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Article

Design of Teaching Aids for Children to Understand Digestive Tract and Low-Carbonate Diet

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Abstract: Commercially available teaching aids related to the human digestive tract were primarily provided in the form of human organ graphics or models for teaching. Such teaching aids often lacked practical operation and game-experiential learning methods, which were less likely to arouse children's interest in learning. Thus, we designed a set of teaching aids for teaching young children to understand the human digestive tract and low-carbonate (low-carbon) diet. The teaching aids had the interchangeable appearance of a robot detective and an ambulance. They contained the four digestive tract games: the mouth, esophagus, stomach, small intestine, and large intestine. The dynamic game design that simulated the function of the digestive tract, combined with low-carbon diet board games, provided young children with learning in a playful context. The results showed that the teaching aids had advantages, including adaptive learning effects and fun games, enhancing learning motivation and interactive operation, and lightweight and environmentally friendly materials. More extensive teaching applications and follow-up research were recommended in the future.

Keywords: Game-based learning, Digestive tract, Children's teaching aids

1. Introduction

Children's knowledge of human body organs is affected by age, culture, religion, and education (Chen & Qiu, 2011, Jaakkola & Slaughter, 2002, Panagiotaki, & Nobes, 2014). Most children aged four to five know the names and locations of several major body organs (Chen & Qiu, 2011; Panagiotaki & Nobes, 2014). Slaughter et al. (1999) argued that children between the ages of four and six begin to understand the essential functions of organs. Jaakkola and Slaughter (2002) indicated that children's comprehension of organ names and functions increased with age. However, Panagiotaki and Nobes (2014) found that children in their comparison countries did not naturally increase their understanding of the names and functions of organs by age, and there was a significant difference in whether the relative educational experience was provided in school. Such findings expressed the importance of school education for learning the abstract functions and knowledge of body organs and showed that young children do not understand the connections between organs (Jaakkola & Slaughter, 2002; Panagiotaki & Nobes, 2014; Slaughter et al., 1999). For young children, the greatest difficulty in learning the digestive organs was the function of the digestive organs and the chemical transformation of the ingested food (Teixeira, 2000).

To help young children understand the functions and characteristics of the human digestive tract, we designed interactive games that provided stimulation and experience to inspire children's senses and learning. The teaching aids had four characteristics: innovation, functionality, operability, and fun to play. Through the practical operation, children gained an intuitive learning experience, activated the mechanism of brain learning, and satisfied children's curiosity and interests in exploration. We reviewed the literature and sorted out and analyzed the types of children's teaching aids related to human organs on the market and found that the types of teaching aids related to the digestive system were relatively similar. The position, name, and function of the parts of the digestive system were illustrated with diagrams and models. From a psychological point of view, teaching aligns with young children's physical and mental development and needs. Therefore, teaching aids need to avoid cognitive teaching in the form of indoctrination. Instead, arousing children's spontaneous learning motivation and interests helps children build their understanding and skills of knowledge concepts. Given this, we explored aspects to describe the overall design plan, the function, the operability, and the playfulness of the teaching aids as follows.

(1) Transformational design plan of the overall teaching aids

The concept of SPACE SYNTAX was proposed according to Hillier in 1984 (Hillier, 1996). In terms of architectural form, the logical relationship of spatial configuration was emphasized, and the realistic layout and spatial relationship of architectural images were considered. Therefore, in this study, the teaching aids were designed to emphasize the transformation of visual and spatial construction modes regarding the main structure and appearance design. A combination of a robot detective with an ambulance was designed to present the appearance of the teaching aids that could be transformed from a car body to a humanoid structure as a deformation toy. By careful arrangement of shapes in the space of the main structure, the construction of visual flow was emphasized to extend the relationship between the subject and the space in a multi-dimensional way. The whole structure allowed for the deconstruction and laying out of different learning parts corresponding to its appearance, which is innovative.

(2) Multi-functional teaching aids

The theoretical basis of this study was children's development and learning process. The progressive learning process of constructing knowledge connected between individuals and the external world requires consideration of the context in which learners engage in dynamic learning. Learners construct knowledge from learning actions, and the experience of real situations helps them think, improve their ability to solve problems, and further internalize abstract knowledge into interactive practice (Mayer, 1992). Also, young children's learning in shared contexts enhanced their analytical and reasoning abilities (Brown & Kane, 1998). We designed the tasks in a game in each part of the teaching aids to help children engage in the learning context and promote children's reasoning of the digestive tract and related functional knowledge through guided exploration and game interaction. The teaching aids used the independent space of each part of the overall structure to represent four parts of digestive organs, including the oral cavity, stomach, small intestine, and large intestine. The dynamic game design simulated the function of the digestive tract and guided children to learn in various aspects. Children achieved their learning goals through contextualized and play-based experiences. For example, in an oral health task game, dental caries were detected so healthy food was chosen, combining visual and tactile exercises with fine motor skills. Also, such oral health knowledge was essential for children's digestive tract health. To sum up, the role of teaching aids was designated to present the overall connection of the digestive tract and to independently create dynamic game content with specific knowledge for achieving learning objectives.

(3) The operability of the teaching aids

Young children's cognitive learning involves comprehensive performance of perception, thinking, understanding, and memory. Through information processing, children learn to collect information, process information, and solve problems (Ross, Maureen, Schultz, 2001). Fleming and Mills (1992) proposed the visual, aural, read/write, and kinesthetic (VARK) learning model theory, indicating that individuals learn differently. Four learning types included visual, auditory, reading and writing, and kinesthetic. Teachers were encouraged to use various teaching methods to accommodate children's learning styles. Based on the perspective of children's cognitive development, we integrated intuitive teaching theory with multi-sensory stimulation exercises to simulate the dynamic process of gastric digestion, using different action methods, steps, and rules, to provide children with reference and imagination of gastric digestion. In the task of Small Intestine Maze, children chose one food picture from the food group with the indicated points they turned on the turntable. Then, they took the same number of plush balls with the points they drew. Children learned that the more nutritious food had more points and plush balls. Also, children used strategies to solve the problems by pushing the plush ball to go through the home of the maze to score. The manipulative future of the teaching aids was considered to link the learning content so that children achieved enhanced learning results in the operation of the contextual tasks.

(4) Gamified design of teaching aids

Children are natural explorers. Based on the characteristics of children's learning and development status, game-based learning support children's learning more effectively than traditional learning (Bento & Dias, 2017; Brooks & Sjöberg, 2022). Therefore, we applied the game-based learning approach to make our teaching aids. We designed five game blocks. Each game contained a theme related to the human digestive tract and its specific task, and different rules were designed to provide exploratory activities, combination activities and creative learning content. Task categories included moving, repeating, collecting, challenging, and operating techniques, and game specifications combined with reward mechanisms to encourage children to experience the process of actively constructing knowledge. By exploring and challenging the goals of game tasks, children can display creative behaviors and interactions that result in having a sense of accomplishment.

2. Materials and Methods

Through a literature review and analysis of children's teaching aids on the market, we found that most of the available digestive system teaching aids were provided for teaching purposes in the form of puzzles, graphics, or models. The lack of practical operation and game-experiential learning methods made it difficult to stimulate children's interest and maintain children's attention in learning.

Chen and Qiu (2011) found that young children's concept of the human digestive tract included the name or location of the organ rather than its function and operation of the organ. Only a few children described the functional relationship between organs by drawings or during interviews as preschoolers had a general idea of how body systems work. All, Castellar and Van Looy (2015) argued that game-based learning increased learners' comprehension of the learning content and helped learners apply what they learned in everyday life. In addition, games motivate and interest learners in learning. We compared and contrasted the differences between commercially available teaching aids and the proposed design concept of the self-made teaching aids as shown in Table 1.

Table 1. Differences between commercially available teaching aids and self-made teaching aids.

Teaching Aid Type	**Commercial Products**			**Self-Made**
Product name	Human Internal Organs Apron Teaching Aids (Shoppe a, n.d.)	Recognize Organ Dolls (Shoppe b, n.d.)	Human Digestive System Puzzle (Shoppe c, n.d.)	Digestive Tract Teaching Aids
Product picture				Design concept
Suitable for young children	v	v	v	v
Suitable for basic learning objectives (understand organ name/shape/location)	v	v	v	v
Comprehensive learning content(understand organ function)				v
Providing scaffolding learning	v	v	v	v
Providing interactive operation				v
Playfulness	v	v	v	v
Multi-function operation				v
Self-correcting	v	v	v	v
Improve learning motivation				v
Enhance learning interest				v
Adaptive learning effects				v

Generally speaking, both of them met the developmental needs of children with clear learning goals and helped children recognize the location and names of organs emphasizing the playfulness of games. However, in terms of the learning content and contexts, the commercial teaching aids were relatively monotonous and lacked various manipulative and gameplay mechanisms to make the learning experiences more profound and diverse. In addition to retaining the advantages of the current commercially available products, we overcame the design limitations of these teaching aids by integrating a scaffolding learning approach to support children's cognitive learning. Also, combined with the operation of children's fine motor and various game-based learning designs, such designs helped children use what they learned in daily life while playing with the new teaching aids. On the other hand, it reduced the negative impact of the cognitive load on children's learning due to too much emphasis on cognitive and memory learning in the currently available products. According to the characteristics of children's development and the design principles of the teaching aids, we formulated a teaching-aid design framework (Fig. 1). This framework emphasized the function, operability, and diverse game features of teaching aids. According to the type of digestive organs, we designed manipulative games that integrated sensory and cognitive abilities. Children learned through play context and learned the social context of multiplayer interaction, which increased cooperation and interactive learning with peers.

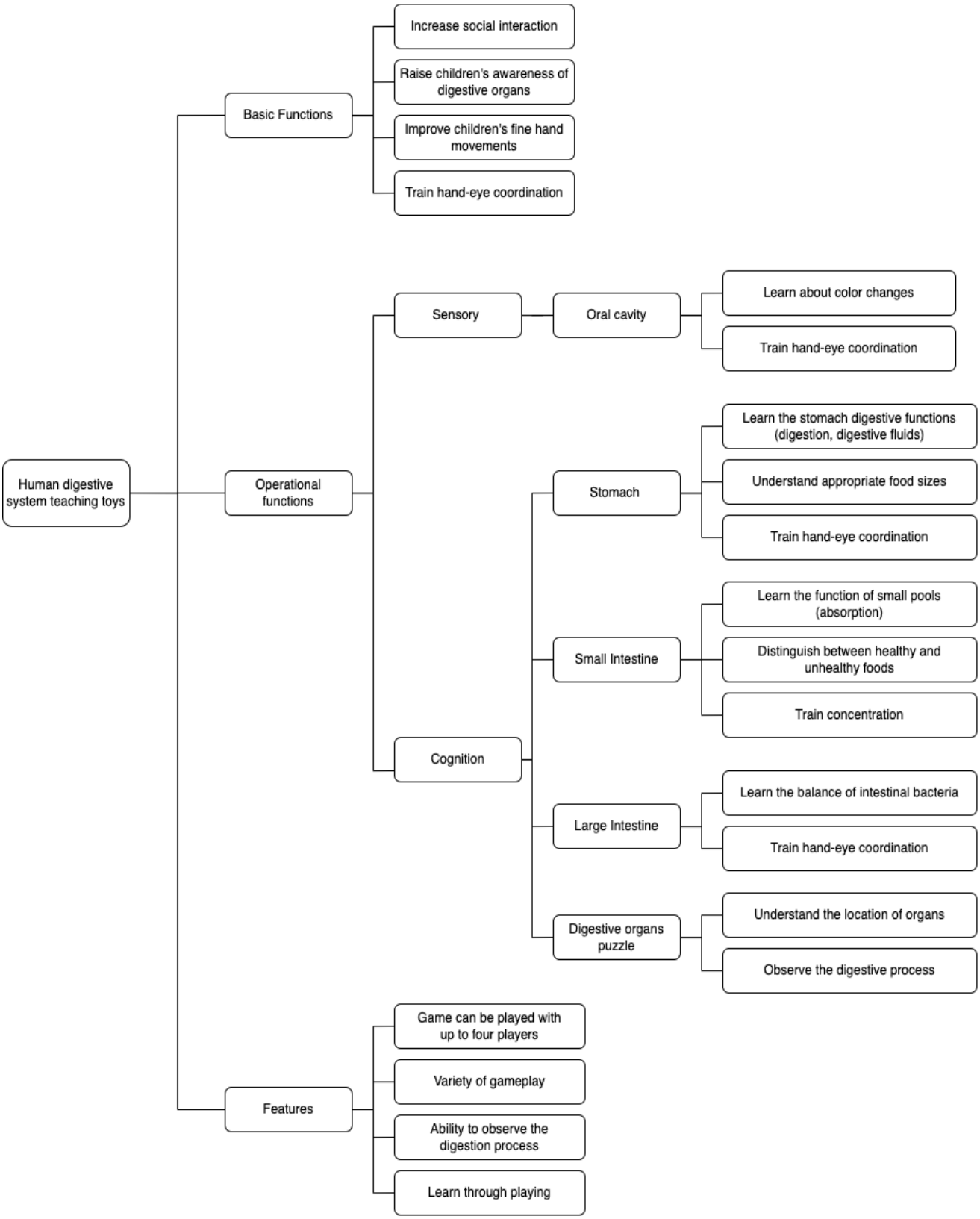


Fig. 1. Design framework of the teaching aids for a human digestive tract.

2.1. Design of Appearance of Teaching Aids

According to the theme and design, we created the structure and different game activities for the teaching aids. The design of the appearance and overall structure of the teaching aids are described in Table 2, and the design and instructions of the manipulative games are illustrated in Table 3. Referring to the framework and rationales of the teaching aid design, we transformed the teaching content into gamified and situational learning situations. From selecting tools and materials to finished products, economical, environmentally friendly, and sustainable low-carbon goals were achieved.

Table 2. The design of the appearance of the teaching aids.

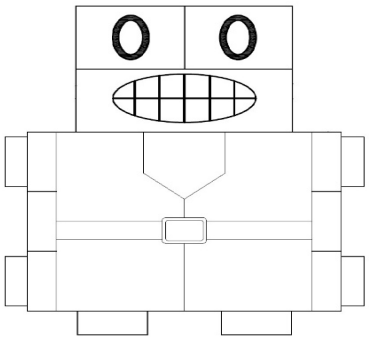
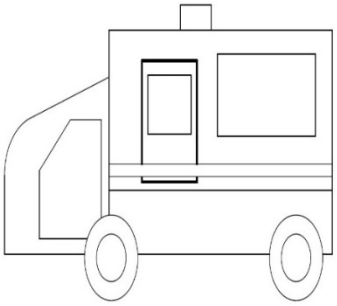
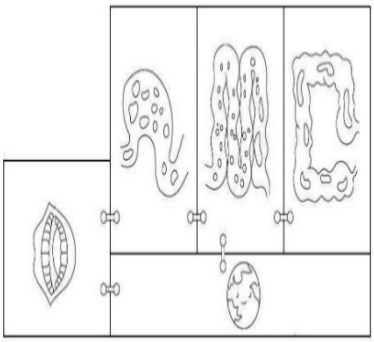
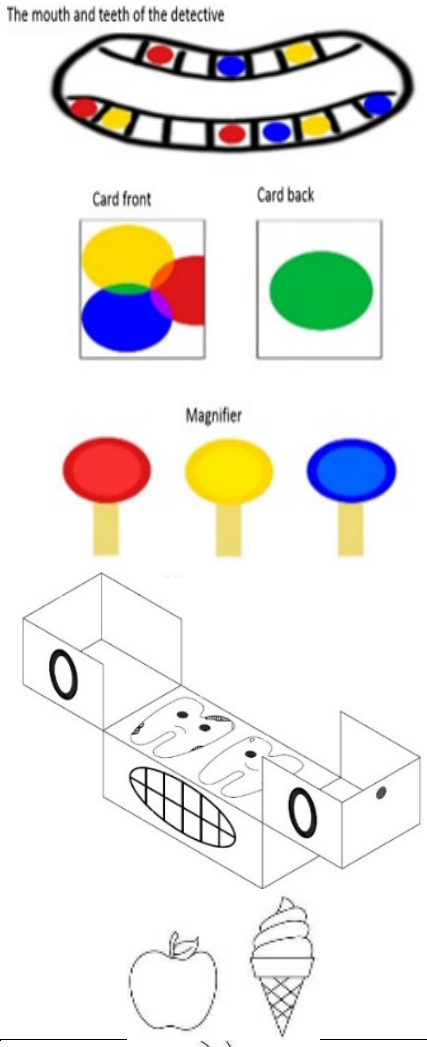
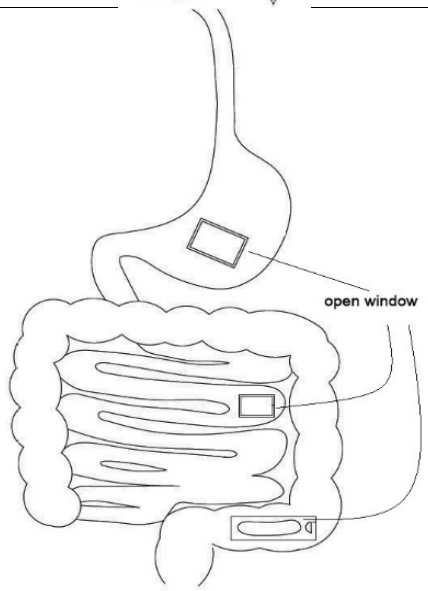
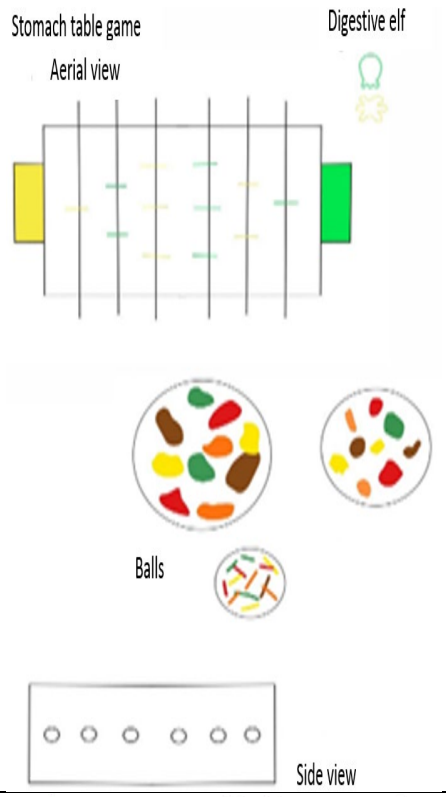
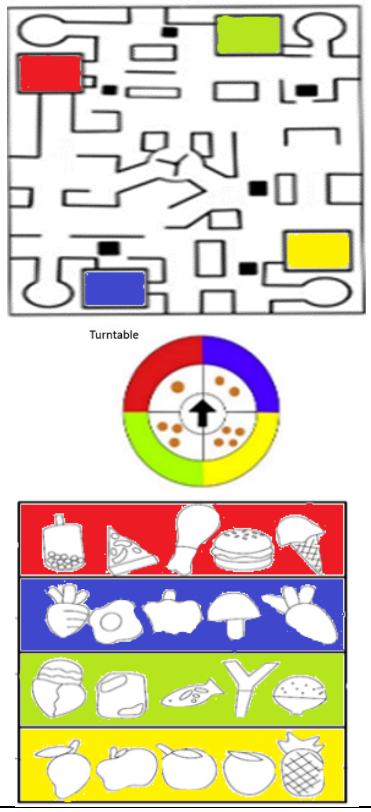
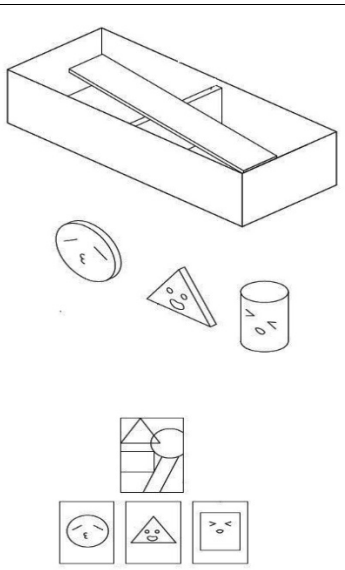
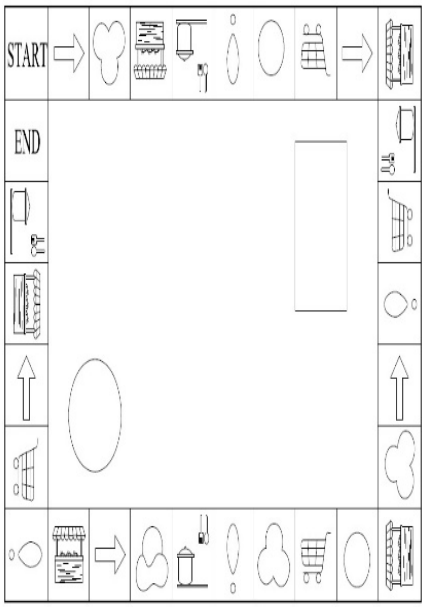
Name of Teaching Aids	Exterior Design	Design Concept
Digestive & low carb robot-detective		The overall shape of the teaching aids combines a robot and an ambulance in a transformed way. The robot's appearance mainly includes two parts, the head and the torso.
Digestive & low carb ambulance		Another appearance design of the teaching aids is the shape of an ambulance. In ambulance simulation design, there is a reflective strip on the body and a switchable ambulance warning light and sound.
Main storage		The main body is divided into five independent spaces to store individual teaching aids. Four interactive situational learning games are designed according to the functions of each part of the organs. The last game is a low-carb diet table game for more advanced learning of the concept of a low-carb diet.

Table 3. Manipulative game design and instructions.

Names of the Teaching Aids	Game Design	Game Instructions
Oral health game		1. The appearance of the robot head is designed for the oral health game. Three-colored non-woven stickers are put on the teeth to represent caries. 2. Children take turns drawing cards and put the magnifier made with glassine on caries and observe the change in tooth color. The cards contain six colored cards, including yellow, red, blue, green, orange, and purple. If the tooth color observed on the magnifier is the same as their card, they can use the clips to remove the sticker. The child who gets the most stickers in one minute is the winner. 3. The small food pictures made with non-woven material contain healthy and unhealthy food. Children put healthy food on the healthy tooth spot and vice versa. Children learn to choose healthy food instead of unhealthy food, which helps children maintain the health of the oral cavity and digestive tract.
Gut jigsaw puzzle		1. Inside the robot's clothes, there is a robot's body with a jigsaw puzzle of digestive organs. Children manipulate the spatial position of the puzzle in a jigsaw way that helps them recognize the position of the digestive organs. 2. An openable window block is designed in each organ, through which the food status in the digestive tract can be observed. This game helps children improve hand-eye coordination, imagery skills, and spatial organization.

Stomach-digestive football game		1. The game is designed as a table football game, simulating the dynamic functions of the stomach. 2. The balls in three different sizes simulate food of different sizes in digestion. The green and yellow baffles called the digestive elves, act as gastric acid and digestive enzymes, respectively, to aid in the digestion of food in the stomach. 3. When the sticks on both sides are turned, the baffle can slap the food ball to deliver the food to the lower part of the stomach. Children experience the peristalsis of the stomach and the gastric juice secreted by the cells of the stomach through the game.
Small intestine maze-the nutritional microcosm		1. This game is designed to use the nutrition maze that helps children understand the differences in nutrition between healthy and unhealthy food absorbed by the small intestine. 2. Foods are divided into four categories according to nutrition levels. The game uses a four-color turntable to determine which food group to choose and how many plush balls to get. The higher points are on the turntable, the more nutritious the food is. The task of this game is first to put the food figure into the food box at the corner of the maze corresponding to the color turned in the turntable. Then, starting at the center of the maze, a child uses a small wooden stick to transport a plush ball to the end of the circle next to the corresponding food box. The more nutritious food, the more plush balls are sent to the box. The winner is the person who gets the most plush balls in one minute. 3. This game can also train children's attention and eye-hand coordination.

Large intestine game - master of balance		1. Through three different shapes of paper clay figurines, representing good bacteria, bad bacteria, and medium bacteria, respectively. 2. Each child draws a card first and then, according to the shape on the card, picks up the figurine that matches the card, and puts it on the balance board to keep it balanced. 3. This game allows children to understand that the balance of good and bad bacteria in the intestinal flora will affect digestion and absorption as well as health.
Low-carb diet board game		1. The board game accessories include a game board, cards, and seasons vegetable/fruit book, and a shopping list. 2. Each player gets one special card to collect carbon footprint points and a shopping list to buy food. Through the game board, whoever has the least carbon footprint points or completes the shopping list first wins. 3. Children learn the concept of the low-carb diet, which is how to correctly choose local fresh and healthy food, to avoid buying processed food to reduce carbon emissions.

2.2. Data Collection and Analysis

To develop teaching aids, we used a purposeful sampling method for recruiting research subjects. We interviewed a principal and two educare givers in an experimental preschool affiliated with a university. Before the interview, the subjects were asked to sign the research consent form. We demonstrated how the "Digestive Tract Teaching Aids" operated, and the subjects played with the teaching aids. The interview was conducted in a semi-structured method to understand their experiences and feedback in using the teaching aids. We recorded audio and transcripted it to collect data and coded it to analyze the data as a reference for researchers to correct and improve the teaching aids later.

The interview outline is listed as follows.

(1) The design of the teaching aids presents the learning content of digestive organs in the form of situational games. How suitable are they for preschool children aged three to six?
(2) The teaching aids have interchangeable appearances and separate games. How about the playful function of the teaching aids?
(3) How do you think these teaching aids can improve children's motivation to learn about digestive organs?
(4) What do you think of the interactive operation function of the teaching aids?
(5) What are the advantages and disadvantages of this teaching aid regarding materials?
(6) What are the advantages and disadvantages of this teaching aid in the storage function?

(7) What needs improvement for the teaching aids, or what else would you like to suggest?

3. Results

3.1. Advantages of Teaching Aids

In terms of the findings from the teacher interview, the advantages and disadvantages of teaching aids were summarized as follows.

(1) Adaptive learning effect
It was good for children to understand the digestive tract through the interactive operation games of teaching aids. The design of teaching aids was in line with the development of children. The teaching aids were set up with different challenging tasks and had adaptive ways of playing appropriate for children with different abilities aged 2−6, which was of great help to the teachers on site.

(2) Playfulness
The creativity of the teaching aids improved various board games and made them feel more exciting and closer to children's life experiences.

(3) Learning motivation
Children's curiosity and understanding of the digestive system were enhanced and improved through playing interactive and manipulative games.

(4) Interactive operation
Each teaching aid provided an opportunity to interact with peers. Most games were played as interactive games for two or more people, suitable for companions, family members, and teachers and students to play together. If the child wanted to play alone, there were also teaching aids (e.g., puzzles) to be played alone.

(5) Lightweight and environmentally friendly materials
The material was lightweight so suitable for children to move freely. The teaching aids were made of paper, non-woven, and wood, which were environmentally friendly and non-toxic. It was safe for children to operate without worrying about injury. If a piece of the teaching aids is lost, it is convenient for the teacher to find materials to make up.

(6) Convenient storage of individual teaching aids: Each teaching aid had its own storage space.

3.2. Disadvantages of Teaching Aids

(1) Improving the storage function of the overall teaching aids
It required space when all parts of the teaching aids were assembled into the robot detective. Therefore, improving the storage function was recommended. For example, the teaching aids could be assembled into the shape of a table or a chair cabinet for convenient storage.

(2) Finding the balance of beauty and texture of the materials
Although the materials of the teaching aids were lightweight and environmentally friendly, the choice of materials needed to consider the beauty and texture of the materials.

(3) Providing child-friendly instructions
Although the teaching aids were fun to play, child-friendly instructions were necessary for children to use them independently without the assistance of adults.

According to the subjects' suggestion regarding the provision of child-friendly instruction, we wrote the instructions for the teaching aids in the form of leaflets and online videos via scanning QR codes for children's reference. The descriptions of the games based on pictures and stories and the use of visual and audio instructions helped children understand the rules of the games and increased their comprehension of the content of the digestive tract and low-carb diet.

4. Discussion

Based on the theory of intuitive teaching, we designed the teaching aids of the digestive tract, which appeared as a robot detective that could be transformed into an ambulance to attract young children's curiosity and interest. Children started with the oral health game that was close to their life experiences and then played with the names and locations of digestive organs, which was easy to understand. Children learned the dynamic functions of the digestive tract through specific games and gradually built the cognitive structure and function of the digestive tract as well as the principle of the low-carb diet in the playful context. This teaching aid linked the relationship between different digestive organs, which was also affirmed by the teachers on-site. Rowlands (2004)

stated that the use of analogies helped young children learn the digestive mechanism and functions. As the cognitive development of young children is limited, it was necessary to instruct children to comprehend and to understand the concept of the flora balance in the large intestine.

5. Conclusions

Overall, the teaching aids of the digestive tract were developmentally appropriate for young children and provided age-appropriate intuitive learning experiences for young children. The teaching aids helped young children learn the names and locations of the digestive tract. Also, children learned the concept of how the digestive tract operates and learned how to choose a healthy low-carbonate diet. The innovative outside and inside design of teaching aids had the appearance of a robot or ambulance and multiple operating functions of games integrating abstract concepts into a simulated reality for interactive learning. The diverse and rich game design enhanced children's learning motivation. Through exploring manipulative learning, children gradually built a cognition structure of the digestive tract, and their fine motor skills improved. In addition, the teaching aids provided opportunities for self-expression and socializing with peers in context. In the future, such teaching aids will be developed for a wider range of teaching applications to carefully examine the safety and durability of the materials and systematically optimize them according to users' suggestions.

6. Patents

This product was registered as a utility model patent, and the invention patent was filed, which shows the originality and novelty of this product and the research:

C.L. Tien, H.C. Lo, H.Y. Liu, & H.S. Chen (2023). Digestive System Teaching Aids. Republic of China, Utility Model No. M643674, 2023.July.11–2032.December.19.

Author Contribution: C.L. Tien developed the ideas and design frame of the teaching aids and the research, supervised this research, wrote interview questions, analyzed data, and drafted/ finalized the manuscript. H.C. Lo provided teaching aid ideas, guided product production, and drafted the manuscript. H.Y. Liu and H.S. Chen had ideas, conducted an interview, helped draft the manuscript and made the product under guidance. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The data of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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