Analyze the Quality of Math Kangaroo Problems with a Content Analysis

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Abstract. The research analyzed problems in Math Kangaroo (5&6) with a content analysis method from four aspects: problem background, knowledge structure, cognitive structure and thinking mode. There were several detailed analysis indicators for each aspect. The research results show that the problems in Math Kangaroo have the following characteristics: the pictures are beautifully presented, the backgrounds are natural and interesting, and it does not deviate from the essence of mathematics; the knowledge points are not much, but a deep understanding is required; mathematical thinking and problem analysis are needed. Then enlightenment is: good problems are problems that the problem solving process should help improve students' thinking ability and they should be solved by serious thinking.

1. Introduction
Mathematics learning has important value in cultivating students' philosophical thinking and rational spirit. Because of this, mathematics is one of the subjects with the longest learning years for students in various countries around the world. Children learn mathematics from an early age. In order to stimulate children's interest in learning mathematics, many mathematics competitions designed for children have appeared. Math Kangaroo is such a contest for cultivating students' interest in mathematics. Each year, over 6.5 million pupils aged 5-18, from over 70 countries around the world, participate in the Contest [1]. Math Kangaroo is the world’s largest international Math classroom competition [2]. The Contest is more of a game than an uncompromising competition [3]. Analyzing the characteristics of the problems in Math Kangaroo helps to understand why the activity can arouse so many children's interest in participating, and helps to understand how to cultivate children's interest in mathematics. This article mainly studies the problems of Math Kangaroo in grades 5&6 with a content analysis method. The objectives of the research is to answer: What are the characteristics of the problems in Math Kangaroo?

2. Research Design

2.1. Research Objects and Methodology
Most of the problems of Math Kangaroo in each country were the same. This article selected the fifth and sixth grade problems of Canadian Math Kangaroo from 2016 to 2018 as the research objects. The study analyzed the problem background, knowledge structure, cognitive requirements, and thinking mode needed to solve the problems, and explore the spiritual and mathematical educational value...
The research method was the content analysis method. A content analysis represents an effective tool for analyzing a sample of research documents in a systematic way. Content analysis generally includes five steps: raising research questions, sampling, coding, analyzing data, and reporting research results. The data processing and charting software was SPSS 22.0.

2.2. Four aspects involved in problem solving

Problem solving is the process of searching the problem space with conditions, requirements and the connection between conditions and requirements as the basic components, in which the problem refers to the gaps between conditions and requirements, and the solution of the problem is to establish the connection between conditions and gaps. Schoenfeld pointed out that resources, heuristics, control and belief systems are the four main cognitive factors that affect people’s problem solving [4]. In this research, the problems are analyzed from four aspects: the problem background, knowledge structure, cognitive requirements, and thinking modes needed to problem solving.

The problem background of the problems is divided into four categories: fun tasks, practical life, scientific applications and mathematics itself. A fun tasks problem means that the problem background is to complete an interesting task. A real life problem means that the background of the problem is the real life scene. A science application problem means that the background of the problem is the application of mathematics in science and technology. A pure mathematics problem means that the background of the problem is mathematics itself.

The content of mathematics is closely related to student achievement, and learning appropriate mathematics is conducive to improving students’ abilities [5]. The mathematical content involved in the problems is divided into three parts: number and algebra, figure and geometry, and statistics and probability.

There are new methods for cognitive classification of problems [6], but this research believes that Bloom's classification is more suitable for primary school students. In this research, the cognitive level is divided into memory level, understanding level and analysis level. The three-level analysis framework and detailed indicators of the cognitive requirements of the problem are shown in Table 1. Low-level cognitive level requirements are necessary conditions for high-level cognitive level requirements. For example, being at the analytical level necessarily means that you have reached the level of memory and understanding.

| Level   | Description                                                                 |
|---------|-----------------------------------------------------------------------------|
| Memory  | Add, subtract, multiply and divide according to the algorithm remembered     |
| Understanding | Understand the problem and transform it through simple deformation      |
| Analysis | Analyze unfamiliar problems and find ways to solve them                   |

In this research, the reasoning model is divided into four types: transitive reasoning, causal reasoning, analogical reasoning and inductive reasoning. Transitive reasoning is a reasoning that infers the relationship between two objects through a third party. Causal reasoning is the mutual reasoning between cause and effect; analogical reasoning is reasoning based on similarity. Inductive reasoning is the reasoning from special to general, part to whole. This research selects the main reasoning mode that the problem focuses on as the thinking mode required to solve the problem by means of expert judgment.

3. Research Result

3.1. Problem Background

The problems for grades 5&6 of Math Kangaroo are very exquisite. Figure 1 shows problem 28 in 2018 Math Kangaroo (5&6). The smiling face makes the problems show a kind of intimacy, which makes people want to see what is the problem to be solved. Such a layout makes the problems.
attractive to the pupils and can stimulate their interest and motivation to solve the problem. The exquisite pictures not only attract pupils, but also clearly express the meaning of the problem. It helps them to concentrate on the key to the problem. Problems in Math Kangaroo (5&6) are not only beautiful, but the context of the them is also interesting and life-like.

Figure 1. Problem 28 in 2018 Math Kangaroo (5&6).

The statistics of the problem background are shown in Figure 2. The backgrounds of the problems are mostly based on actual life, followed by mathematics itself and interesting tasks. There are almost no problems based on scientific applications. The backgrounds of the problems are mostly derived from real life and are loved by children. There are few test questions on the background of scientific application, which is in line with the cognitive development of primary school students. The application of mathematics in elementary school to science is not obvious. If scientific applications must be incorporated into elementary school mathematics competitions, it will inevitably increase the amount of information and difficulty of the problems. The number of problems with the background of interesting tasks is not low, but it is less than the problems with the background of mathematics itself. This shows that although the contest pursues fun, it does not deviate from mathematics, but presents mathematics in an interesting way as much as possible. The starting point and destination of the contest are to cultivate students' true interest in real mathematics.

Figure 2. The bar graph of the problem background.

3.2. Knowledge Structure

The contest focus on the ability to analyze problems. The concepts and knowledge involved are not much. A problem generally only involves 2-3 knowledge points. Figure 3 shows a representative example.

Figure 3. Problem 22 in 2018 Math Kangaroo (5&6).
The above problem only involves the addition and subtraction of integers and the comparison of sizes. There are not many knowledge points involved and the knowledge points tested are very simple. It can be seen that the focus of the competition is not how much knowledge is known.

The statistics of the knowledge structure are shown in Figure 4. The contest mainly examines the knowledge of number and algebra, figure and geometry, and focuses more on number and algebra. Statistics and probability are basically not examined. Primary school students mainly use intuitive methods to observe and think about the world. The problems emphasize intuitive figures and geometry, but pay more attention to abstract mathematics and algebra, and focus on testing students' abstract thinking ability.

![Figure 4](image_url)

**Figure 4.** The bar graph of the problem knowledge structure.

### 3.3. Cognitive Requirements

Although the problems involve not much knowledge, they have higher requirements for cognition. To answer the questions correctly, pupils must not only understand the meaning of the questions, but also conduct a serious comprehensive analysis. The statistics of the knowledge structure are shown in Figure 5. The problems put the most emphasis on the ability to analyze problems, followed by understanding and memory.

![Figure 5](image_url)

**Figure 5.** The bar graph of the problem cognitive requirements.

### 3.4. Thinking Modes

In terms of thinking and reasoning, Math Kangaroo problems require flexibility in thinking and the ability to comprehensively use various reasoning modes, especially focusing on classification thinking and comprehensive thinking. Figure 6 shows a representative example.
Problem 29 in 2016 Math Kangaroo (5&6).

To solve the problem, you must know how the two gears side by side in the upper right corner of the picture rotate, and to know how these two gears rotate, you must first know the third one from the right. According to this reverse thinking method, the key to the problem lies in how the clockwise rotating gear at the lowest point affects the gear that engages with it. This is a kind of analytical thinking based on effect and cause. After this critical part, you can follow the path of the original analysis and then solve the problem. This is comprehensive thinking. There are two ways of influencing the gears in the question, one is through the bite, the other is through the transmission belt. The former two gears rotate in opposite directions, while the latter have the same direction, which reflects the idea of classification. The statistics of the thinking modes are shown in Figure 7.

Various reasoning modes are not without intersection. The classification is determined based on the main reasoning mode used to solve the problem. The main reasoning types required by the problems are transitive reasoning and causal reasoning. This is consistent with the contest requiring analysis and comprehensive thinking. Analysis and comprehensive thinking should consider the part and the whole. There are almost no problems for analogical reasoning. It shows that Math Kangaroo pay more attention to deductive reasoning based on analysis and synthesis, and do not make higher requirements for analogy.

4. Conclusion
The problems in Math Kangaroo have the following characteristics: the pictures are beautifully presented, the backgrounds are natural and interesting, and it does not deviate from the essence of mathematics; the knowledge points are not much, but a deep understanding is required; mathematical
thinking and problem analysis are needed. That’s may be why the reputation, the merit, and the quality of inspired learning are at a very high level [7]. We can get a lot of inspiration from the success of math kangaroo. The fundamental purpose of holding elementary school mathematics competition is to stimulate students’ interest in mathematics, improve students’ thinking ability and cultivate students’ will and quality. The background of problems should come from the lives of the children or things they find familiar. Problems must be interesting, which is an important factor to attract students to participate. The characteristics of good primary school math problems are: the problem solving process should help improve students’ thinking ability and the problems should be solved by serious thinking, which helps to develop students’ thinking ability.

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