

Original Paper

Designing a Rich Numeracy Task in Early Childhood Mathematics

Education: Teaching Addition in a Kindergarten in Macao

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Abstract

This paper presents an overview of the first cycle of collaborative action research of a kindergarten teacher who with the help of a university researcher, has designed a rich tool-based numeracy task for K3 children at a kindergarten in Macao. The rich numeracy task coupled with a tailor-made physical tool allows the children to investigate a model of addition with the manipulation of the critical selection of number cards by paying attention to a combination of corresponding numbers. Major data sources were documents, classroom observation, reflective dialogues between the two classroom teachers and with the university researcher. The results indicate that this rich tool-based task not only facilitates children's numeracy development but also promotes the development of other domains, such as social and linguistic development. Mathematical concepts, such as sum of three single digit numbers, are prominently emerged in the implementation of the rich numeracy task. This first cycle illustrates that the purposive design of rich tasks, coupled with appropriate artefacts for kindergarten children, is beneficial for promoting children's comprehensive development. It can also serve as an example to create rich numeracy tasks in early childhood mathematics education for kindergarten teachers to develop teaching strategies corresponding to the education reform in Macao.

Keywords

numeracy, (rich) task design, early childhood mathematics education

1. Introduction and Background

Research has shown that acquiring numeracy competence in early childhood enables children to gain physical and social knowledge in order to ultimately develop logical-mathematical knowledge (Kamii,

2006), something that is positively related to people's future mathematics capabilities, performance in other school subjects and life itself (Carmichael et al., 2014). Shen and Edwards (2017) claim that gaining numeracy skills in early childhood stimulates creative and innovative thinking in both young children and their educators. Numeracy has also been recognized as an important learning area across the world and Macao is no exception. Some countries use the term numeracy and some use mathematics in early childhood education. We use the term numeracy as it denotes the capacity to deal with quantitative aspects of life (Goos et al., 2013).

Approaches to helping children develop numeracy proficiency are suggested by both national curriculum guides and researchers across the world. For example, Dijk et al. (2004) propose that children learn through games of schematising activities, integrating both the child's personal constructions and the educator's pedagogical considerations. This means that semiotic activities designed by teachers play a prominent role, not only in cultivating children's individual development but also through conceiving didactical communication in classrooms. Academic and intellectual quality is embedded in rich numeracy tasks because they facilitate deep mathematical learning (Zevenbergen & Niesche, 2008). In Macao, mathematics and science is among the five learning areas in the General Guides for the Requirements of Basic Academic Attainments at Infant Education Level, which suggests that learning activities should be based on young children's daily life experience, taking games as a fundamental learning activity approach (Education and Youth Affairs Bureau, 2015).

In Macao, the Requirements of Basic Academic Attainments at Infant Education Level provide a point of reference and basic standards in curriculum organisation and development, the selection of teaching materials and teaching content in various learning areas, as well as education and learning, and the devising of assessment (Education and Youth Affairs Bureau, 2015). Kindergartens and teachers are given autonomy to decide appropriate teaching contents and assessment strategies in accordance with the Requirements.

Some researchers (e.g., Hu et al., 2018) point out that teachers in Macao tend to design close-ended teaching leading to the failure to foster children's higher-order thinking. The variation of responses gathered from children is not being appreciated or further elaborated. The teacher in this paper identified the existing problems and wanted to make a change after taking the in-service training courses in a university. She with the help of the university researcher managed to design a teaching activity, utilizing both a rich numeracy task and tool-based task methods in the lesson design, with the main aim of developing children's mathematics knowledge, in particular the concept of addition in a K3 classroom and implemented it with the help of a teaching assistant. This article presents the first cycle of the action research covering the design, the implementation, and the reflections on the activity and concludes with its implications for the design and implementation of the rich tool-based task for kindergarten children, for numeracy learning and beyond.

2. The Process of the Action Research

2.1 The Design

The general principle of infant education in Macao was taken into consideration in the design; that is, the teaching should be based on young children's daily life experience and take games as the fundamental learning activity approach (Education and Youth Affairs Bureau, 2015). Additionally, young children are to be given opportunities to explore, discover, feel and learn, in life and games, and to gain experience through direct perception, personal experience and hands-on practice, all of which have led to their growth with the accumulated experience (Education and Youth Affairs Bureau, 2015).

2.1.1 The Learning Objectives/Outcomes

The major objective for the teaching activity is within learning domain 3 of the mathematics and science learning area. The specific objectives are to enable the children to: a) basically understand the relationship between numbers and quantities; b) group and divide quantities within 10, with the assistance of real objects or figures, and perform simple addition (Education and Youth Affairs Bureau, 2015). In addition to promoting children's cognitive development, the teacher also aims to promote children's language and social development. Specifically, in terms of language, the children should be willing to talk to others and participate in discussion and feel able to express their personal opinions. Socially, the children ought to like learning, be willing to participate in learning activities, have the basic ability to think about and solve simple problems, and be willing to communicate, co-operate and share with others as well as participate in group activities (Education and Youth Affairs Bureau, 2015).

2.1.2 The Theoretical Basis

The design is based on the numeracy model, rich numeracy tasks and basic principles of infant education in Macao. The numeracy model (Goos et al., 2013) frames a design of rich numeracy tasks using a tripod with three prominent considerations, which are dispositions, tools and mathematics knowledge.

Disposition is positively embedded into rich tasks promoting students' confidence, initiative and willingness to flexibly and adaptively construct knowledge through its application. The rich tasks should be designed with consideration of affective issues, applying a central role to emphasising positive attitudes towards mathematics learning. Tool should be involved in the design of the rich tasks, mediating students to connect with the mathematics knowledge through manipulation of the tool. Cognitive tools (Norman, 1993) help students to contact with abstract mathematics through visualised symbols as the representation of certain mathematics concepts. In addition to explanation of mathematics knowledge in the numeracy model, the knowledge involves fluency of accessing the concepts and skills, and problem-solving strategies, alongside the ability to make sensible estimations in the process of application (Zevenbergen, 2004).

For the mathematics contents of addition in early childhood mathematics education, composing and decomposing numbers, combining with counting strategies, is one approach to addition and subtraction (Clements & Sarama, 2007). It explains the sum and difference between small numbers as part-whole

relations in early childhood mathematics education that contributes to important accomplishments in arithmetic (Kilpatrick et al., 2001).

According to Wolf (2016), a rich numeracy task has six characteristics, accessible to all learners; real-life tasks; multiple approaches and presentations; collaboration and discussion; engagement, curiosity and creativity; opportunity for expansion, which are in correspondence with the general education principle and three of the seven specific principles in Macao namely, life-oriented, enlightenment and expansibility.

2.1.3 The Task and the Tool

The preliminary design of number cards was intended to cultivate collaboration among the children, who were paired to select a number card. The number cards were created in colourful designs allowing children to discuss and show them to other children. The number cards consisted of symbolic numbers together with corresponding cups of water, allowing children to visualise and count in order to assure their understanding of the represented quantity. The orders of the cups of water were placed in such a way that perceptual subitizing the small numbers (Clements, 1999) was formed, through which the cluster of the cups could be identified and unitised easily by the children. Each card was printed with a hook for children to display the numbers in a proper way so that they could hold the card and communicate with others simultaneously. The children were asked to negotiate with their partners to pick the number cards in such a way that the sum of the numbers of the two selected cards was the number as displayed by the teacher. Problems of the equation

$$a + b = c$$

are formed where c is a one-digit integer. The flow of the activity and questions raised to the children were modified in the discussion with the university researcher prior to the implementation of the lesson in order to initiate children's play with the cards with confidence.



Figure 1. The Number Cards as a Tool in the Lesson

2.1.4 Formative Assessment

The teacher employed observation in the implementation process to assess the children's learning process and outcomes. The teacher asked the children to actively collaborate in pairs and to form combinations of numbers with the number cards, and raised instant questions to probe their

mathematical reasoning behind the selection of the cards. Additionally, the teacher adopted observation in the process in order to improve the future design and implementation of tasks.

2.2 The Implementation

The whole activity session lasted for thirty-five minutes. There were two adults in the classroom who conducted this tool-based lesson collaboratively. One teacher was the key person to lead the teaching activities by introducing, questioning and guiding the children to interact with each other, while the teaching assistant supported the teaching through classroom management. Both collaboratively set up the activities with the number cards and designed the flow of the activities in the lesson. The teacher orchestrated the children to participate in the activities while the teaching assistant took care of the children's general behaviours.

2.2.1 Leading in/Warming-up

The lesson started with a story and a mission. The teacher told the children that different animals needed different amounts of water, quantified as numbers of cups of water as shown Figure 2. The children were asked to save the animals by finding sufficient amount of water with the number cards. Moreover, some animal cards consisted of some numbers larger than the numbers shown in the cards with the cups of water. It required the children to work collaboratively in order to satisfy the required numbers for the animals.



Figure 2. A number Card Posted by the Teacher with a Hippopotamus Showing Three Cups of Water Required

2.2.2 The Activity Process

The main activity of the matching game lasted about twenty minutes. The children were divided into pairs. They discussed within the pairs in order to negotiate which two cards were to be chosen. The teacher posted numbers, one by one, so that each pair of children came to the front of the classroom to demonstrate to the class their selected number cards. After a pair of children illustrated the combination of two selected number cards, the teacher changed another number for another pair. In addition to the selection of the number cards and the demonstration to form their sum, the teacher read aloud the

equation of the sum, for example, “the sum of three and four is seven”. The children showed interest and actively participated in the game revealing engaging communication among themselves.

The task was designed to allow pairs of children to choose from the number cards and combine the selected numbers in order to obtain the numbers set by the teacher. In addition, the verbal form of equation expressed by the teacher enabled the children not only to get used to formal mathematical language, but also to understand the numeracy relation of the numbers.

Based on the lesson observation and the children’s work on the selection of number cards, it was found that the children not only conceived knowledge, in the sum of two numbers as the combination of a number within nine, but also understood the sum of three numbers in a line. Figure 3 reveals a case in which the teacher posted a number eight. A child from the pair first selected a number card with four cups while the partner child selected a number card with three cups (the number cards were created with a limit that the number card with four cups was not duplicated). The child who first selected the number card with four cups found the sum of the two numbers was not eight, then she took one more number card with a cup to form the sum of three numbers.

Thus,

$$a_1 + a_2 + b = c$$

is the advanced arithmetic knowledge the children discovered via the flexibility of the manipulation of the number cards in the rich task.



Figure 3. Three Number Cards Selected by a Pair of Children Demonstrating Combination of Eight

2.2.3 Summing-up

The teachers concluded the activity by recapping the combinations of number cards and their corresponding sums. The children read the equations according to the addition of two or three number cards. In some cases, the teacher held the number cards to the whole class to illustrate the equations. It, thus, extended to the cognitive ideas of the mathematics concept of addition selected by the pairs the children in all scenarios. These cognitive ideas were developed through mathematization process grounded on the language and the words produced by the children with the help of the manipulatives and the assistance from the teachers.

3. Data Collection and Analysis

Major data sources were documents, classroom observation, reflective dialogues between the two classroom teachers and with the university researcher. Documents were General Guides for the Requirements of Basic Academic Attainments at Infant Education Level, the Requirements of Basic Academic Attainments at Infant Education Level, the lesson plan, and the teaching materials/tools. Classroom observations were conducted by the teacher and the teaching assistant. The university researcher kept records of the reflective dialogues conducted between the teacher and the teaching assistant shared by the teacher and the dialogues conducted between the teacher and the researcher. Qualitative content analysis is utilised to analyse the collected data, because qualitative content analysis “allows researchers to understand social reality in a subjective but scientific manner” through exploring “the meaning underlying physical message” (Zhang & Wildemuth, 2009, p.1). The analysis followed the following steps: a) the researchers coded the qualitative data; b) the researchers categorise the codes referring to the teaching objectives and the theoretical basis; c) the researchers presented and interpreted the result.

4. Results and Discussion

The tasks implemented in the lesson achieved the set learning objectives. The children gained not only knowledge of fluency via accessing the numeracy concepts through the cardinal display of the cups of water, along with symbolic presentation of the numbers on the cards, but also problem-solving skills and communication skills. Therefore, the number cards were viewed as the tools representationally emerging in the tool-based lesson. The case of selecting three cards to the sum of numbers made it evident that children had thought reflectively and made a correct decision accordingly. Therefore, the semiotic potential of the number cards that enables the children to think reflectively and acquire mathematics knowledge was realised in this case.

In addition, it involved positive dispositions for the children to manipulate with the number cards and discuss among themselves with autonomy, in such a manner that confidence, initiative and willingness to participate in the tasks were highly underlined. It also enabled the children to participate as active insiders engaging in the activity with curiosity and creativity. Affective considerations of the children have been held to play a critical role in the design of the lesson, with a storytelling scenario being adopted in order to develop positive attitudes toward mathematics.

“...The children participate in culturally specific social settings which are variously structured as in peer interaction or small group interaction guided by a nursery teacher or primary mathematics teacher etc. These social settings do not function automatically” (Krummheuer, 2014, p. 75). Cooperation among children participating in social settings takes place in the deliberate design of a lesson. The inclusion of peer interaction through negotiation with partners among the children in the design of this tool-based lesson for the development of numeracy may serve as a good example. Besides, observation of children demonstrating the addition in lines with the chosen number cards further confirmed that

using this rich tool-based task helped the children to develop mathematical language through discussion and negotiation among themselves.

The tool used in the lesson provides opportunities for the children to decompose a number into two numbers in which concept of addition is acquired. Crucially, addition of three numbers is conceived by the children, who then generalise the rule of decomposition of numbers. The designated rich task associated with the children's manipulation of the tools enables them to develop high order thinking skills in terms of creativity, problem-solving and mathematical numeracy.

5. Concluding Remarks

Since the article presents only the first cycle of the action research, it has limitations. Nevertheless, it offers some implications for early childhood mathematics education in Macau and beyond. This idea could be further extended to the learning of subtraction. In addition, duo of material and digital tools (Maschietto & Soury-Lavergne, 2013) that advocates combination of a physical tool and its digital counterpart could be utilised in a mathematical task. The duo of material and digital tools has the potential to further stimulate children to reinvent mathematics concepts (Lei et al., 2019). The curriculum reform in Macao values integration of themes grounded on daily life experience. The selection of object, which was the cup of water, purposively related to a theme of health and life in early childhood education offers a good example of relating learning to children's interest and daily life experience. It also shows that themes of various content knowledge in the curriculums can be integrated. This approach not only integrates learning into daily life situations, but also magnifies children's motivation to engage in the games.

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