How to Support Fraction Learning with Math Game “Run Fraction”: Theory, Design and Application

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Abstract: Though fraction knowledge is critical for Math learning, fraction learning is still challenging for both teachers and students in many countries. Some game-based interventions can be designed to help children learn fraction knowledge. In order to better understand the strengths of game-based learning, we establish a framework of game-based experiences based on learning theories and cognition theories. Based on some related theories, a fraction game “Run Fraction” has been designed to help children to learn fraction conceptual knowledge. Further, a quasi-experiment has been conducted to investigate the effect of using fraction game in Mathematic setting.

Keywords: Game-based Learning, Fraction Learning, Learning Theories, Serious Games, Design-based Learning

Compared with other educational technologies that can support learning, game-based learning provides more pleasant learning experiences for students. The establishment of the framework of game-based learning experiences based on learning theories and cognition theories would greatly improve the understanding of the educational values of game-based learning, and support the theory-driven game design. The core emphases of authentic learning theory, experiential learning theory, and generative learning theory have been analyzed. There are three emphases in authentic learning environment theory: a. Cognitively real learning environment, b. Instruction and collaboration, c. Engagement, reflection and expression. Experiential Learning Theory view learning as a continual process based on experience, instead of a result, and highly valued the human beings’ interaction with the environment. The core ideas of generative learning theory can be pointed out based on the four steps in Wittrock’s generative learning model: a. learners’ attitude, interest and cognitive strategies greatly influence learners’ attention and memory; b. the connection of learners’ past experience and new knowledge should be build; c. both teachers and students are in the center status. Based on the analysis above the framework of learning experience is established and we generate three types of learning experiences: cognitive experience based on context, social-interactive experience based on collaboration, and agentic experience based on motivation. With regard to the cognitive experience based on context, game-based learning provides a cognitively real learning environment, in which learners can gain tacit knowledge and embodied learning. The social-interactive experience based on collaboration includes the interaction between teacher and students and among learners. Motivation is primarily important in the agentic experience, and students also need to make reflection upon their learning process. Further, some cognition theories that help to understanding the values of game-based learning have been analyzed within this framework.

As a significant Mathematical concept in daily life, fractions are crucial for later success in Math learning. From the perspective of numerical development (Siegler and Lortie-Forgues, 2014), which is a process of broadening the set of numbers and requires children to accurately represent the magnitude of numbers, the learning of fraction expands the category of children’s understanding of number from whole number to rational numbers. The game “Run Fraction” has been designed to improve children’s learning experiences with fraction learning (see Figure 1). First, based on Sigler’s integrated theory of numerical development (Siegler, Thompson, &

Schneider, 2011), a number line has been adopted in this game as the cognition scaffolding. Number line has been regarded useful to improve children's understanding of the magnitude of numbers (Hamdan & Gunderson, 2017). There are two meaningful interpretations of the conceptual meaning of fractions with regard to its rational quantity (Hecht, Close, & Santisi, 2003). The first understanding of fraction number is based on the relationship of part-and-whole, which refers that the fraction could present a part of the whole object (Ni & Zhou, 2005). Children could have the experience of sharing during kindergarten. The second type of understanding, the measurement interpretation, means "fractions can be understood as measured quantities that can be compared on the basis of ordinal size" (Hech, 1998). The number line has been applied to improve children's understanding of the measurement interpretation (Siegler, Thompson, & Schneider (2011); Booth & Siegler (2006). Some embodied learning elements could also be found in this game, in which children can control the avatar's position with their figures. From the perspective of motivation theories, the designers of this game also referred to the intrinsic motivation and extrinsic motivation theories. Players are provided with the opportunity to choose the avatar and the level to begin with (see Figure 2). In this game, the number line appears with the form of a wall, and the avatar's sight is blocked, which creates a sense of curiosity and encourages the player to explore further. A system of reward and ranking has been designed aiming to maintain motivation (see Figure 3). In order to guarantee the knowledge transfer from the game setting into the formal learning setting, test items have been made embedded in the game, and children need to complete these items otherwise they cannot move to the next level (see Figure 4).

Figure 1. Run Fraction Game

Figure 2. The interface of levels choice

Figure 3. Reward system of the game

Figure 4. Test item

In order to investigate whether this fraction game can improve children's knowledge on fraction magnitude understanding, we conducted a quasi-experiment in a primary school in Beijing. Six classes from Grade 4 and Grade 5 participated in the experiment. In each grade, the students in Class A spent 20 mins each day in playing this fraction game (5 days in total). Students in Class B spent 20mins in doing pencil and paper test (5 days in total). And students in Class C watched an instruction video (about 20mins) each day (5 days in total) for the control purpose. The results will be presented on the conference.

Acknowledgement

This study is based on the project "Study of Game-based Learning from the Perspective of Learning Sciences", which belongs to the 2017 General Projects of Educational Research for the 13th Five-year Plan and was financed by China National Social Science Foundation NO. BCA170072.

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