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Early childhood students' mathematical ability in highscope and lesson study context

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Abstract

This research aimed to (1) compare students' mathematical ability between pre- and post-stages of implementation of HighScope and lesson study and (2) analyze the qualitative detail of the students' mathematical ability. This research used mixed methods. The sample group included 42 early childhood students, studying in kindergarten 2 level in the 1st semester of 2019, Demonstration School, Khon Kaen University, Thailand. Research instruments were a mathematical ability evaluation form, field notes, a photo camera, and worksheets. Data were collected by evaluating the mathematical ability and taking field notes and photos. Quantitative data were analyzed by statistics, i.e. Mean, *SD.*, and *t*-test. Qualitative data were analyzed by applying the framework of mathematics content (National Association for the Education of Young Children [NAEYC], 2010). The results revealed that the post-stage average score (Mean = 3.03, *SD* = 0.12) on mathematical ability was higher than the pre-stage average score (Mean = 2.85, *SD* = 0.16) with the statistical significance at the level of .01 and *t*-value of 5.68. The students were able to express their mathematical ability through five mathematics content: (1) Number and operations, by the idea of groups, number, symbol, and number sense, (2) Geometry and spatial sense, by the idea of line, angle, geometric shapes, symmetry, and dimensional relationship, (3) Measurement, by the idea of comparing sizes, characteristics, and the number of items, (4) Pattern/algebraic thinking, by the idea of number relationship, and pattern of objects, and (5) Displaying and analyzing data, by the idea of representation of their preferred activities in the form of a bar chart.

Introduction

Young learners' future understanding of mathematics requires an early foundation based on a high-quality, challenging, and accessible mathematics education. Young children should experience mathematics through effective teaching practices (National Council of Teachers of

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Mathematics [NCTM], 2013). Children begin to develop their mathematical thinking and ability long before they enter school (Hansen, 2005). Children notice differences in quantity, they compare the shape and size of objects, and they use early math concepts while playing and also in other aspects of their daily lives (Gopnik, Sobel, Schulz, & Glymour, 2001). Math helps children develop the ability to think critically and solve problems (Institute of Medicine & National Research Council, 2015), which ultimately leads to the development of their mathematical ability. High-quality, challenging, and accessible mathematics education for three- to six-year-old children is a vital foundation for future mathematics learning and mathematical ability (NAEYC, 2010). The above studies indicated the importance of mathematics and mathematical ability for early childhood students.

Teaching early childhood students to develop mathematical ability is a great challenge. Many teachers do not know how to teach mathematics for early childhood students. They have a limited understanding of what kindergarten mathematics education entails and what is required to implement it effectively (Ginsburg, Lee, & Boyd, 2008). Teachers need innovation for an effective teaching practice. Lesson study, which focuses on instructional improvement, is an innovation that was developed for Japanese teachers' professional development and was later expanded and adapted in many countries around the world (Isoda, 2015). In Thailand, lesson study was adapted and implemented in the mathematics classrooms in 2002 (Inprasitha, Pattanajak, & Tesarin, 2007). In the context of Kindergarten Demonstration School of Khon Kaen University, a team of early childhood teachers and researchers conducted lesson study by working collaboratively to design lessons, teach and observe, and reflect on the lessons for every week. Additionally, the lesson study was incorporated with a HighScope approach in order to design and provide learning activities for children to learn mathematics. HighScope, including plan-do-review activities, was recognized by many educators who encourage the students to construct knowledge by themselves (French, 2012). Hypothetically, the integration of lesson study and HighScope might be an important factor to encourage students to learn mathematics, and especially, would help develop the early childhood students' mathematical ability.

Mathematical ability could be considered as the base of five mathematics content, i.e. number and operation, geometry, measurement, algebra and pattern, and data analysis (NAEYC, 2010). This study focused on the mathematical ability and what the qualitative details of mathematical ability for early childhood students are. The research includes two objectives—comparing the early childhood students' mathematical ability between the pre- and post-stages of implementation of HighScope and lesson study and analyzing the qualitative details of the students' mathematical ability. This mathematical ability could be used by teachers and researchers to evidence and examine not only how early childhood students learn mathematics and develop their mathematical ability but also what is the appropriate approach to teach mathematics for early childhood students.

Literature Review

Lesson Study as a Process of Instructional Improvement

Lesson study or Jugyou kenkyuu (Japanese) means lesson research (or lesson study), and refers to the process of instructional improvement of which the research lesson is the core piece (Lewis, 2000). Lesson study is an innovation that was introduced around 130 years ago as the Japanese approach to teacher professional development (Shimizu, 2006). Lesson study was implemented in the Thai mathematics classroom in 2002 by breaking it down into 3 main steps: collaboratively designing a research lesson (Plan), collaboratively observing the research lesson (Do), and collaboratively discussing and reflecting on the research lesson (See) (Inprasitha, 2015). The process of lesson study elaborates the lesson through the continuous cycle of "Plan-Do-See". Through lesson study, teachers learn from each other, develop their abilities and self-confidence, and construct better lesson models. It is a kind of accumulation of teaching improvements at the classroom level (Institute for International Cooperation [IFIC] & Japan International Cooperation Agency [JICA], 2004). According to the mentioned idea of lesson study, this study defined lesson study as the instructional improvement process that includes three steps—Plan-Do-See—in which the teachers and researchers work collaboratively in order to design the HighScope lessons, teach and observe the lessons, and reflect on the observed lessons. Through this process, early childhood mathematics lessons were improved and focused on developing early childhood students' mathematical ability and mathematics learning.

HighScope for Early Childhood Students

The term 'HighScope' refers to the high purposes and far-reaching mission of a model of education originating in the USA. Its goal is to improve the life chances of children and young people by promoting high-quality educational programs. HighScope, which was designed by David Weikart and colleagues at the beginning of 1962, drew extensively from Piaget's research on child development

through active learning and Dewey's philosophy of progressive education on playful active engagement in real-life experience using real materials (Hohmann & Weikart, 1995). 'High' refers to the maximum level of achievement for children and 'Scope' implies the variety of experiences that can be offered to children so they can achieve their personal height (French, 2012; Holt, 2010). In a HighScope setting, the children learn through a three-phase cycle: Plan, Do, and Review (Izadpanah & Gunce, 2014). This study determined HighScope, including Plan, Do and Review activities, as a teaching approach. It was implemented in the kindergarten classroom at KKU Demonstration School in 2015. A team of teachers and researchers tried to incorporate mathematics content into the designed lessons and expected to improve early childhood students' mathematical ability.

Early Childhood Students' Mathematical Ability

Mathematical ability can be defined as the ability to obtain, process, and retain mathematical information (Krutetskii, 1976). Mathematical ability refers to the studying of thinking processes manifested at solving different mathematical problems and the existence of a general (group) or specific mathematical ability (Mihajlovic, Egeric, & Dejic, 2008). Teachers need to understand how mathematics learning and mathematical ability are promoted by the young students' engagement in play, and how can they best support that learning (Dooley et al., 2014). The components of mathematical ability are arithmetical-numerical, abstraction and generalization, geometrical, and logical-combinatorial (Mihajlovic, Egeric, & Dejic, 2008). Mathematical ability involves mathematics content that students learnt in their classroom. There is a wide range of mathematics content for young children, including number and operations, shape, space, measurement, and pattern. This idea conforms to the big ideas that mathematics must include the content in areas such as number and operations, geometry, algebraic reasoning, and measurement (Clements, 2017). Mathematical ability is accorded to mathematics content areas, i.e. number and operation, geometry, measurement, algebra, and data analysis (National Council of Teacher of Mathematics [NCTM], 2000). Moreover, it is related to the common core state standards for mathematics (National Council of Teacher of Mathematics [NCTM], 2010). The national professional standards outline the core ideas in each of the five major content areas: number and operations, geometry, measurement, algebra (including patterns), and data analysis (NAEYC, 2010). The framework of NAEYC (2010) covered the ideas of early childhood students' mathematical ability and content. Therefore, this study used the idea of NAEYC (2010) and defined mathematical ability as performance relating to the abovementioned five mathematics content. It was proposed as a framework for examining early childhood students' mathematical ability.

This research determined the conceptual framework that consists of the variables including pre- and post-stage mathematical ability, HighScope, and lesson study. The pre-stage students' mathematical ability was evaluated by three teachers at the beginning of the semester. In classrooms, implementing lesson study (Plan-Do-See) and HighScope (Plan-Do-Review) and focusing on mathematical ability, lesson study, and HighScope are treatments that affect the students' mathematical ability. Teachers plan the lesson by considering how to improve the students' mathematical ability. They teach their lessons and observe the students' mathematical ability. Moreover, they reflect on how to improve instructions and enhance the students' mathematical ability. The qualitative data of students' mathematical ability was investigated by the researchers. Finally, post-stage students' mathematical ability was evaluated by three teachers at the end of the semester. The conceptual framework is demonstrated in the following Figure 1.

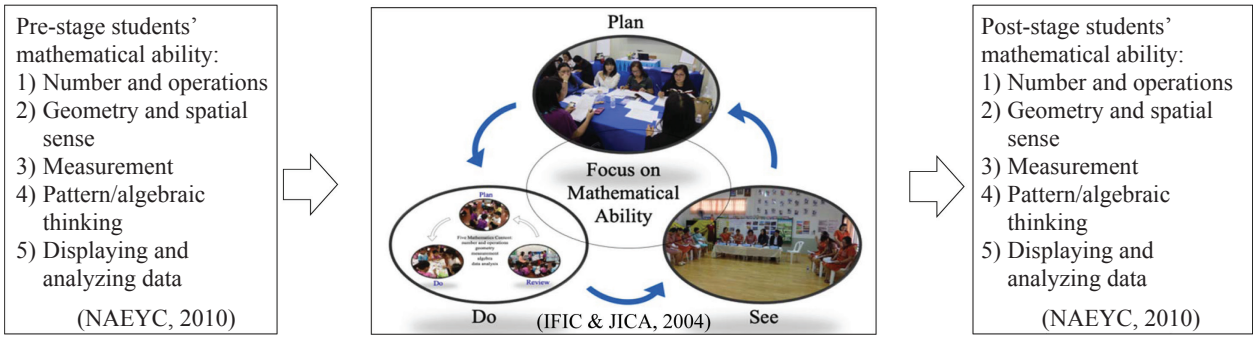

Figure 1 Conceptual Framework
Source: IFIC and JICA (2004) and NAEYC (2010)

Methodology

This research used mixed methods, type II embedded research design (Creswell, 2007) by mixing quantitative and qualitative data and analysis. This type of mixed methods investigates the quantitative pre-stage data and results, then the qualitative data and results, and finally, the post-stage data and results. The details of the research methodology are as follows.

Research Instruments

The research instrument for collecting quantitative data was the mathematical ability evaluation form, which was synthesized by the researcher based on the framework of NAEYC (2010) and verified by three experts in mathematics education, early childhood, and educational assessment. The determination of mathematical ability is shown in Table 1. Additionally, the instruments for collecting qualitative data were field notes, a photo camera, and worksheets.

Participants

The sample group was a class of 42 kindergarten students (K 2/6) who were statistically random sampling selected in the 1st semester of the 2019 academic year in the Demonstration School, Khon Kaen University, Thailand. On account of each class having a mixture of all student abilities (excellent, good, fair and poor), a cluster random sampling method was employed in this research. One class (K 2/6), out of 7 classes comprising of 278 kindergarten students, was chosen to be the sample group. The teachers and all the students in K 2/6 were content to participate in this research.

Data Collection

Research data were collected by three teachers who evaluated the individual student's mathematical ability at the beginning period of the semester using the mathematical ability evaluation form and determination as shown in Table 1. Then, lesson study and HighScope were implemented as the intervention. The researchers took field notes and recoded photos of the early childhood students' mathematical ability based on five mathematics content in learning activities and worksheets within the context of HighScope and lesson study. Finally, the three teachers evaluated the individual students' mathematical ability at the end period of the semester by using the mathematical ability evaluation form.

Table 1 Determination of Mathematical Ability

Score	Interpretation
1	The students' mathematical ability needs to improve
2	The students' mathematical ability is at a fair level
3	The students' mathematical ability is at a good level
4	The students' mathematical ability is at a very good level

Data Analysis

Quantitative data was analyzed by statistics, i.e. Mean, Standard Deviation, and t-test for the dependent group. Qualitative data of mathematical ability was analyzed by applying the framework of mathematical ability for early childhood (NAEYC, 2010).

Results

This study was implemented within the lesson study context, which consisted of a collaborative Plan, Do, and See. The students were taught using HighScope, which consisted of Plan, Do, and Review activities. The students' mathematical ability was assessed on five mathematics content. The research results show the following details.

The Quantitative Result of the Comparison of the Early Childhood Students' Pre- and Post-Stages Mathematical Ability

The early childhood students' mathematical ability between the pre- and post-stages of implementation of the HighScope approach and lesson study are shown in Table 2.

According to the statistics in table 2, the early childhood students have a post-stage average score ($\bar{x}$ = 3.03, SD = 0.16) on mathematical ability higher than the pre-stage average score ($\bar{x}$ = 2.85, SD = 0.12) with their statistical significance at the level of .01 and the t-value of 5.68. These statistics indicated that the implementation of HighScope and lesson study could improve early childhood students' mathematical ability.

The Qualitative Result of Early Childhood Students' Mathematical Ability

The early childhood students' mathematical ability was based on the following five mathematics content.

Number and operations

The students' written works show the mathematics content involving number and operations. The students were able to express their ideas of groups, numbers, symbols and number sense as can be seen in Figure 2.

Table 2 The early childhood students' pre- and post-stage mathematical ability

Period	Number of Students	Mean	*SD.*	t	df	sig
Pre-stage	42	2.85	0.16	5.68	41	.00**
Post-stage	42	3.03	0.12			

Note: ** statistical significance at the level of .01

Figure 2 Group of water frogs, numbers, and prices of items

Geometry and spatial sense

The students' worksheets and artifacts show the mathematics content involving geometry and spatial sense. The students were able to use lines, angles, shapes, symmetry, 2- and 3-dimensional relationships as shown in the below Figure 3.

Measurement

The students' artifacts, activities, and worksheets show the mathematics content related to measurement. They were able to express the ideas of comparing sizes, characteristics, and numbers as is shown in the following Figure 4.

Pattern/Algebraic thinking

The students' worksheets and artifacts show the mathematics content relating to the quantities relationship and pattern of objects. They were able to realize the difference in the prices of snacks and the order of decorative papers as shown Figure 5.

Displaying and analyzing data

After the students were done with the four activities including sculpture, origami, a small book or booklet, and paper plate craft, they collaboratively worked to present their own cards representing their preferred activities in the form of a bar chart. This kind of collaborative work is a basic statistic since the students are able to display and analyze the data of their preferred activities as shown in the below Figure 6.

Figure 3 The straight lines, angles, shapes, symmetry, and dimensional relationships

Figure 4 Comparison of length, characteristics of soil/rock/sand, and number of items

Figure 5 Students' idea of quantities relationship and pattern of objects

Figure 6 The bar chart displayed the students' preferred activities

Research results from the qualitative data analysis found the mathematical ability through the five mathematics content: (1) Number and operations, the students being able to express the ideas of groups, numbers, symbols, and number sense, (2) Geometry and spatial sense, they being able to represent lines, angles, geometric shapes, symmetry, and dimensional relationships, (3) Measurement, they being able to compare sizes, characteristics, and the number of items, (4) Pattern/algebraic thinking, they being able to realize quantities relationship and pattern of objects, and (5) Displaying and analyzing data, they being able to collaboratively work to present their own cards representing their preferred activities in a form of bar chart. This qualitative result is evidence of the students' mathematical ability, which is the dependent variable, and the consequence of the implementation of lesson study and HighScope, which is the independent variable.

Discussion

The first research result found that the early childhood students' post-stage average score on mathematical ability was higher than their pre-stage average score with regards to statistical significance. This result is a consequence of lesson study and HighScope because lesson study is an important treatment and condition that engaged the teachers to focus on the students' mathematical ability and how they could improve their teaching practice. Additionally, HighScope engaged the students to express their mathematical ability independently. This result conforms with that of Chujan and Kilenthong (2019), who found that the HighScope-based curriculum can improve child development in multiple dimensions. Moreover, Schweinhart (2013) indicated that the HighScope program group of children significantly outperformed the no program group on various intellectual tests from their preschool years up to 7. This study applied the HighScope approach and obtained a successful result. It could support Weikart's (1996) conclusion that over a span of 30 years, the HighScope Foundation and many other organizations

have learned to apply the principles of child growth and development in successful early childhood education and child care programs.

Additionally, the qualitative result found that the students have the mathematical ability in five content areas, consisting of number and operations, geometry and spatial sense, measurement, pattern/algebraic thinking, and displaying and analyzing data. This is a consequence of the HighScope activities that were well-prepared by the teachers in a collaborative Plan, Do, and See within the lesson study treatment. The students' mathematical ability was developed because the teachers carefully designed the activities according to five mathematics content and critically discussed how to improve their instructions and the students' mathematical ability. The result according to NCTM (2000) and Clements (2017) indicated that the five big ideas in mathematics must include mathematical experiences that incorporate mathematics content in areas such as number and operations, geometry, algebraic reasoning, measurement and data analysis, and probability. Additionally, the research result reflects the children's mathematical ability that conforms with NAEYC (2010), which was based on children's natural interest in mathematics, using it to make sense of their physical and social worlds and building a new knowledge base on their experience, cognitive, linguistic, physical, and social-emotional development. The result is important evidence that expresses appropriate preparation for early childhood students. This preparation ensures the early childhood students are ready to learn mathematics in primary education. Moreover, mathematics helps early childhood children make sense of their world outside of school and constructs a solid foundation for their success in elementary school.

Conclusion and Recommendation

This research concludes that the integration of lesson study and HighScope in the classroom could be an important condition for developing early childhood students' mathematical ability. Moreover, this integration could encourage early childhood students to learn mathematics appropriately. Additionally, besides the research result, early childhood students had learnt mathematics meaningfully and were very happy to participate in the designed learning activities.

Early childhood teachers or mathematics teachers for early children as well as researchers could use the research results for designing learning activities for three- to six-year-old children in order to engage children in learning mathematics meaningfully. Learning activities should be designed by covering not only the five mathematics content areas but also appropriating the levels of difficulty and the children's affective and cognitive development. Moreover, it should be interesting for the children and make sense to them both in their physical and social worlds.

This research focused on the mathematical ability of early childhood students based only on the five mathematics content, which is a limitation of this research. The future research should focus on mathematical learning processes, such as problem-solving, communication, connection, reasoning, and representation, in order to gain more comprehensive knowledge of the early childhood students' learning of mathematics.

Conflict of Interest

There is no conflict of interest.

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