European Proceedings of
Educational Sciences
EpES

www.europeanproceedings.com

e-ISSN: 2672-815X

DOI: 10.15405/epes.23056.18

ERD 2022
Education, Reflection, Development

CAN I TEACH? ASSIMILATION OF EARLY CHILDHOOD ARITHMETIC CONCEPTS AMONG PRESCHOOL PARAEDUCATORS

Sofia Ben Yair (a)*, Olga Chiș (b)
*Corresponding author

(a) Kaye College- Early Educational Department, Azriel Nitsani St 6, Beer Sheva, Israel, sofiby16@gmail.com
(b) Department of Educational Sciences, Faculty of Psychology and Educational Sciences, Babes-Bolyai University, 7 Sindicatelor Street, Cluj-Napoca, Romania, olgachis76@gmail.com

Abstract

Early-childhood education has undergone a change in recent years, shifting its emphasis from literacy to STEM, as well, the knowledge and skills necessary for effective preschool mathematics teaching have been given much attention in recent studies. Early-childhood teaching knowledge is a key factor in mathematics teaching, impacting future teaching-learning processes and students' achievements. The study presented in this article is part of broader research conducted among Preschool Para-Educators in Israel. In Israeli kindergartens, the educational staff consists of an academic teacher and a Preschool Para-Educator (PPE), who is a high school graduate. Despite their lack of academic background and training, the PPEs are required to deal with mathematics teaching in their everyday encounter with kindergarten children. Hence the need for a unique training program for PPEs, in order to provide them with basic knowledge for teaching Early-Childhood Arithmetic (ECA). One aim of the study was to show how teaching experience activities contribute to constructing the knowledge of teaching ECA in a specific content area: Numeracy Skills. As part of the training program, the participants were required to analyse videos, scenarios, and simulations. The study included 35 PPEs. Data collected from questionnaires and observations were analysed using a qualitative and quantitative mixed method. The results show that most PPEs internalized the knowledge learned throughout the course, applying it in simulation activities. The study confirms the assumption that PPEs need intensive training in ECA in order to refine their teaching skills, giving everyday arithmetic practice in kindergarten a more solid professional basis.

Keywords: Early childhood arithmatic, math teaching knowledge, preschool para-educators, teaching practice

https://doi.org/10.15405/epes.23056.18
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Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2672-815X

1. Introduction

While early-childhood education focused traditionally on developing literacy skills, a current worldwide trend is shifting the attention to the promotion of early math learning for young children (Ginsburg et al., 2008; Moomaw, 2013). Preschool children have the ability to learn mathematical concepts (Clements et al., 2021). The extent of mathematical practice and its quality in early childhood predict a child's success in future math studies (Clements et al., 2017; Ten Braak et al., 2022). The present study is based on conclusions from an early-childhood arithmetic training program for PPEs in Israel.

1.1. Early-Childhood Mathematics Education

Early-childhood mathematics encompasses a range of contents, including pre-number skills (e.g., matching, sorting, or sequencing), numbers and operations, geometry, measurement, pattern, and algebra. The Israeli National Mathematics Preschool Curriculum (INPMC, 2010) recommended developing the concept of number as the primary focus for early years.

The concept of number is central for adults and young children lives alike. Numbers and quantities are an integral part of in everyday adult-life activities and are also integral to the activities of young children in kindergartens and at home. The concept of number is central in everyday life, as well in mathematical studies, which are a crucial aspect of a child's school life, as children constantly engage in mathematics studies in school from first through twelfth grade (Markovich, 2019). Uclés et al. (2020) have found that Kindergarten and first grade students have the potential to develop relational understanding and to symbolically represent arithmetical properties. Their study emphasizes the important implications of this finding for designing innovative learning and teaching environments at these grade levels.

The role of ECA teaching is to provide children with experiences that would help them reach an overall understanding of numbers and develop flexible ways of working with them, beginning with an intuitive and informal encounter with numbers, followed by a formal and symbolic understanding of the various representations of numbers as required at school (Baroody et al., 2006). Therefore adults, including early-childhood teachers, have an important role in the mathematical development of young children (Levenson et al., 2021). Studies have indicated a relation between the development of children's mathematical knowledge and the specific mathematical discourse that their teachers conducted with them (Gjicali et al., 2019; Purpura et al., 2017; Uscianowski et al., 2020).

Indeed, one of the main factors in math instruction is the teacher's subject-matter knowledge (Ball et al., 2008; Shulman, 1986), which is crucial for an accurate mediation of mathematical concepts and the use of accurate mathematical language. However, Preschool teachers' knowledge about teaching mathematics should include explicit math teaching context in addition to free play (Frye et al., 2013; NAEYC, 2010; NCTM, 2010). In fact, teachers who are well acquainted with the three components of learning trajectories - content, children's level of thinking, and the choice of fine-tuned activities to match their level - and are aware of the interplay between these three components, are more effectively professional (National Research Council, 2009, 2011; Sarama & Clements, 2009). Without such

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knowledge, teachers of young children often offer tasks that are either too easy or too hard for their pupils, unaware of the mismatch (Clements et al., 2021). However, as soon as teachers understand the progression of math-thinking levels and use this knowledge to sequence and individualize teaching activities, they can create effective math-learning environments for all children. Thus, learning trajectories facilitate appropriate and effective teaching and learning for all children (Clements et al., 2021).

1.2. Preschool Para-educators in Israeli Kindergartens

The Israeli early-childhood education system serves children aged 3–6. The staff at these kindergartens consists of a kindergarten teacher and a preschool para-educator (PPE). The PPE serves as an assistant to the kindergarten teacher. The kindergarten teacher has a bachelor's degree in education, but the PPEs are merely high school graduates. The Israeli Ministry of Education (2015) defined a PPE's professional role as that of an educator, required to fulfil educational needs of kindergarten children. The PPEs are responsible for keeping the kindergarten clean, taking care of the children, and engaging in pedagogical activities under the guidance of the kindergarten teacher. According to the Israeli Ministry of Education (2016) outline, the PPEs must participate in a training program for preschool para-educators.

1.3. Early-childhood Math Teaching Knowledge

Early-childhood mathematics is considered simple, but a lack of basic knowledge among early-childhood educators can cause assimilation of mistakes among preschool children. It has been thus claimed that public capital investment in early childhood education pays off economically in the short and long term (Barnett & Masse, 2006). NCTM (2010) notes that effective teaching of mathematics requires in-depth knowledge of mathematical content, acquaintance with the mathematics curriculum, and an understanding of the challenges students may encounter in learning mathematics. Preschool teachers' knowledge was examined by McCray and Chen (2012), Lee (2017), and Li (2021), based on Shulman (1986, 1987) and Ball et al. (2008) teachers' knowledge definition. They contended that preschool teachers' pedagogical content knowledge involves noticing the relevant math concepts that are reflected in children's activities. The following components, drawn from studies on the development of children's ability to count and perceive numbers, define preschool teachers' math teaching knowledge and skills:

i. Common Content Knowledge (CCK)—the basic ability to calculate or solve mathematical problems (Ball et al., 2008).
ii. Specialized Content Knowledge (SCK)—Mathematical knowledge and skills that are unique for teaching. For example, the teacher should be able to recognize object-counting sub-skills, such as reciting a correct sequence of numbers with a one-on-one correspondence (e.g., Gelman & Gallistel , 1978; Wynn, 1992), or number recognition, which involves quantity-to-number correspondence and the production of the correct number word (Wynn, 1992). An understanding of these subskills is needed in preschool teaching in order to diagnose counting difficulties and help the child advance to a higher level (Li, 2021).
iii. Acquaintance with early-childhood mathematics curriculum (Ball et al., 2008).

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iv. Knowledge of Content and Teaching (KCT)—a combination of teaching skills and knowledge of mathematics (Ball et al., 2008). Teachers should be able to identify children's developmental needs and to design instructional tasks to suit these needs (Sarama & Clements, 2009). For example, KCT should include knowledge of tasks or strategies that can help a child with his or her counting errors (Li, 2021).

v. Knowledge of Content and Students (KCS)—A combination of knowledge about mathematics and knowledge about students (Ball et al., 2008). For example, understanding students' mathematical ways of thinking or acquaintance with common student errors. Two examples of errors in object counting are when a child uses one number word that is related to multiple quantities, or when they skip an object while counting (Clements & Sarama, 2011; Li, 2021; Wynn, 1992).

1.4. Practice Teaching

Practical experience is a key factor in the teaching training process. The purpose of field experience is to learn from actual of teaching, thus applying pedagogical and didactic principles to real-life situations and integrating theoretical knowledge taught in the academic courses (Lunenburg, 2012). Experiential Learning is a basic element in an active-learning educational approach that evolved from constructivist theories. Its role is to bridge the gap between theoretical knowledge acquired in courses and the practice in the field (Kolb, 1984). Kolb's (1984) "experiential learning cycle" describes four stages: (1) concrete experience—the learner has an initial concrete experience; (2) reflective observation—the learner reviews their new experience; (3) abstract conceptualization—the learner learns something new or draws a conclusion from their experience; (4) active experimentation—the learner applies their idea(s) to the world around them and sees what happens.

The research literature on this topic describes diverse ways of applying teaching experience during a course of study:

1.4.1. Scenario-based Learning Process

A scenario-based learning process draws on the principles of two related theories: situated learning theory (Lave & Wenger, 1991), which argues that the best learning takes place in the context in which it will be used, and situated cognition theory, maintaining that knowledge is best acquired and more fully understood when situated within its context (Kindley, 2002). Scenario-based learning (SBL) (Lave & Wenger, 1991) uses interactive scenarios to support active learning strategies such as problem-based or case-based learning. In the process, students get a chance to apply their subject knowledge, along with critical thinking and problem-solving skills in a safe real-world context. Hill et al. (2004) and Ball et al. (2008) used teaching scenarios to measure teachers' content knowledge and knowledge of students and content. Li (2021) used the practice-based approach in Ball et al. (2008) to categorizing early childhood teachers' knowledge—through math teaching scenarios. Using math scenarios for preschool teachers could reflect the unique learning context for young children (Lee, 2017; McCray & Chen, 2012), so that math teaching knowledge can be gauged in a specific manner and at a deep level (Li, 2021).

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1.4.2. Video-cued Learning Processes

A video-cued Learning Process (VCE) (Adair & Kurban, 2019) is a process in which film is used in order to demonstrate educational contexts. It can reveal people's understanding of educational ideas, practices, policies, and relationships. The methodology of video-cued ethnography (VCE) has been introduced by Tobin et al. (1991), called the three-culture method (also called a "multivocal ethnography method"). In their studies, Tobin and his colleagues made video recordings of activities on one typical day of a preschool in China, Japan, and the U.S., and showed the videos to teachers, parents, and administrators within the three cultures. The insiders' explanations and the outsiders' comments provided insightful reflections on values, practices, and questions concerning early-childhood education in each culture.

1.4.3. Simulation in Education

Simulation is a tool that allows one to experience real-world situations without facing their real dangers (Dotger, 2013). Simulation evolved as a method for integrating theoretical knowledge and practical experience in fields such as medical training and research, training of military or piloting crews, information-system management, and business administration. In the field of education, simulation is a tool that allows teaching trainees, new teachers, and educators throughout the various stages of their careers to experience lifelike situations. Within the simulated setting, trainees can make decisions, act, examine the results of their actions and change their behaviour in a safe and controlled environment. Three main types of simulations are generally used: simulations based on human interpersonal interaction; Computer-based simulations; and integrated simulations, combining digital and human interactions. The present research will focus on simulations based on human interpersonal interaction.

Simulations for didactic purposes usually include the following steps: writing down the scenario and presenting it to participants who will experience it; videotaping the experience; debriefing—analysis of the simulation in a supportive and safe environment, by watching the video experience; reflection—individual reflection, group reflection, analysis of strategies, skills and tools used in the simulation, discussion of challenges and successes in the experience (Dotger, 2013). It has been shown that simulations can improve the self-efficacy of trainees (Salman & Fattum, 2019; Weissblueth & Linder, 2020), as simulation workshops enhance and enrich their practical experience and professional knowledge. A study by Chernikova et al. (2020) concluded that combining several types of simulations—ones using professional actors, role-playing and virtual reality—had more impact on the participants than the use of one tool only.

2. Problem Statement

PPEs in kindergartens in Israel are required to engage in various pedagogical topics throughout the day, including some that involve mathematics. However, when training programs for PPEs in Israel were examined, it was found that among the topics of these programs, no attention was given to early-childhood mathematics or to early-childhood arithmetic. In fact, in a 2021 study we found that PPEs lack the knowledge and tools necessary to promote mathematical skills of young children, wherefore we

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concluded that math training for PPEs is necessary (Yair & Chiș, 2022). Considering this, the author of this article created a training program for PPEs (Arithmetic Thinking Training Program – ATTP), focusing on early-childhood arithmetic (ECA) and numeracy skills, which are elementary topics in math. The purpose of the study is to review the development of the ability to teach arithmetic, during the training program.

3. Research Questions

The following are the research questions in this paper:

i. What are PPEs' beliefs regarding ECA teaching, and does it change following their participation in the training program?
ii. To what extent can PPEs identify ECA concepts that are embedded in activity with children?
iii. To what extent can PPEs identify object counting errors embedded in a given scenario?
iv. Can PPEs plan and execute activities to promote ECA, using precise mathematical discourse?

4. The Purpose of the Study

The present study examines the development of PPEs knowledge and skills in the topic of ECA and its application in teaching.

5. Research Methods

5.1. Participants

The research population comprised 35 participants, Jewish females, ages 22–55 years, from the south area of Israel. They were all employed in kindergartens for children ages 3–6 and had seniority of over three years in their profession. The participants were high school graduates. The PPEs participated in the ATTP for 8 months.

5.2. The Course

The ATTP aimed to expose its participants to kindergarten mathematics curriculum, placing an emphasis on numeracy skills and introducing the way young children develop number concepts. It taught contemporary pedagogical models in kindergartens, discussed meaningful learning of arithmetic, how to teach in a small group and Characteristics of the alpha generation. The course consisted of twelve meetings in a duration of eight months. It combined lectures, presentations, video watching, workshops, practice and experience, simulation activities and scenario analysis.

5.3. Research Tools

In this study we conducted three experimental activities based on the practice approach of Ball et al. (2008). The activities involved arithmetic teaching scenarios, which made it possible to classify the knowledge and skills of the participants in ECA teaching tasks. The participants filled out a questionnaire,

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right after topics of ECA were covered. The participants were also required to fill out a pre-post questionnaire about PPEs beliefs regarding mathematics teaching.

The following are the topics focused on in our study, with their relevant clauses in the questionnaires:

Beliefs about teaching mathematics: The pre-post questionnaire, administered before and after the training program, focused on the beliefs held by the PPEs toward mathematics and its teaching (Markovits, 2011). The following question from the questionnaire is relevant to this topic: *Do you think you need to learn mathematics in order to teach mathematics to young children? Yes / No.*

Video-Cued Learning: The participants watched a video during one of the meetings, in which a PPE is seen engaging with five children. The PPE suggest an activity in which the children prepare a track game. Each child chooses the materials, colours, stationery, number stickers, and coloured stickers for their project. During the activity, the PPE holds a mathematical discourse with the children, mediating number skills for the children if necessary. After watching the video, the PPEs answered a questionnaire, which included an open question: *What arithmetic concepts and skills did you identify in the activity?* The arithmetic concepts embedded in the activity were: oral counting, object counting, cardinality, number recognition, number line, comparing quantities, and quantity-to-number correspondence. This question measures the SCK of the PPEs (Li, 2021). Such activity is suitable for examining the SCK, because the game serves as a learning tool for young children (Bredekamp & Copple, 1997) and allows for the integration of number development sub-skills.

Scenario-Based Learning: In one of the activities, the PPEs were asked to read a scenario and fill out a questionnaire. In the scenario, a PPE plays with two kindergarten children, Omer and Noa. Omer and Noa are asked to pick a card with a number from 1–10 and place a quantity of small wooden blocks in a personal basket according to the number that appeared on the card. In the scenario, Omer makes a mistake in counting the wooden blocks, and the PPE is trying to help him. The questionnaire and scenario are based on Li (2021). The following question is a multi-choice question from the questionnaire, that is relevant to this article: In the scenario, the PPE pointed to each block and counted together with Omer: “One, two, three, four, five, six.” Then she asked, “So, Omer, how many blocks do you have?” Omer said, “1, 2, 3, 4, 5, 6.” What is Omer’s difficulty?

i. One-to-one correspondence difficulty.
ii. Skipping a block.
iii. Difficulty in Cardinality principle.
iv. No difficulty was observed.

(The correct answer is C: difficulty in Cardinality principle)

The Participants were asked to identify a child’s counting errors. The development of children’s counting skills is sometimes accompanied by counting errors (Clements & Sarama, 2011; Wynn, 1992). Thus, the above question measures the KCS of the PPEs. Ball et al. (2008) and Li (2021) explain that KCS should include knowledge about errors and misconceptions of children, such as the inability to tell the final quantity of all the counted objects.

Arithmetic Simulation Activities: In one of the meetings, the participants experienced arithmetic games, created by the PPEs themselves. By preparing the arithmetic games, the PPEs showed their

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understanding of the concept of number. The games created by the PPEs promoted a series of skills: oral counting, object counting, number recognition, set production, number composition, one-to-one correspondence, number line, comparison, etc. This activity revealed the KCT of the PPEs, as they used the relevant vocabulary for teaching ECA (Li, 2021). It was conducted in the form of a simulation, in which one PPE played the role of PPE, and another three played the role of kindergarten children. The method of simulation was explained to the PPEs, and they were asked permission to have the activity videotaped and then analyzed. At the next meeting, all course participants watched the videos, analyzing the ECA concepts that came up in them. The participants who had created the games had to specify what ECA skills they wished to promote.

Procedure

Questionnaires were handed out to the participants during the meetings. The participants received no compensation for filling out the questionnaires.

6. Findings

The questions were analysed quantitatively and qualitatively. Below are the analyses and results for each research question.

Question No. 1: Need for learning how to teach early childhood arithmetic

Figure 1 presents the answers given before and after the training program. As we can see, before participating in ATTP, 51% of the participants thought there was no need to learn how to teach early-childhood arithmetic. After eight months in the training program, these percentages were reduced, so that only 20% held the same opinion, while 80% of the participants agreed that PPEs must learn how to teach early-childhood arithmetic.

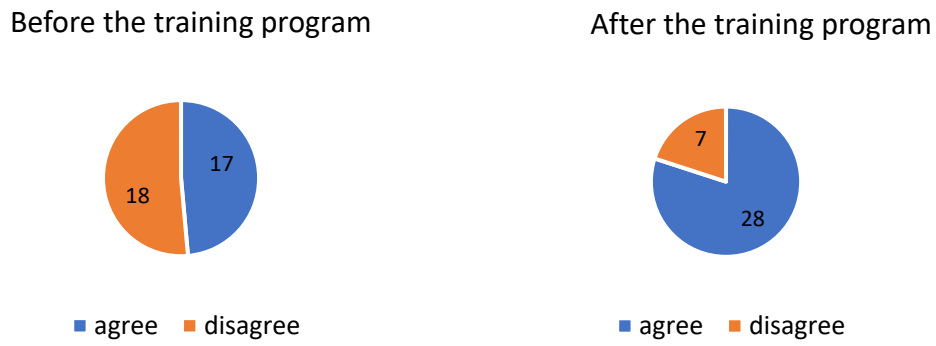

Figure 1. Results for Question No. 1

Question No. 2: Can PPEs Identify the arithmetic concepts embedded in an activity with children?

After watching a video of a math game activity between a PPE and kindergarten children, the participants were asked, “what arithmetical skills are involved in the video?”. This question was aimed at assessing whether participants can identify key concepts that are embedded in the depicted math game – oral counting, object counting, cardinality, number recognition, number line, comparing quantities, quantity-to-number correspondence. Figure 2 presents the skills reported by the participants for the

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question: "what arithmetical skills are involved in the video?". We see that 77% of the participants noticed that the activity was engaged with counting objects; Less than half of the participants recognized the concepts: oral counting, cardinality, number recognition, number line, comparing quantities, quantity-to-number correspondence; And 22% of participants gave answers that did not describe the required skills at all, for example: "everything starts and ends with math", or "drafting rules for the game".

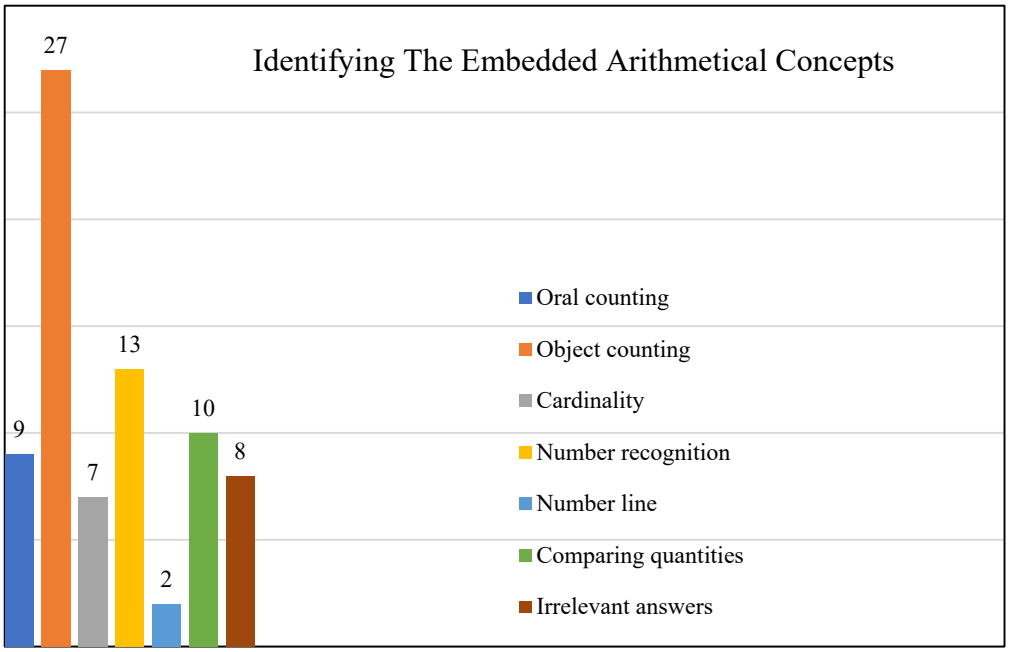

Figure 2. Results for Question No. 2

Question No. 3: Can PPEs identify a child's counting errors?

The analysis shows that 77% of the participants identified the error. Twenty percent of the participants identified a wrong answer, and one participant stated that there was no error in Omer's counting. Figure 3 presents the answers reported by the participants for the question: "What is Omer's difficulty?".

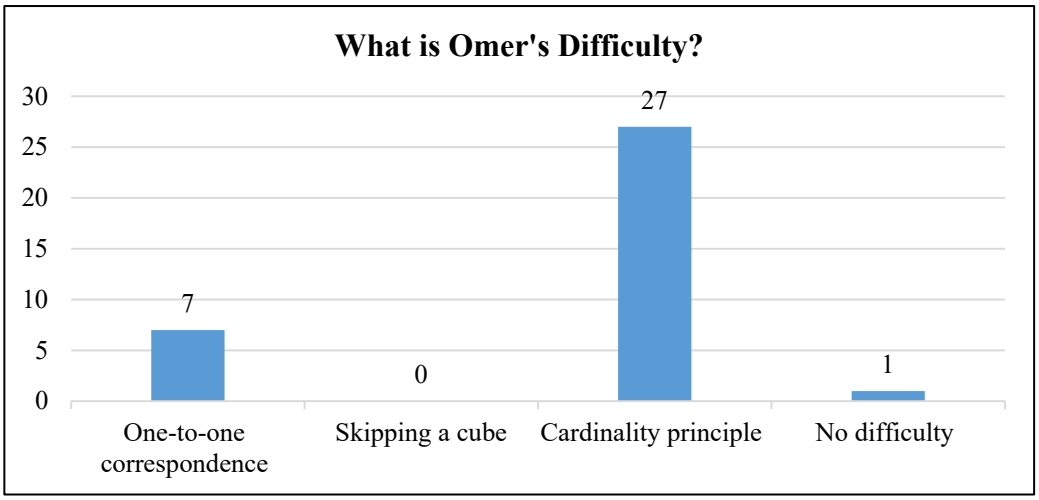

Figure 3. Results for Question No. 3

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Question No. 4: How do PPEs Attempt to promote ECA?

The PPE participants created arithmetic games that promote various numeracy skills. Then they played those games with a group of other PPEs, using the relevant arithmetical concepts. The arithmetic games the PPEs created were adapted to different arithmetical abilities of kindergarten children. There were also games that could be played at several different levels, as can be seen in the following examples. Figure 4 presents Arithmetic game A: in this activity the child is required to match a quantity of balls to the digit that appears on the flower, and then arrange the flowers into a number line.

Figure 4. Results for Question No. 4, Arithmetic game A

Figure 5 presents Arithmetic game B: in this activity the child is required to roll a die, then pick out the digit that corresponds to the quantity, and fish it. For a simpler level of this activity one can use dots, for children who still do not recognize numbers.

Figure 5. Results for Question No. 4, Arithmetic game B

7. Conclusion

The present study fills some gaps in addressing the need of ECA (early-childhood arithmetic) training for PPEs (preschool para-educators). Arithmetic as a branch of mathematics and ECA is commonly considered simple—any adult can perform it. However, PPEs need to be familiar with the

stages in the development of arithmetical thinking in order to instruct students appropriately. Teachers should be able to recognize arithmetic content within a context of free play (Lee, 2017). Early-childhood mathematics education happens through a balance between spontaneous play and adult guidance (Ginsburg et al., 2008; Uscianowski et al., 2020). In this study we shed light on some of the beliefs held by PPEs concerning ECA teaching. At the beginning of the study, we found that a large percentage of the PPEs did not find it necessary to study ECA methods in order to teach young children. However, after participating in a training program, a large percentage of participants changed their minds and agreed that ECA had to be learned.

The unique body of ECA knowledge teaching, specifically for enhancing counting ability and concept of numbers, was defined in this article by structures of SCK (Specialized Content Knowledge), KCS (Knowledge of Content and Students), and KCT (Knowledge of Content and Teaching), measuring such knowledge by means of scenario-based questions. The study demonstrated a process of developing ECA knowledge among PPEs. We found that Participants in the ATTP (aritmethic thinking training program) began to apply the knowledge they acquired when they were using ECA teaching vocabulary. Alongside their theoretical justification, teaching scenarios have a practical advantage, as the participants experience their own responses from a teaching perspective (Li, 2021). By combining practical field experiences with the theoretical courses, students are faced with various teaching challenges during the course of their training, while enhancing their sense of professional growth (Ronen & Weissblueth, 2021). This study confirms the assumption that PPEs need intensive training in ECA: their SCK, KCS and KCT need to be more knowledge informed. It is thus clear that PPEs must acquire ECA skills so that their teaching would be challenging yet appropriate for children. Policymakers throughout the world should give more thought to the quantity and contents of the courses needed in order to prepare PPEs for introducing arithmetic into kindergartens.

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