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How Cognitively Guided Instruction Model Develop Mathematical Knowledge For Teaching?

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Abstract:
This research aims at obtaining an overview of how the Cognitively Guided Instruction (CGI) model develops Mathematical Knowledge for Teaching of Early Childhood Education (ECE) teachers. The participants of the research were five kindergarten teachers in one district in West Java, Indonesia, who were purposively selected. The research design employed is a qualitative case study approach and thematic analysis to process and analyze the data. The findings show that the Cognitively Guided Instruction (CGI) model applied in the Professional Development Program (PDP) can develop Mathematical Knowledge for Teaching (MKT) of Early Childhood Education (ECE) teachers. This model is considered to be useful as the intervention provided can develop teachers' knowledge properly, resulting in the improvement of teachers' MKT.

Keywords: Professional, Development Program; Mathematical, Knowledge,Teaching; Early Childhood Education; Teachers; Mathematics; Cognitively Guided Instruction.

INTRODUCTION

Teachers have an essential role in shaping children's mathematical skills. Teachers' teaching strategy in connecting children's skills and abilities in a new situation promote understanding and stimulate children's thought. Teachers are expected to be well-informed on mathematical content and pedagogy to be qualified teachers, especially in introducing mathematics to children. It relates to Mathematical Knowledge for Teaching (MKT).

MKT is knowledge of content used in recognizing, understanding, and responding to mathematical problems and tasks faced in teaching (Phelps & Howell, 2016). Ball, Thames, and Phelps (2008) defined MKT as practice-based theory summarizing mathematical knowledge required in repetitive mathematics teaching, noted that they had adopted the flexible

concept of "requirements" that enables perspective, custom thoughts, and high sensitivity of effective teaching. The domain of MKT can be seen as follow.

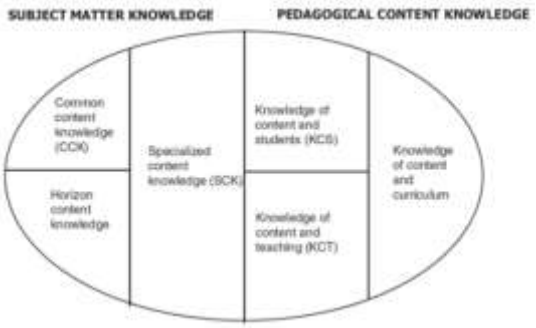

Figure 1. Domains of Mathematical Knowledge for Teaching
Source: Ball et al. (2008)

Furthermore, this research is the follow up of the previous research on Mathematical Knowledge for Teaching of Early Childhood Education Teachers (Noviyanti, 2019). The findings show that teachers have limited knowledge of children's mathematics development. In this case, teachers do not have an understanding of 1) children's responses when they are given problems, 2) learning trajectories of children numeral concept, and 3) knowledge on counting sequence concept, one-on-one correspondence, and cardinality (Noviyanti, 2018a, 2018b). Besides, teachers also have a limitation on basic mathematics knowledge (Noviyanti & Suryadi, 2019). In this case, teachers forget the definition of basic mathematics so that many of them making mistakes when doing mathematics developmental activities in class (Noviyanti, 2018a, 2018b; Noviyanti & Suryadi, 2019).

Regarding the importance of MKT and the limited teachers' knowledge of children's mathematics development, the researcher designed the Professional Development Program (PDP) for ECE teachers. In this regard, Cognitively Guided Instruction (CGI) is considered to be appropriate to overcome the problems. CGI is a mathematics teaching approach that is built on children's natural problem-solving strategies (Carpenter & Fennema, 1988; Carpenter & Fennema, 1992; Carpenter, Fennema, & Franke, 1996; Carpenter, Fennema, Franke, Levi, & Empson, 2000a, 2000b). The CGI program identifies specific strategies that help teachers to understand how children think so that teachers can direct them to gain mathematical understanding (Carpenter & Fennema, 1992). CGI is an attempt to make teachers adjust themselves to students' mathematical understanding (Carpenter & Fennema, 1992; Carpenter et al., 1996; Carpenter et al., 2000a). CGI stands in contrast with the traditional approach that focuses more on symbolic counting first and then trying to make students apply this knowledge in a problem-solving situation.

Nonetheless, to overcome the limited knowledge of basic mathematics that occurred because of forgetfulness, the researcher modified the CGI model with the method of giving a summary. Summary giving is an appropriate strategy to overcome limited knowledge of basic mathematics. Summary in the teaching communication process will reduce the occurrence of forgetfulness as well as increase reference that will determine the learning outcomes of the students. (Briggs, 2013; Muijs, Aubrey, Harris, & Briggs, 2004).

Based on the background explained, this article will give an overview of how the CGI model develops MKT of ECE teachers. The overview will be obtained from the results of PDP.

RESEARCH METHODS

Research Design

As explained in the background, this research promotes the Professional Development Program (PDP) as a media to develop Mathematical Knowledge for Teaching (MKT) of Early Childhood Education (ECE) teachers. According to that statement, the constructivism paradigm is appropriate to guide this research. Ernst Von Glasersfeld popularized the constructivism paradigm in 1988. Von Glasersfeld (2012) stated that knowledge is the result of our constructions (forming). Besides Von Glasersfeld, Egon Guba and Yvonna Lincoln are also popularized this paradigm. Guba and Lincoln (2009) said that the constructivism paradigm is directed to obtain various understanding that is reconstructive (Guba & Lincoln, 1994; Lincoln & Guba, 2013); and have the vision that something real is construction in an individual's mind (Lincoln & Guba, 2013) .

Meanwhile, the research design employed is a qualitative case study approach. According to Yin (2017), the case study's questions questioned not only the level of "what", but also "how" and "why". The use of the “how” and “why” questions are very appropriate to gain in-depth knowledge of the phenomenon under study. Since the research aims to obtain an overview of how the CGI model develops Mathematical Knowledge for Teaching of ECE teachers, the researcher focused on the process and meanings contained in the phenomenon. Therefore, the research did not involve a large number of participants because it prioritized the quality and depth of the data and outcomes instead of data quantity.

Participants

The participants were five kindergarten teachers in one district in West Java, Indonesia, who were purposively selected. In this regard, the researcher determined the sampling by setting specific requirements. Those requirements are 1) having taught at a kindergarten (with children of 5-6 years old); 2) having teaching experience of approximately ten years. The duration of teaching was chosen because it is indicated that by ten years of teaching experience in kindergarten, teachers already could manage the class, interpret, and improve children’s mathematical thinking (Lee, 2017); 3) holding a bachelor’s degree in early childhood education; 4) teaching in public ECE (not private) schools. It is decided with the assumption that they use the same curriculum; 5) having at least 20 students in the class. The researcher collaborated with the District Education Service to get recommendations for choosing the research participants. Then, the participants with pseudonyms, namely Srimaya, Popon, Siti, Santi dan Ani were selected.

Data Collection

The data collection was conducted in two activities, which are the execution of PDP and implementation. The following are the methods of data collection.

Focus Group Discussion (FGD)

Focus Group Discussion (FGD) method was conducted in every Professional Development Program (PDP) meeting, consisting of the researcher and five participants. In the PDP implementation, some videos and articles/stories about problems faced when children learn mathematics were provided. Through this activity, teachers discussed with a focus on the problems/cases provided. All FGD activities were conducted between the researcher and the participants and were recorded with two audio-recorded.

Interview

The type of interview used in this research was the unstructured one, conducted when the researcher would like to follow up on the research’s results/findings. In this case, the

interview was carried out based on the results obtained from the findings on the field. All interview activities were audio-recorded to obtain maximum results.

Documentation Study

A documentation study was done to analyze the lesson plan and evaluation documents made by the participants. In this activity, the researcher analyzed the documents by using the lesson plan observation and evaluation form developed by the researcher and approved by the expert. The form was made in the form of a checklist with explanations.

The aspects analyzed in the lesson plan documents were the suitability of competences, indicators, learning objectives, teaching materials, learning sources, learning media, learning model, learning scenario, and learning assessment design. As for evaluation, the aspects analyzed were the evaluation of ECE students' work's notes, ECE anecdote notes, and children's development rating scale. Furthermore, the writing pattern of the Children's Development Report and the technic to deliver Children's Development Report's results were analyzed.

Research Period

The research was conducted for one year (in 2018). PDP was designed in the form of a workshop with five meetings. Besides, didactic situations designed to develop respondents' MKT were a) giving a summary of basic mathematics concepts; b) presenting video and learning cases; c) arranging lesson plan. Below is the topic discussed in each meeting.

Tabel 1. Topic in The Meeting

Number of Meeting	Topic/Activites
1	a. Mathematics for young children b. Concept of numbers (counting)
2	a. Concept of numbers (one-on-one correspondence) b. Concept of numbers (cardinality)
3	Children's understanding in problem-solving - Children's understanding of number concept - Children's strategy also - Subtraction and division
4	Responding to children's mathematical thinking patterns - Starting with what children know and able to do - Supporting/assisting children to count according to its time - Supporting children to improve their counting skills to the problem-solving stage - Supporting children to create their mathematics problems - Supporting children to present their mathematical thinking patterns
5	Curriculum (arranging lesson plan)

Data Analysis

Thematic analysis was employed in this research. Thematic analysis is a way of identifying patterns of themes in a phenomenon with the aims of identifying patterns or finding themes through the data that have been collected by the researcher (Braun & Clarke, 2006; Creswell, 2007). The data were analyzed with the help of the NVIVO 12 plus program.

RESULTS AND DISCUSSIONS

Result

As explained in the introduction, the researcher has developed the CGI model to develop Mathematical Knowledge for Teaching ECE teachers. In its implementation, the CGI model was presented in the form of workshops with five times meetings. Meanwhile, based on thematic analysis, the findings were presented in two themes, which are PDP activity (workshop) and implementation.

PDP Activity (workshop)

The PDP activity (workshop) theme was divided into some subthemes according to the didactic situation conducted, which are a) giving a summary of basic mathematics concepts; b) presenting video and learning cases; c) making lesson plans; and d) implementation. Detail explanations are provided below.

Giving a summary of basic mathematics concept

In the first situation, which was giving a summary of basic mathematics concepts, the results showed that the respondents were able to follow all activities properly. Below is the notes field during the activity.

Activities	*Progress*	*Problem*
- *The tutor gave basic mathematics material* - *Question and answer session was conducted* - *Basic mathematics test was given*	- *All respondents understood the materials directly* *Ani stated that she has remembered basic mathematics material and was sure there were no conceptual errors. All respondents agreed with Ani's statement.* - *All respondents correctly answer all questions*	*None*

Daily Journal, 28 September 2018

From the daily journal, it was revealed that all respondents could directly understand and stated that a summary presented was able to improve their knowledge.

Presenting video and learning cases articles

The other didactic situation is presenting videos containing children's counting knowledge, one-on-one correspondence, and cardinality. One activity example was when the tutor divided participants into two groups and presented four videos at one time. Those four videos are about children's mistakes concerning one-on-one correspondence.

The results showed that those two groups explained the videos adequately. Group one (Srimaya, Popon, and Santi) emphasized more on the children's various initiatives in doing one-on-one correspondence. Additionally, they also emphasized on the children's consistency in counting despite their mistakes. Meanwhile, group two (Ani and Siti) emphasized more on the teachers' strategy. In this regard, teachers should lead children to do one-on-one correspondence. For example, teachers asked the children to put their toys in a plastic container, tidy up their toys, etc. Srimaya added that children often missed out if they only touch objects.

> *I just knew that this kind of activity is called* one-on-one correspondence. *I often do this kind of activity. Usually, I ask the students to put a cross mark on the picture,*

write number symbols if the touching activity is not enough. Children usually missed the numbers if they only touched the objects. Field notes, 28 September 2018

Srimaya's statement provoked the tutor to open a discussion on the teachers' strategy related to one-on-one correspondence. Some ideas that came from the respondents were asked a few questions or convincing children that they can do one-on-one correspondence. Below is Ani's statement.

In my opinion, asking the questions of "which one have you counted and which have you not?" or "let me see what you put in the container while counting" can ensure that children have done one-on-one correspondence. That can make children focus on their objects one by one. Field notes, 28 September 2018

According to the interview results, all respondents agreed that video analysis activity was the advantage of PDP. Through the videos presented, respondents analyzed children's problems in the counting process, one-on-one correspondence, and cardinality; moreover, they concluded the solutions for the problems presented in the videos. Besides children's mathematics problems, the videos also presented many concepts and examples on how to know children's mathematical development (sequencing, one-on-one correspondence, and cardinality) as well as the solutions. Hence, through the video analysis activity, the workshop was indicated as useful.

Besides presenting videos, the didactic situation provided by the tutor was the presentation of an article on children's strategies in solving problems. In this case, the articles were presented in the form of a story describing the activities in the class. Below is the example of the article given in the following situation.

The tutor presented a story of Mr. Mardi and his student, namely Yaya, who are talking about grapes. The discussion indirectly led to addition matter. Below is the excerpt from their discussion in the story.

Mr. Mardi: What do you have, Yaya?
Yaya : I have grapes.
Mr. Mardi: Yaya, how many grapes do you have now?
Yaya : (unhesitatingly counting the grapes) 1, 2, 3, 4, 5, 6,7.
(looking at Mr. Mardi)… 7.
Mr. Mardi: If you add two more grapes to your seven grapes, how
Many grapes you will have?

The tutor invited the participants to do the Focus Group Discussion (FGD) based on that story. Based on the story, the participants discussed what Yaya would do. However, the participants' answers were not satisfying enough because the answers were not focused on the questions provided. Accordingly, the tutor presented another story. The story tells about Ms. Mia, who was sitting with Selfi and Ghea, counting little dolls. They put eight dolls on the table and counted them by touching each doll together. Ms. Mia then added three dolls and asked the total number of dolls to both children. In that case, Selfi and Ghea may have different ways to answer. Then, the tutor asked the participants to discuss what the children will do.

Same as the previous answers, the participants' answers were not fulfilling the tutor's expectations. Hence, the tutor discussed and explained the addition strategy by combining and showing the subject matter of learning trajectories of numbers concept. The subject matter could help the participants in answering the questions given. In this case, Santi successfully answered the question.

I think Selfi may take the eight dolls and combine them with the other 3. Selfi counts all dolls from 1 to 11. Meanwhile, Ghea takes the 8 dolls and add them with the other 3. However, Ghea has understood that the 8 dolls do not have to be counted anymore. So, Ghea counts from 8. Eight, nine, ten, eleven...I think. Field Notes, 28 September 2018

Santi answered the question correctly because some children who understand the concept of counting uses a strategy like Ghea's, which is counting from eight. Children counting started from the number more significant than 1 (do not always count from 1) is an understanding developed in five years old (Carpenter, Franke, Johnson, Turrou, & Wager, 2017); this kind of understanding can be employed in counting objects by combining them with the first collection (Carpenter et al., 2017; Clements, Fuson, & Sarama, 2017).

Through videos and articles presentations, all participants tried to learn, discuss, and understand children's mathematical development and combine the concept with their daily experiences. Also, as a practice and preparation for the implementation in class, the tutor asked the participants to make two groups for a role-play activity. Below is the part of the daily journal about the role-playing activity.

Activities	*Progress*	*Problem*
- *Roleplay activity, group 1 (Siti, Srimaya, Ani) and group 2 (Santi, Popon)* - *Group 1, Ani became the teacher, while Siti and Srimaya became the children. Siti had limited one-on-one correspondence, and Srimaya had a counting sequence limitation. Ani properly helped them.* - *Group 2, Santi became the child, and Popon became the teacher. In this case, the child had limitations in counting sequence, cardinality, and one-on-one correspondence. Popon, who became the teacher, gave a proper intervention.*	*All respondents were indicated to understand all the materials given.*	*None*

Daily Journal, 28 September 2018

Lesson Plan-Making

At the end of the workshop meeting, the participants made a lesson plan to implement the knowledge obtained from the workshop in each class. All participants presented the steps of the activities accurately. The format used consisted of the date of activity, theme/topic, activity, media, and the detail and clear steps.

Discussion

The results of the research show that all respondents develop MKT properly. All respondents developed Subject Matter Knowledge (SMK) while they tried to understand the summary of basic mathematics materials presented. Furthermore, unlike during the developmental activities, there were no errors in the teachers' mathematical concepts during the implementation activity. It is in correspondence with the statement that giving a summary is a strategy to increase retention (Ismail, 2011; Morrison, Ross, Kalman, & Kemp, 2012). The strategy is appropriate to recall the main ideas of the material presented, as well as to prevent the occurrence of forgetfulness and reduce the difficulties experienced by students in remembering all the material (Ismail, 2011).

Besides developing SMK, PDP activities also successfully developed PCK, especially in the domain of Knowledge of Content and Students (KCS). According to the findings, the respondents have understood children's mathematic development by providing proper solutions for children's responses in problem-solving.

Regarding the Knowledge of Content and Teaching (KCT), the respondents' process to develop KCT was shown during the workshop. KCT is a combination of knowledge about developmental activities and mathematics (Ball, 1990; Ball & Bass, 2002; Ball & Cohen, 1999; Ball et al., 2008; Hill, Rowan, & Ball). During the workshop, the respondents obtained materials on the theory of study, strategy, and learning through play principle, especially concerning the concepts of numbers. The respondents also shared many experiences with others in a discussion.

At the end of the workshop, the respondents made a lesson plan . All respondents presented the steps of the activities accurately. That activity shows that the respondents have properly developed Knowledge of Curriculum (KC). KC refers to teacher's knowledge about the curriculum, which is an essential foundation for a teacher to understand their job and role (Ball, 1990; Ball & Bass, 2002; Ball & Cohen, 1999; Ball et al., 2008; Hill et al.). The respondents had already had good KC. Nonetheless, based on the interview results, the respondents felt their knowledge increases because they got feedback from the tutor and peers through the discussions conducted.

According to the findings and theories presented, it can be concluded that the PDP can properly develop teacher's MKT. The development process affects the increasing of respondents' MKT. It had a positive impact on mathematics education, especially mathematics education, for ECE.

The success is attributed to the CGI model employed in PDP that is considered to be effective because the interventions provided can properly develop teacher's knowledge so that it affects the improvement of teachers' KCS. One example of interventions is presented using video. Willmot (2012) stated that some benefits of using video are 1) Facilitating thinking and problem solving; 2) Assisting with mastery learning; 3) Inspiring and engaging students; 4) Authentic learning opportunities. By watching video, the respondents analyzed children's ability in problem-solving and explained their thinking (Carpenter et al., 2000b); using learning trajectories to measure and identify the level of children's understanding in problem-solving (McCool, 2009); hypothesize children understanding and misunderstanding and made prediction on how children will approach the follow-up assessment activity (Carpenter et al., 2000a; McCool, 2009).

Implication

This research contributes to the education of teachers in Indonesia because it provides a general overview of ECE teachers' MKT and their limitations as well as the solutions to overcome those limitations. The PDP design developed is expected to improve the quality of ECE teachers in Indonesia, especially in mathematics education. Through the CGI model, teachers use their experiences in the class to improve their knowledge about children's development and automatically improve their quality as an educator.

On the other hand, this research also contributes to mathematics education, regarding the importance of the mathematical ability of young children to their mathematical achievements in the future. Hence, the improvement of ECE teachers' quality can have a positive impact on mathematics education in Indonesia.

Limitation

The research has some limitations, particularly in the subject matter and the number of respondents involved. This research only focuses on the material of numbers concepts and only involves five kindergarten teachers in one district. Therefore, the researcher suggests that future

research expand the subject matter to geometry, measurement, or other ECE mathematics subjects by involving more respondents by considering a) either state or private schools; b) the class model applied; c) and the region of the respondents, whether in rural or urban areas.

CONCLUSIONS

The findings show that the Cognitively Guided Instruction (CGI) model employed in the Professional Development Program (PDP) can improve ECE teachers' Mathematical Knowledge for Teaching (MKT). This model is considered to be effective because the intervention provided can properly develop teacher's knowledge so that it affects the improvement of teachers' MKT.

In the first situation, which is giving a summary of basic mathematics concepts, the respondents could adequately follow the activity. The situation indicates to be able to develop Subject Matter Knowledge (SMK). In this regard, teachers have limited knowledge of basic mathematics. The reason is that they never been used in teaching kindergarten.

The other didactic situation is presenting videos about knowledge of counting, one-on-one correspondence, and children's cardinality. All respondents agreed that the video analysis activity is the advantage of PDP. Besides watching videos, the didactic situation provided by the tutor was presenting articles about children's strategies in solving problems.

Regarding the PCK, didactic situations of presenting videos and articles can develop Knowledge of Content and Students (KCS). Teachers employed KCS to predict and anticipate children's responses in developmental activities and learn to find solutions to children's development problems through the materials provided by the tutor. In this case, the teacher's limited KCS about children's mathematics development knowledge could be solved.

The respondents' process in developing Knowledge of Content and Teaching (KCT) was shown during the workshop. During the workshop, respondents obtained materials about the theory of study, strategy, and learning by playing principle, especially concerning the concept of numbers.

The success of respondents in building KCS and KCT is attributed to the role of the respondents' Knowledge of Curriculum (KC). In the implementation, the respondents made a lesson plan to implement the knowledge obtained from the workshop in their class. The findings show that all respondents presented the steps of the activity accurately. The evaluation was properly conducted, as well. All respondents have evaluated according to the standard rules. That activity shows that the respondents have properly build KC.

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