Educational game themes of a fraction brick game

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A digital game of fractions has been developed to compare the sizes of fractions using learning objectives that order fractions. The context of the game is about forming staircases of fraction bricks for players to climb to the top of a tower. The fraction bricks represent sizes of fractions and are labelled with symbols of fractions. Tall bricks are used to order fractions from smallest to largest while long bricks are used to order fractions from largest to smallest. Three game themes are proposed to experience fractions from concrete to abstract: visible bricks are blocks representing sizes of fractions that can be seen; broken bricks are blocks divided in part that can be separated into visible fractions ; hidden bricks are blocks with only symbols of fractions labelled on them. The game has been tested with Year 8 students to confirm the appropriateness of the game themes for learning fractions so that the game can be improved. This study focused on the number of attempts made by students to order fractions at every level of the game. The findings confirmed that the game is increasingly challenging because the attempts increased monotonically across the game themes of visible, broken and hidden bricks. However, the attempts were not monotonically increasing across the levels within the same game themes although fractions were designed to be increasingly difficult and required more complicated strategies. This study provides a background to further investigate the learning of fractions occurring in playing the game.

Keywords: Ordering fractions, educational games

A fraction brick game

Order and equivalence are basic to and critical for the understanding of fractions (Smith, 1995; Behr, Wachsmuth, Post & Lesh, 1984; Streefland, 1993). A game of fractions has been designed particularly for comparing sizes of fractions to enhance the understanding of order of fractions. The learning objectives include ordering fractions from smallest to largest and from largest to smallest. The goal of the game is to form staircases using fraction bricks, which represent sizes of fractions and are labelled with symbols of fractions. The game intrinsically integrates game ideas with the content of fractions using game themes of visible, broken and hidden bricks. The purpose of this study was to confirm the appropriateness of the game themes for learning fractions so that the game can be improved. The aim of the game is to create an interesting learning environment for students to refine and practice their understanding of fractions after learning from teachers.

Basic maths game model

Before developing the digital game, a basic maths game model was developed to integrate instructional factors of mathematics games (Booker, 2000, 2004) and game elements (Prensky, 2001). The instructional games in mathematics learning considered conceptual analysis of fractions, students' misconceptions, game structure, instructional strategies, student methods and thinking, and relationship of the game to the New Zealand mathematics curriculum. The six key game elements (Prensky, 2001) are story, rules, goals and objectives, outcomes and feedback, conflict/challenge and interaction.

The model was tested with a group of Year 8 students using a manipulative tool of fraction cards in a pilot study (Lee, 2007). The findings of the study showed that students with different mathematical abilities have different concerns with respect to the fraction game. Their concerns were incorporated into the model in order to develop an instructional game that could fulfil different learning needs. The game could include fractions in a range of different difficulty levels and provide teaching of fractions to overcome misconceptions and difficulties with fractions especially to below average students.

Digital game outputs

The game focuses on the topic of comparing fraction sizes. This is a critical aspect of fractions to school children as well as a key area of knowledge in the New Zealand mathematics curriculum. The relevant content is included into the game to inform teachers and parents about the curriculum behind the game.

The story of the game is about a boy who is lost in the woods and wants to see the way home from the top of a tower. The goal of the game is to form and step up fraction brick staircases in order to reach the top of the tower. Fraction bricks are bricks that represent sizes of fractions and are labelled with symbols of fractions. The rules of the game are to order tall (vertical) fraction bricks (Figure 1) from smallest to largest and long (horizontal) fraction bricks from largest to smallest (Figure 2).

Visible bricks

Visible bricks like tall (Figure 1) and long bricks (Figure 2) are used to represent sizes of fractions. Labelled with mathematical notations like one half and two halves, the bricks enable students to connect symbols of one half with the size of half. Nevertheless, students could play the game without thinking hard because the visible bricks allow them to compare fractions in a concrete way.

Figure 1: Visible tall bricks

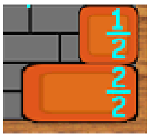

Figure 2: Visible long bricks

Broken bricks

Dividing an object into half is an informal knowledge of fractions gained by children before entering school. Therefore, dividing a circular diagram is often used by teachers to introduce and teach fractions in the classroom. These diagrams are called divided quantity diagrams. A divided quantity diagram shows on paper an object divided into equal parts. Like the divided quantity diagram, broken bricks (Figure 3) are made up from blue and red parts. Players are asked to "select the blue part of each brick to build a staircase". The broken bricks are manipulable and the symbol of each part changes according to the size of the parts selected. For example, the symbol of every part of half is one half and changes to two halves when two parts of half are selected. Splitting the selected blue parts from the whole, provides limited opportunities for children to engage with representation, a key in assisting children build conceptual knowledge in fractions (Kafai, Franke & Battey, 2002). In addition, embedded with equal whole and equal parts concepts, broken bricks allow players to compare the sizes of fractions with different denominators. This is especially important to overcome the typical error in children's drawing that the size of the whole for each fraction is in proportion to the size of the denominator (Yoshida & Kuriyama, 1995).

Figure 3: Broken tall fraction bricks

Hidden bricks

Only fraction symbols but no sizes are displayed on hidden bricks (Figure 4). These bricks do not become visible until after players have placed them in an order. This is harder than previous game themes in that students have to interpret fraction symbols and judge the sizes of fractions independently on the mathematical notation.

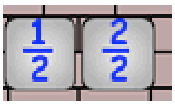

Figure 4: Hidden tall fraction bricks

The fractions of one half and two halves are used to introduce fraction bricks in each of the tall, long, visible, broken or hidden forms because of their simple nature. The aim here is to use well known fractions while the students get familiar with the new concepts of visible, broken and hidden bricks.

Research methodology

A class of twenty-seven Year 8 students from an intermediate school in Dunedin participated in the study. There were fifteen males and twelve females. The Year 8 students had been learning fractions since Year 1. They started with a half, a quarter, a third and a fifth of a given shape or set of objects. Later, they also learned about equivalent fractions, and converting between fractions, decimals and percentages. The knowledge of fractions they learned in class was required as a basis for playing the game of fractions.

The study was conducted during school hours. Each student spent approximately an hour to complete pre and post maths tasks, pre and post quizzes, questionnaires and the fraction brick game. The maths tasks asked students to order fractions and give their reasoning while the quizzes were multiple choice questions. The learning of fractions could be identified from changes of reasoning of pre and post maths tasks and achievement differences between pre and post quizzes. The feedback of students about the game and learning fractions using the game was investigated from their responses in the questionnaires. This study focused particularly on the data of game play recorded on computers. User data is produced from the game played and contains attempts at every level, which are the numbers of trials to obtain a correct ordering. For example, 3 attempts mean that the orderings were wrong for the first and second attempts and right for the third attempt.

Results

Attempts across game themes

The data of game play was categorised into game levels of introduction (100, 110, 200 and 300), visible bricks (101, 102, 201 and 202), broken bricks (111, 112, 113, 114, 211, 212, 213, 214 and 215) and hidden bricks (301, 302, 303, 304, 311, 312, 313, 314 and 315) (Table 1). The mean attempts were obtained from the number of trials of 26 students (one did not complete the study) at every game level. The smallest mean attempts were made at the game levels of visible bricks (mean game levels = 1.02). The most attempts were made at the game levels of introduction (mean game levels = 1.44) and hidden bricks (mean game levels = 1.56). The attempts increased monotonically from visible bricks (mean game levels = 1.02) to broken bricks (mean game levels = 1.12) and hidden bricks (mean game levels = 1.56). The mean game levels of hidden bricks were higher than the mean game levels of broken bricks although the same fractions were used at both levels. For example, the fractions one eight, one quarter, one half were used at level 112 for tall broken bricks and level 302 for tall hidden bricks.

Attempts across levels within the game theme

The attempts did not increase monotonically across levels within the game themes. At the game theme of tall broken bricks, the mean attempt (1.18) made at level 112 was the highest among levels 111, 113 and 114. Similarly, at the game theme of tall hidden bricks, the mean attempt (1.32) made at level 302 was the highest among levels 301, 303 and 304. Since the questions of fractions asked at levels 111 to 114 were also asked at levels 301 to 304, the fractions used at levels 112 and 302 could be more difficult for students to compare and order. Likewise, the fractions used at levels 214 and 215, and repeatedly used at levels 314 and 315, could be more difficult to compare and order when the mean attempts made (214 and 215 = 1.27; 314 = 2.09 and 315 = 2.86) were the highest among other levels within the same game themes of long broken and hidden bricks.

Table 1: Mean attempts at game themes of visible, broken and hidden bricks

Game levels of introduction	Visible tall bricks		Broken tall long		Long visible bricks		Tall hidden bricks			Mean game levels
	100		110		200		300			
Mean attempts	1.45		1.77		1.18		1.36			1.44
Game levels of visible bricks	Tall visible bricks				Long visible bricks					Mean game levels
	101		102		201		202			
Mean attempts	1.05		1.00		1.00		1.05			1.02
Game levels of broken bricks	Tall broken bricks				Long broken bricks					Mean game levels
	111	112	113	114	211	212	213	214	215	
Mean attempts	1.14	1.18	1.00	1.00	1.00	1.14	1.05	1.27	1.27	1.12
Game levels of hidden bricks	Tall hidden bricks				Long hidden bricks					Mean game levels
	301	302	303	304	311	312	313	314	315	
Mean attempts	1.27	1.32	1.23	1.05	1.55	1.36	1.32	2.09	2.86	1.56

Conclusions

Educational game themes of visible, broken and hidden bricks were designed for students to experience fractions from concrete to abstract in the game context of fraction bricks staircases. Visible bricks enable students to visualise representations of fractions; broken bricks are used to manipulate parts of fractions in divided quantity strategy; hidden bricks required students to interpret symbols of fractions. The monotonically increasing attempts across game themes confirmed that visible, broken and hidden bricks were increasingly challenging. The comprehension of students of the relations between manipulative and abstract mathematical symbols needs to be guided and constrained by the instruction (Uttal, 1997). The computer is not only able to link active experience with objects to symbolic representations, computer manipulation may be even more manageable, clean, flexible and extensible than physical objects (Clements, 1999). On the other hand, the attempts were not increasing across the levels within the same game themes. Further investigation is needed to focus on the characteristics of fractions that increase the difficulties of fractions to be compared and ordered, including like and unlike denominators, even and odd denominators, magnitudes of fractions, number of fractions in a question, fractions with similar sizes, and ordering strategies such as divided quantity diagram, numerical conversion (convert fractions into decimals or percentages), common denominators and reference points.

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