more effective, engaging, enjoyable and, ultimately, to stimulate students' interest. This quality of learning process was described by MacNaughton (2005) as providing students with a positive, meaningful and enjoyable experience. This view was supported by Nor (2006) who stated that self-confidence and positive attitudes can be fostered if students are provided with meaningful learning experiences. Pupils' cognitive knowledge and pedagogical knowledge are two important components of pedagogical content knowledge which need to be mastered by preschool teachers in early mathematics teaching if quality teaching is to be assured (Shulman, 1986; 1987; Aintley & Luntley, 2007; Ahmad Yunus & Ab Halim, 2010). As such, teachers play a vital role in enhancing student achievement in the classroom. This can be interpreted through changes that are conducive to student acceptance and, in particular, the implementation of the teacher's teaching process in accordance with the developmental background and knowledge of the student itself. As a result, the student's cognitive knowledge possessed by the teacher with accompanied by the approaches, methods and techniques used in teaching based on teacher pedagogical knowledge capable of making a positive impact in the teaching and learning process.

Major and Palmer (2002) argued that students' cognitive knowledge (SCK) and pedagogical knowledge (PK) are two of the most important core components of pedagogical content knowledge. According to Park and Oliver (2008), students' cognitive knowledge is related to a teacher's need to know certain aspects about a student, including knowledge of what a student knows about a topic, learning problems that students face when studying a certain topic and how to determine an effective learning style for a topic. Grossman (1990) also elaborated on students' cognitive knowledge, stating that it includes knowledge of student concepts of learning about a particular topic, learning difficulties, motivational problems and diversity in students' abilities, learning styles, interests, developmental levels and student needs. Pedagogical knowledge, in contrast, is related to teaching practices such as approaches, principles, classroom management strategies and so on (Shulman, 1987). Lee (2010) points out that teachers need to know how to teach and transform their knowledge specifically at different levels of student development. Therefore, teachers need to have PCK and PK based on an understanding specifically of who their students are, their learning styles, the impact of different student cultural backgrounds and the influence of their family backgrounds (Khakbaz, 2014).

It is clear, then, that the level of SCK and PK of preschool teachers is potentially very influential for improving preschool student achievement in early mathematics. A process of creative teaching and learning becomes more meaningful when the preschool teacher is able to combine PCK and SCK (Reilly & Paker, 2012) and develop positive mathematical thinking among students. Therefore, SCK and PK can only be interpreted by preschool teachers through changes that foster the acceptance of preschool students through their approaches, methods, strategies and techniques used in early mathematics teaching and learning. This paper focuses on the discussion of SCK and PK in the process of teaching and learning early mathematics.

Children learn mathematics through their experiences, whether in or outside the classroom. The role of preschool teachers is very important in enabling children to understand mathematical concepts correctly. Teachers need to be

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knowledgeable, innovative and understanding of what and how to teach and why and how students need to learn mathematics (Shulman, 1986; Mccray, 2008; Abdul Razak & Nor Asmah, 2010). However, it has been found that preschool teachers are less knowledgeable about teaching and learning processes and teaching strategies are still teacher-centered and neglect pre-developmental education pedagogy of developmentally appropriate practice (DAP) because they do not understand the basic development of children, especially in mathematics teaching in preschool (Nurul Amirah & Zaidatun, 2008; SIQA, 2012; 2013; Jain et al., 2016; 2017). In fact, according to Van der Sandt (2007) who divided mathematics teachers' belief systems into four parts: beliefs about teaching, learning, mathematics, and pupils, there are still some teachers who do not understand children's development and the basics of mathematical development; in particular, the problem that children cannot relate math skills to real situations (Nurul Amirah & Zaidatun, 2008). A study conducted by Peter et al. (2010) showed that constructivist approaches have a positive impact on students in academics, especially mathematics (Zainal Abidin & Afrinaleni, 2010). Indeed, according to Vighnarajah, Wong and Kamariah (2008) teachers using a constructivist approach were able to engage students in classroom activities that are hands-on, 'mind-on' and authentic (Mohd Fadzli & Fuziyah, 2011). However, Fatimah (2009) states that there are still preschool teachers who teach early mathematics to preschool students using paper and pencil, without referring to manipulative materials or games that provide students with real experiences. Wu and Lin (2016) observed that the use of realistic materials such as concrete objects (manipulative materials) can stimulate children's physical and mental well-being. It could be said that the effectiveness of teaching and learning processes depends on a teacher's understanding of factors such as student learning readiness, student experience, student observation of information from sensory influences, and pupils 'perception of concepts based on students' long-term and short-term memory (Kamarul Azmi & Ab. Halim, 2007; Sahabuddin, Rohizani & Mohd Zohir, 2003). Therefore, this paper aims to explore SCK and PK among preschool teachers during the early mathematics teaching process based on the National Preschool Standard Curriculum (2016) and its implications for the world of preschool education.

II. METHODOLOGY

The design of this study is qualitative, using case studies. According to Creswell (2014) and Merriam (2009), the case study method is a holistic study method using descriptive evidence from various sources to be analysed or evaluated in-depth, even in bounded systems. Four preschool teachers from the district of Seremban, Negeri Sembilan were selected as participants of the study through purposive sampling. The participants of this study were selected because they have certain characteristics or qualities in accordance with the research objectives (Coyne, 1997; Koerber & McMichael, 2008). The participants of the study were graduates of the Malaysian Institute of Teaching (MIT) who specialized in Preschool Education. They all had teaching experience from 8 to 15 years. All of the participants in this study had a background in preschool education teaching in the Ministry of Education Malaysia (MOE) preschool class. Prior to the interview process, all of the study participants had signed a letter of agreement that their participation was voluntary. All data collected was kept confidential and for informational purposes only. The study participants were labelled as P1, P2, P3, and P4, to represent the findings through the interview process in this study. Table 1 summarizes the demographic profiles of the study participants.

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Table 1. Review of Participants' Demographic Profile

Participant	*Teaching Experience*	*Specialisation*	*Educational Background*
P1	25 years	Preschool	Bachelor's Degree
P2	14 years	Preschool	Bachelor's Degree
P3	13 years	Preschool	Master's Degree
P4	13 years	Preschool	Bachelor's Degree

Interview questions were constructed based on research objectives that discussed the practice of ABP in the early mathematics teaching process of preschool teachers. For the validity of the interview protocol, four experts evaluated and reviewed the protocol questions. The specialists consist of pre-school mathematics specialists, two early childhood education lecturers and one teacher who is also a Primary Coach (PC) of preschoolers. Subsequently, for the reliability of the interview data collected, the Cohen Kappa Reliability Index calculation method was used as suggested by De Wever et.al. (2006). The Cohen Kappa Index Analysis aims to determine the degree of agreement of the analytical unit with the theme under study (Zamri & Noriah, 2003).

To validate the findings, three external reviewers reviewed and commented on the transcriptions of the interview participants (Othman, 2012). These three experts represented 3 different fields: mathematics, early childhood education and qualitative research. The reliability of the study was calculated using the Cohen Kappa Reliability Index method (Fraenkel et al., 2012) using the following formulas:

$$K = fa\text{-}fc/N\text{-}fc$$

which K – the value of the Kappa coefficient

fa – frequency of approval

fc – frequency of 50% of the expected agreement

N – number of units tested for approval value

The value of consent obtained from experts is averaged to obtain the true Cohen Kappa Reliability Index value. Here is the value of the Cohen Kappa Reliability Index and its interpretation, related to the level of agreement obtained in the actual study.

Table 2. Kappa Value and interpretation (stage) (Fraenkel at al., 2012)

Kappa Value	*Interpretation*
Less than 0	Very weak
0.00 – 0.20	Weak
0.21 – 0.40	Moderate Weak
0.41 – 0.60	Moderate
0.61 – 0.80	Good
0.81 – 1.00	Very Good

The reliability of the experts in the actual study was 0.90, which is a very good interpretation value. All interview sessions, teaching observations through checklists and document analyses were recorded and transmitted into

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transcriptions. They were then encoded using a number of methods such as open coding, axial coding, selective coding and memos through the Atlas.ti version 8 application, where what are considered super codes are connected not only to a passage of text but to the code itself (Smit, 2002). In addition, the relationships between codes can be represented graphically and defined or redefined as well as being interpreted in accordance with standard logical relationships (Muhr, 1997), all of which can be coded and categorised by theme. Data from all interviews were transcribed and reviewed in order to identify key themes. The same process continued until the data saturation stage. The degree of saturation of the data was obtained from the study participants when the information reached a sufficient level to replicate the study (O'Reilly & Parker, 2012; Walker, 2012) or when the ability to obtain additional information was achieved and the encoding process was no longer feasible. (Guest et al., 2006). The results of the clean transcriptions were obtained through members' review.

III. RESULTS AND ANALYSIS

This SCK is based on the preschool teacher's knowledge of the DAP of the child; the teacher's knowledge associated with the development of children's learning in accordance with Bronfenbrenner's ecological theory and Thorndike operative theory. Students' cognitive knowledge based on ABP accountability is referenced in Table 3.

Table 3. Students' Cognitive Knowledge (SCK) of Developmentally Appropriate Practice (DAP)

Participants	*Content of the Sentences*	*Code*
P1	"This means that our teaching must be appropriate to the level of student development. This is how, when we want to do something, we have to know how well our students are like ... there are half of the students who can accept high levels and some of the students are very low so we have to balance it". (IVP1-IS2-21922:22011).	The level of student development
P2	"So if we want to do that activity we need to know the level of development of our students as well ... there are half of the students who can accept high level and some of the students are very low level so we have to balance near there". (IVP2-IS2-17158:17405).	The level of student development
P3	"It means that the activities we do are looking at the existing knowledge of the student and also surrounding him. So when he was in town school his exposure was different as in Mantin his exposure was also different. So what teachers need to do is look at the relevance of the level of student development of what we need and should teach. We are likely to start from the KSPK which is 4+ (5 years old) even though the student age is 5+ (6 years) as the student has never attended kindergarten". (IVP3-IS2-24459:25487).	The level of student development
P4	"In general, I understand that as a teacher we want to teach students of various cognitive levels. In one class there are students who are smart, some students are simple and some students are too simple. So we have to use appropriate methods to teach our students those three levels. So in order to achieve our learning objectives that day, we must apply practices according to the level of student development in our school". (IVP4-IS2-30835:31286).	The level of student development

The findings for the SCK in early childhood mathematics based on DAP are shown in Table 3. For the majority of the participants, DAP means knowledge of how preschool teachers plan and implementing instructional activities based on the developmental stages of preschool students because preschoolers have different backgrounds.

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Regarding their view of SCK, based on the theory of developmental learning of children according to Bronfenbrenner's theory, results are shown in Table 4.

Table 4. Students' Cognitive Knowledge (SCK) Of Bronfenbrenner's Theory

Participants	*Content of the Sentences*
P1	"This knowledgeable student is one of the influences of the family and later he or she is used to watching TV (television) meaning the student is exposed to mass media influence. This existing knowledge is important to further strengthen his or her limited knowledge. We can reinforce it ... not exactly what he got at home, not even with the opinion of the teacher, as I explain. So he was able to enrich himself and strengthen his existing knowledge. When we bring together knowledgeable students this discussion is very interesting ... I know this ... I know it's near home. In contrast to a student who has no knowledge of his own ... he does not know that he is quiet, passive and soft-spoken. So collaborating in groups is less than just looking at her friends. We feel sorry for him when he has no knowledge" (IVP1-IS2-19888:20910).
P2	"But the best of yesterday is came from the An-Nur Group. The other groups all questioned why this fish was turned upside down. An-Nur replied that "The fish had been bitten... so the fish is dying. So when he was dying he turned around and turned around. I think An-Nur has an aquarium at home. He used to see how the dead fish would turn and turn around. Nearby we know that An-Nur has some knowledge of aquatic life. That is why this knowledge is important to the student because he is ready to learn, he understands the concept and is able to further develop his skills" (IVP2-IS2-14743:15028).
P3	"If we had just seen Ali ... he would eat whatever he liked. When the other students were excited to buy chicken rice, nasi lemak .. but he went to buy crackers at the same price. This shows that Ali already has some knowledge of money. He knows how to use a currency note worth RM1. I think he used to go to this school canteen" (IVP3-OB4-8491:8713).
P4	"All students have experience either formally in kindergarten or informally at home through their parents or older siblings. Someone told me I had studied with a teacher near a kindergarten in the past. They tell the story to those who have experience. Only those who have never been to a preschool are scared or shy" (IVP4-IS2-28137:28594).

In this study's analysis of SCK in early mathematics is based on Bronfenbrenner's theory shown in Table 4 the participants PK1, PK2, PK3 and PK4 agreed that there are some preschoolers who already had knowledge from direct experience of an event, from influence at home through parents or through television and had received early childhood education from as early as 4 years old before entering preschool.

The following selection concerns student's knowledge based on the developmental theory of children's learning according to Thorndike's theory shown in Table 5.

Table 5. Students' Cognitive Knowledge (SCK) Of Thorndike's Theory

Participants	*Content of the Sentences*	*Code*
PK1	"I will call back my three students and ask them to repeat by doing this activity. Repeat the activity over and over…many times" (IV1-OB2-7132:7219)	Repetition
PK2	"Because this student needs repetition. With this repetition, they can master that skill. Because of their lower focus when doing something and when we practice it they will remember" (IVP2-OB2-7230:7420).	Repetition
PK3	"By doing repetition it is most effective. Because it helps improve memory power. In fact, some studies suggest that in teaching and learning there should be a concept of repetition in order to make the memory permanent. I will repeat it a lot until they got it. Usually, I would have my student repeat 10 times if he couldn't do it 10 times again until they got it" (IVP3-OB2-26754:27270).	Repetition

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PK4	"As their teacher, I will give them guidance ... there must be examples and repetitions because preschool students just started the learning process, so they need constant guidance in training" (IVP4-OB4-27764:27986).	Repetition

In the above findings on SCK in early mathematics based on Thorndike's theory the participants PK1, PK2, PK3, and PK4 explain how repetition techniques are used in early mathematics teaching and learning processes for preschoolers. The participants agreed that this repetition technique is most effective in helping preschoolers to understand early mathematical concepts as there is a link between stimulation and response, as explained by Thorndike through the Law of Learning (1911).

Meanwhile, Pedagogical knowledge (PK) is based on preschool teachers' knowledge of teaching and learning through approaches to student learning and activities and materials. PK is based on a student-centered approach to teaching and learning processes and activities and is closely linked to Piaget's theory of constructivism. The teachers' views of this are shown in Table 5.

Table 5. Pedagogical Knowledge (PK) Piaget's Theory of Constructivism

Participants	*Content of the Sentences*	*Code*
P1	"In the game activity, there are a lot of pupils involved ... especially in group activities where three groups are created where the students will play together in that group. When the pupils roll the dice, they can see 5 dots on the dice and then the pupils take 5 marbles or beads and put them in a cup. The pupils used an object to match with a number value. Here we can see pupils doing hands-on learning and minds-on learning activities" (IVP1-IS2-6847:7058).	*Hands-on learning* *Minds-on learning*
P2	"There can touch, explore and there are hands-on learning and minds-on learning. The pupils gained that experience because it's a practical activity. Indirectly this can reinforce the existing knowledge of the students. I mean maybe before this they only knew about those shapes of woodblocks, for example, but actually, when they learned this pattern they understand that different shapes could be created. This learning process is fun and meaningful to the pupils" (IVP2-IS3-14737:15201).	*Hands-on learning* *Minds-on learning*
P3	"The teaching and learning implementation by Mr. Halim is very interesting with the use of learning techniques while playing and there are matches using dice as well as counting tools. This means that when the dice reach a point the pupils will take 1 counting tool and put it in the cup. It's very nice there. And here it is… it's fit together because one activity is counts and another one is matching. So here the pupils need to focus on these two aspects. This activity involves a lot of hands-on learning and minds-on learning. That is why I say at the first time is very inappropriate because the pupils had to gain two skills at one time but if the pupils already know the number and can count, this activity is good for them" (IVP3-IS2-3290:3877).	*Hands-on learning* *Minds-on learning*
P4	"Touch and see activities means that they need to see which mineral bottles are high or low for the arrangement in order. There is a recognition process where the student can state the characteristics of the object. Not only in early mathematics but also in other activities because I think pupils need to touch so that students can feel those objects and explore and can better understand when they are experiencing not only theoretically but practically. This activity has elements of hands-on learning and minds-on learning. So when they touch it is a matter of fact so they can easy to understand" (IVP4-IS3-8938:9117).	*Hands-on learning* *Minds-on learning*

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The summary analysis of PK in early mathematics related to theory of constructivism of Piaget in Table 5 shows that the participants agreed that hands-on learning and minds-on learning activities are approaches to teaching and learning that have a positive impact on preschoolers with the use of teaching aids (TA) which are concrete and recognisable. In other words, these two types of activity are essential for helping pupils to understand early mathematical concepts.

The next selection is related to PK regarding the teaching and learning process approach based on materials such as teaching aids (TA) used by preschool teachers when teaching early mathematics. Table 6 shows the findings related to material-centered teaching.

Table 6. Pedagogical Knowledge (PK) of Teaching Aids

Participants	*Content of the Sentences*	*Code*
PK1	"I used some actual materials. The pupils themselves can see and hold the objects ... they are not just virtual ... if we just say the words pupils can only understand for a moment .. then they can't remember. By using this revealing material in front of the students' eyes, it's good for them" (IVP1-IS2-11415:11960)	Actual material
PK2	"I use a lot of actual and manipulative materials like counting tools and wooden blocks. I think these materials are good and fit for me to use to teach early" (IVP2-OB3-15446:15954).	Actual material & Manipulative
PK3	"Hmm, in math there are a lot of material things right ... at this preschool level to me, these two types of things such as actual material and manipulation is important. They are important because for the brain of some pupils of the abstract objects do not make it possible to comprehend, even some of the details. So the importance of these real things and manipulative material is to reinforce that they have an original concept such as an adding concept. If we just talk about this adding concept it is a little harder for pupils to understand but when a pupil makes use of real things and manipulates them, they will see and become more and more understanding of the concept. Usually I use straws, we have wooden blocks and counters that are made up of whole objects but they are already broken. To make the learning process meaningful I prepared for each pupil special actual materials and manipulative things so I use a small straw stick for this addition concept" (IVP4-OB3-20546:22159).	Actual material & Manipulative
PK4	"Usually these pupils need other support materials like actual material or manipulative things to attract them so they are interested in focusing on the learning. So I like actual material and manipulative things like LEGO, wooden blocks of all shapes and sizes, using fruit and scanning card replicas. All of these materials are not sharp, not too heavy, easy to hold and can be touched by pupils" (IVP4-OB2-4292:4523).	Actual material & Manipulative

The analysis of the findings of PK in pre-school early mathematics related to materials-based teaching based on Table 6 shows that the participants all explained that the use of teaching aids (TA) was their preferred choice. The two things they mentioned were actual materials and manipulative materials.

IV. DISCUSSION

The first finding of the study addressed SCK based on DAP. Table 3 shows that all four participants had a good level of DAP knowledge. This finding contradicts findings from previous studies of the MOE related to DAP practices which indicated that preschool teachers do not implement DAP (SIQA, 2012; 2013) and that DAP practices among

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preschool teachers were very limited (Jain et al., 2017). The findings of this study demonstrate that preschool teachers do, indeed, plan teaching and learning activities based on the National Preschool Standard Curriculum (2016) description of guided activities. In other words, the participants in this study were all in line with DAP practice that mathematical activities must be in line with the potential and levels of the cognitive development of students and that activities also need to be diversified and balanced in order for students to learn more effectively and meaningfully. This finding is also inconsistent with previous studies by Jain et al., (2017), Nurul Amirah and Zaidatun (2008) which argued that preschool teachers do not fully understand the development of basic children, especially in mathematics teaching in preschool and that they consequently distort the true DAP principle that these activities need to be in keeping with student development (Nor, 2006; NAEYC, 2008).

The second finding regarding SCK based on Bronfenbrenner's and Thorndike's theory shows that preschool teachers have knowledge related to both theories because all four participants were able to relate the influence of the environment and learning styles repeatedly, shown in their willingness to study preschool students in preschool. The findings of this study support the findings of previous studies which suggested that the effectiveness of the teaching and learning process depends on teacher actions that take into account factors such as student readiness, student experience, student observation of information from sensory influence and student perceptions of concepts based on students' long-term and short-term memory (Kamarul Azmi & Ab. Halim, 2007; Sahabuddin et al., 2003).

The findings of this study regarding PK also indicate that preschool teachers do, indeed, have pedagogical knowledge related to their approach to teaching and learning by applying Piaget's theory of constructivism and by their use of appropriate teaching aids: actual material things to manipulate when teaching early mathematics in preschool. The findings of this study support the results of previous studies showing that effective and appropriate constructivist approaches in teaching and learning mathematics (Zainal Abidin & Afrinaleni, 2010) and authentic hands-on and minds-on activities are closely related to the constructivist approach (Mohd Fadzli & Fuziyah, 2011) Further, the use of manipulative materials by preschool teachers in the findings of this study is in line with previous studies by Wu and Lin (2016) where the use of realistic materials such as concrete objects (manipulative materials) are shown to stimulate children's physical and mental health. These findings are not supported by Fatimah (2009), who claimed that there are still preschool teachers who teach early mathematics to preschool students using paper or pencil without reference to manipulative materials or games that can provide a real student experience.

V. CONCLUSION

Based on the findings of this study, it is clear that PCK embraces information related to different levels of student development as well as the impact of the environment on students' existing knowledge, in addition to the need for repetition techniques in helping students master a skill. In turn, this has to do with PK as it is vital for preschool teachers to select the best pedagogical approaches to be practised in the classroom to suit the level of student development and learning, in order to stimulate their learning with suitable activities. In conclusion, as is clearly demonstrated by the remarks of the participants of this study, celebrating the diversity of students in the classroom will make preschool teachers more sensitive to the environment around them and will open new opportunities for creative innovation in

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teaching practices. Ultimately, more innovative and creative teaching practices are able to make the teaching and learning process of preschool mathematics more meaningful, enjoyable and effective for preschoolers.

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