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App-Infused Preschoolers' Storyline Concept-Driven Numerical Curriculum Design

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Abstract: For preschoolers, Apps can facilitate them to learn mathematical concepts, such as number recognition, counting, comparison, mixture problem, combination, etc. However, most of the mathematic Apps currently are drill-and-practice design which provides numerous questions and answers matching exercises for preschoolers, that leads them paying attention on doing exercises instead of concepts acquisition. We will argue that for the preschoolers, mathematical concept acquisition is more important than drill-and-practice exercises. Therefore, to response, for three to five-year-old preschoolers, we developed a mathematical concept learning App named Kid+ which aims to build up their conceptual understanding and cognitive ability. By integrating storyline design with situated learning, the preschoolers can use the App in a concept-embedded role-play story. As three preliminary preschool experts' using feedbacks, the result revealed that the App might help the preschoolers navigating through the storyline to learn the mathematical concepts embedded. However, further evaluation of preschoolers is needed.

Keywords: preschool, mathematics, gamification, conceptual awareness

1. Introduction

For preschoolers, even a two-year-old toddler can show some math abilities (Harris, 2017), but for them, mathematical learning is not just a combination of complex formulas. They may have a hard time gaining math skills, but with their parents' guidance, the more support they receive, the more learning achievement they can earn (Skwarchuk, 2009). Educational Apps are choices for the preschoolers to learn math, but most of them are not instructive enough. Only few Apps provide feedback about user's learning effectiveness, while others use the drill-and-practice strategy and only give back answers, which is relatively cheaper and easier to develop (Callaghan, 2018). Using the correct method to build study habits and a learning environment is highly recommended, even though it may not be immediately effective but will be beneficial in the future (Anders, 2012).

Recently, National Council of Teachers of Mathematics (NCTM) has categorized preschool mathematics into five standards, namely "Numbers and Operation", "Algebra", "Geometry", "Measurement", and "Data Analysis and Probability" (NCTM, 2000). At the same time, preschoolers can be grouped by ages, and their math skills would show a significant gap between each age range due to their body and brain functionality (Chang, 2015). For example, toddlers under three years old can only recognize the difference in quantity between two distinct groups but can not tell the amount. A three-year-old child can count with his fingers but can't fully understand the meaning of numbers. Children aged four years old can easily read the number of a small amounts of objects without counting, and older children will not have difficulty calculating with small numbers (Harris, 2017). In addition, Chang (2003) and Chang (2009) detailed the abilities of children between three and five years old, and records have shown that they are capable of higher-level skills involving numbering or ordinal numbers, which are proportional to age. This means that younger children may be able to count successfully but may not understand the meaning of orders or comparisons. In addition, there are principles listed for instructors to follow while students delve into math, in order to ensure

that every student has the right to education, which includes fair treatment, continuous courses that suit students' concentration, support and challenges according to their demands, assessments at proper intervals, and most importantly the use of technology to increasing students' learning capacity (Cesarone, 2008), including number sense.

Number sense is not just the ability to calculate, but the skill of converting numbers into concepts. Numbers in different positions have various definitions, including switching and adjusting numbers. "Friendliness with number" preceded number sense. It's the sense of flexibly determining whether to comprehend or compute when one sees a number (Howden, 1989). In the meanwhile, other studies define number sense as a feeling of numbers. Wilson (2009) and Dehaene (2011) claimed that humans who have acquired number sense can roughly measure amounts by simply looking at a chunk and comparing them to another at the same time. People are commonly curious about how to teach number sense. Number sense must be built on a student's own knowledge and skills. Advanced knowledge and courses based on the student's natural learning development. Afterward, the fluency in calculating should be increased and concept understanding should be strengthened. Then opportunities for exploring, problem-solving, and communicating should be given. Finally, the major way that math presents itself should be introduced to the student (Griffin, 2014).

Therefore, the goal of this research is to build up a concept-driven math learning App which has a situated storyline where the preschoolers can explore the story on tablet. To design the App, a CEO-Awareness model which represents Concept learning, Experiencing, Objects & artifacts, and Awareness was applied. The App design and the preliminary results are elaborated.

2. Method

2.1 The Concept-Experience-Object Awareness Model

Artifacts such as digital aids occupy an important position in technology education. They allow users to use, create, and understand while looking for solutions and explanations of a subject, in order to gain experience during the progress (Sundqvist, 2016). On the artifacts, the learners can learn, apply, and achieve mathematical objectives serving as activities, contents, strategies, types, purposes, tasks, resources, and principles (Bell, 1993). To facilitate the mathematical learning design, a Concept-Experience-Object Awareness (CEO-Awareness) model was proposed. Figure 1 illustrates the CEO-Awareness framework in which there are four components including Concept Learning, Experiencing, Objects & Artifacts, and Awareness.

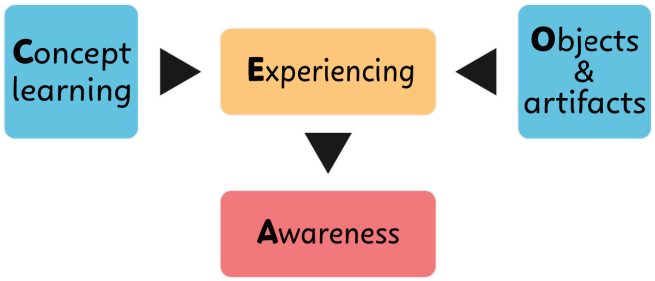

Figure 1. The Concept-Experience-Object Awareness (CEO-Awareness) model.

Technology development today makes children's cognitive skills better. The earlier the students experience multimedia devices, the more opportunities they get to think and explore. Preschoolers' math abilities with an abstract mindset would get enhancement only if the mobile learning game was well-designed (Kokkalia, 2016), and they could feel awareness by experiencing objects or artifacts afterward. As shown in Figure 1, to help the preschoolers learn concept-driven numerical curriculum systematically, an App named Kid+ is designed based on the concept of the CEO-Awareness model, which was implemented as Figure 2. In Figure 2, the "Concept" is displayed by dialogue, and several "Objects" will be displayed to assist the preschoolers to "Experience" the concept by manipulating the "Objects." Through

the activity on the App, we hope the preschoolers can aware the mathematical concepts embedded in the storyline by him/herself.

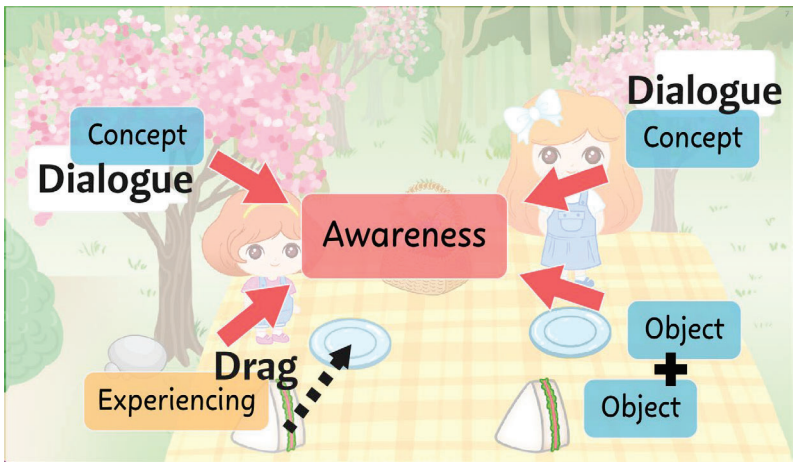

Figure 2. The CEO-Awareness model within the game.

2.2 Storyline

The story starts with a delightful morning at home. The main character, who is leading the learning content, is going on a picnic with her elder sister, assuming spending a peaceful and usual day, but it turns out facing adventures and quizzes during and after the way. The current demo of our system has ten rooms built in, including a main page, a select menu, seven stages, and a data presentation page. The seven stages contain three main concepts: number introduction in the first toward the third stage, one-to-one correspondence in the fourth and fifth, and the order of numbers in the sixth and seventh stages, which are shown as the previews for every stage with each concept in Figure 3.

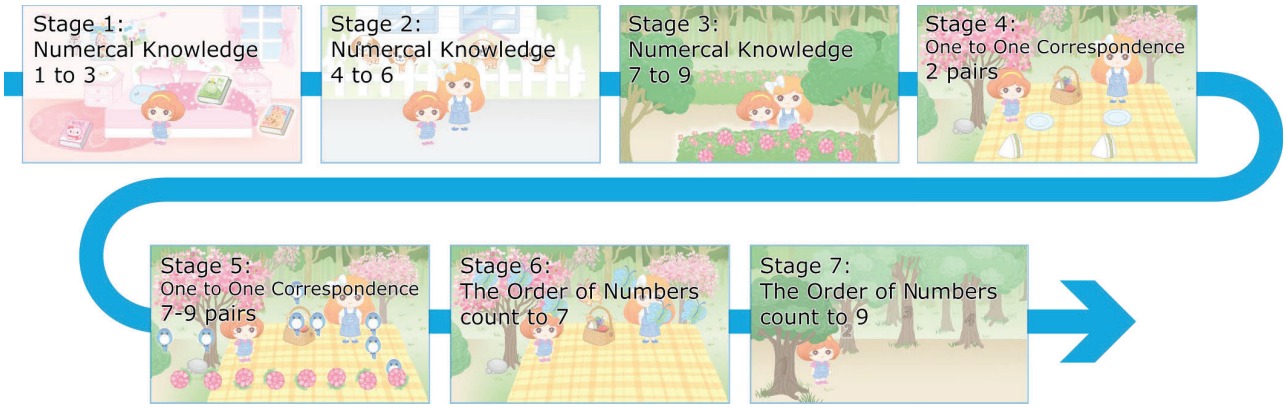

Figure 3. The previews for every stage of the game.

It is an interactive game combined with exploration and situations inspired by television programs with similar concepts such as “Dora the Explorer” and “Micky Mouse Clubhouse”. A goal, with three main lessons, would be told first at the beginning of each episode. The lessons are obstacles during the process of reaching the goal, with the main character using the word “we”, guiding audiences to progress together without just being an audience (Ryan, 2010). There are three models, observing, collecting, and delivering, that could be added repeatedly to the lesson based on the current storyline in each episode. Additionally, partners or tools would show up as assistance (e.g. Dora’s backpack, Micky’s transportable device Toodles), providing comments and hints, making the audience feel like a helpful warrior (Dietrich, 2015).

2.3 Learning Materials

Avoiding arithmetic in lessons, learning aids are integrated with must-learn concepts from preschool to lower-grade elementary school. They are presented in a specific order, assisting students in understanding and exploring on their own. The contents are arranged

according to preschoolers' learning characteristics and are laid out with terms and icons they are familiar with. Moreover, they are imported with tutorials, explanations, and summaries (Lee, 2018). The chapters are subdivided into several difficulties, starting with basic ones and then increasing in complexity step by step.

2.4 Implementation

We use GameMaker Studio 2 as the development foundation of the system and GameMaker Language (GML) as the visualized coding language. Furthermore, we choose joyful melodies as background music and higher pitch voice lines, providing more attraction and motivation for children (Sudarmilah, 2013). We also approach the composition from children's point of view (Cheng, 2021), including naivety and simple illustrations, bright pastel colors, and a 2-Dimension platformer layout.

The system was designed to operate on mobile devices, though it was built to be multi-platform. Since preschoolers have difficulty using mobile devices, we rearranged the controls to only involve touching and dragging. Besides, in order to provide more specific operations, objects that are interactable were marked with animation to indicate when they can be interacted with. However, due to the database not connecting to the system, researchers would need to manually write down the results after a user finishes all stages. Despite the inconvenience, it makes no difference without the function.

We follow the steps below to investigate the concept awareness of a participant. Conducted an initial clinic interview about the activities the participant engages in with parents indoors and outdoors. Noted the participant's preliminary knowledge of mathematics and mobile devices. Participants then began operating the system. Recorded the process and the end of the operation, including the frequency of questions asked, mistakes made, distractions during the progress, as well as the operating time of each stage and overall. Additionally, the frequency of screen touches was noted. Conducted a second clinic interview to gather feedback on the system. The surveys were modified from Keller's (2010) ARSC model to account for the cognitive abilities of preschoolers.

3. Preliminary Evaluation

The Kid+ App is still under construction but the prototype now is available for preliminary study. To collect the feedbacks from the preschool experts who have the rich experiences interacting with preschoolers, we invited two kindergarten teachers, one of whom is a kindergarten principal and the other one is a preschool teacher. Meanwhile, we also included an assistant professor who is an expert in the field of early childhood education. These experts were asked to evaluate the content in our system.

3.1 Viewpoints from the preschool principle and the teacher

Based on the teachers' years of experience, a two-year-old toddler is able to operate a tablet, even if s/he could not quite understand the meanings. The abilities of preschoolers' can also be different due to family factors. Children may have a higher learning ability while older children may easily lose patience with basic tasks. Teachers believe that the illustration styles applied in our system are suitable for preschoolers, and the scale and colors of the layout are well-balanced. The story line is well-scripted, giving users a feeling of listening to a story. They believe that students will have a high interest in the game and will be likely to replay it. The game takes about thirty to forty minutes to complete, which aligns with the schedule of their kindergarten. If a child shows interest in the system, s/he can absolutely concentrate on it for at least thirty minutes.

The teachers also mentioned that the number of preschoolers participating in an experiment can affect the results, so it is recommended that each preschooler operates the system individually. The teachers imagined that instead of being quiet, kids would have lots of questions to ask. Therefore, recording is necessary. In addition, when surveying preschoolers, it should be done orally by asking questions. Older children may have more independent

thoughts, while others may only respond with yes or now, and require more guidance. If questions need to be presented on a paper, they should be multiple choices with visual cues allowing children to respond by pointing at.

3.2 The Preschool Experts' Opinions

Since there is evidence of a gap in preschoolers' learning ability some three-year-old kids can handle math problems beyond their ages, which need to be discussed later. In the system, the professor can introduce three concepts for kids to learn, which precisely cover the basic form the numbers and operations for preschoolers. Currently, it takes three to five minutes to complete a stage, with a total of seven stages, kids would be more concentrate if each concept can be complete within seven minutes. It is proper that adding difficulties to every concept, which can serve as checkpoints or save points in the game, in case some children is impatient to stay or want to quit.

Before conducting experiments, it is essential for children to familiarize themselves with the environment, and explanations must be told beforehand. Besides, while conducting surveys with preschoolers, they may have a hard time expressing their thoughts, and could possibly forget the details. Letting children discuss the question together would provide a better opportunity for them to accurately express their feelings.

4. Discussion and Conclusion

4.1 System Operating

Kids under three would have difficulty using the system, due to their limited reading and hearing abilities, as well as their numerical knowledge is under about three. Kids between the age of three and four can operate the system smoothly, but they would need more prior knowledge before assigning objectives. For example, it would be beneficial to introduce what a sandwich is before asking them to collect sandwiches. Kids between the age of four and five are highly recommended to use and learn from the system. However, kids over five years old may feel the system too easy, resulting in potential impatience. It is suggested to add more choices, characters, images, and stages, with some aspects of the objects be modified such as scales, rotations, colors, etc. Moreover, improvements are needed in terms of animations.

Unlike the interactive and situated television programs such as "Dora the Explorer" and "Micky Mouse Clubhouse", give questions and problems during main character explores. Though they offer answers and choices simultaneously, they cannot be interacted with due to being TV programs. While playing a game, the game should provide instructions, choices and feedbacks, also, when it comes to a stage clearance, content review is unnecessary due to reciting can have a negative impact. Otherwise, it wouldn't feel like playing a game but rather listening to a lecture, and children will be bored. Also displaying a progress bar and a pause menu is important.

4.2 Concept Understanding

The "Numbers and Operation" concept in our system seems to be too easy for children above the age of four, making it more suitable for children under four to operate and learn from. However, there are always some differences between them. We expect preschoolers who use our system can achieve effective learning outcomes in the early "Numbers and Operation" concept, and understand the three concepts in the game: counting, one-to-one correspondence, and the order of numbers. In traditional school settings, the three concepts are taught through students writing down the number or representing the quantities. Nevertheless, with the system, students can learn through the simultaneous presentation of numbers, patterns, and sounds, which is more efficient and facilitates their comprehension of the concepts.

4.3 Awareness

The system was designed for mobile devices, by arranging the content for preschoolers. We expect to increase children's interest, so they can continue learning outside of school. Learning math is like learning language; it needs lots of efforts and time. The more parents and teachers engage preschoolers in math practice, the better their math abilities and motivation will become. This, in turn, enable them to develop number sense and unlock their potential in math for the future. Therefore, we expect preschoolers to develop self-awareness while learning concepts. Even without the presence of their parents, they can engage in mobile learning using a mobile device. By telling the story and showing hints constantly, we aim to reinforcing their ability to grasp the concepts they have learned. Figure 3 illustrates the concept awareness within the game This approach enables preschoolers to apply the knowledge when eventually go to school.

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