OPEN ACCESS
EURASIA Journal of Mathematics Science and Technology Education
ISSN 1305-8223 (online) 1305-8215 (print)
2017 13(4):1075-1083
DOI 10.12973/eurasia.2017.00659a

Role-Playing Game Based Assessment to Fractional Concept in Second Grade Mathematics

Fu-Yuan Chiu
National Tsing Hua University, TAIWAN
Mei-Ling Hsieh
National Tsing Hua University, TAIWAN

Received 27 July 2016 ▪ Revised 12 September 2016 ▪ Accepted 16 September 2016

ABSTRACT
This study developed a set of Role-playing game (RPG), which was used to explore whether significant differences exist in academic performance and learning attitudes between RPG-based assessment and traditional lectures. This study also investigated the satisfaction of students toward the RPG scenario. Research participants included 100 second grade elementary students. The experimental results showed the different teaching methods affected the academic performance and learning attitude of second grade elementary students in fraction concepts. Learning by using RPG-based assessment can effectively improve the academic performance and learning attitudes of students. Students with high learning achievement were most satisfied with the RPG-based assessment scenarios, whereas those with low learning achievement demonstrated low levels of satisfaction. It is hoped that the innovative learning method provided by this study will help students.
Keywords: game-based assessment, mathematics education, role-playing game, second grade.

INTRODUCTION

Digital game based learning (DGBL) has become an educational trend in the information age (All, Castellar, & Looy, 2015; Vandercruysse et al., 2016), among game based assessment is most popular of students and teachers (Tsai, Tsai, & Lin, 2015). Nevertheless, a more realistic presentation equipment, such as a head-mounted display (HMD) (e.g. Oculus Rift with, HTC Viva, Google cardboard, Samsung Gear VR, LeapMotion, and Virtuix-round) (Kuliga et al., 2015) began to apply in education (Borthwick et al., 2015), along with visualizing, experimenting, experiencing and other VR (virtual reality) advantage (Buń et al., 2015), role-playing games (RPGs) have the most potential for development. In RPGs, players are able to control avatars in time and space, assume different roles, and perform various tasks. Moreover, new 3D technology produces images that are more realistic and allows individuals to become immersed more easily in digital content (Maratou, Chatzidaki, & Xenos, 2016). Therefore, its application in education increases students' sense of participation

Correspondence: Fu-Yuan Chiu, *No.521, Nan-Da Rd., Hsinchu City 30014, Taiwan, R.O.C.*
chiu.fy@mx.nthu.edu.tw

State of the literature

- Sections on RPG in DGBL literature were extracted for discussion. The literature verified that allowing students to complete tasks via role playing in VR (virtual reality) could become a novel assessment method.
- Some studies have shown that the understanding of fraction concepts plays a key role in students' mathematical learning. Hence, educational materials that are based on students' cognitive abilities should be developed in order to establish a good mathematical foundation.

Contribution of this paper to the literature

- In this study, the progress of students before and after RPG-based assessment was examined in six dimensions: "learning attitude," "anxiety," "self-efficacy," "acceptance of digital convenience," "flexibility of e-learning curriculum," and "e-learning satisfaction."
- Not only can RPG-based assessment be regarded as an entertainment game, but it can also assist academic performance in the same way that traditional teaching methods support learning.
- The main contribution of this article is to verify that RPG-based assessment is effective, enjoyable, and able to reduce the stress associated with learning mathematics.

and supports effective learning (Shih et al., 2010). As the RPG background can be set in ancient times or in foreign countries, it has been applied in learning activities related to history (Chua, Yang, & Chen, 2015) and foreign languages (Cornillie, Clarebout, & Desmet, 2012). Compared with other types of games, the requirement in RPGs to complete certain tasks in order to advance to the next level effectively enables students to acquire problem-solving abilities (Liu et al., 2014). Psychological researchs on mathematics learning were mostly chosen young adult and less in Early Elementary School (Ramirez et al., 2013), however, the low-grade math unit such as "fractional" requires a prior understanding of "integer" operations (Empson, 1999), and it is a bridge to subsequent stages, such as "decimals", "ratios", "arithmetic", and so on (Behr et el., 1992). Therefore, acquiring an understanding of fraction concepts has been regarded by many teachers as the most serious obstacle in the mathematical learning process (Liu et al., 2013). If teaching is not developed based on students' life experiences, then elementary students will have difficulty grasping concepts of abstract symbols, which could lead to problems in mathematical learning during high school (Watt & Therrien, 2016). Hence, teaching the fractional concept at the elementary level is a topic worthy of discussion. According to the cognitive developmental theory, the concrete operational stage characterizes the level of elementary school students. At this stage, their thinking has greater flexibility, and hands-on operations involving concrete objects can assist them in understanding mathematical knowledge (Wubbena, 2013). Hence, changing mathematical symbols in fraction tests to scenarios in daily life—such as "If you share a bag of sweets with your classmate, how many sweets will your classmate get?" or "How to cut a watermelon divided equally among four people?" - will help students gain a

better understanding of the test questions (Behr et al., 1992). However, compared to the real world, students operate in the virtual world will reduce costs (e.g. buy candy and watermelon) and improve security (e.g. cut watermelon with a knife) (Johnson & Levine, 2008), and finally, the RPG developed in this study can be applied to complete tasks, such as sharing sweets or cutting watermelon, in order to achieve the aim of performing concrete operations.

MATERIAL AND METHODS

The aim of this study was to investigate whether the use of RPG-based assessment activities in the classroom could be more effective than traditional lectures (Review each question wrong place) for improving the academic performance and learning attitudes of second grade (elementary) students. Additionally, the satisfaction level of students after their participation in RPG-based assessment activities was explored.

A quasi-experimental design was employed in this study to investigate the use of RPG-based assessment activities and traditional lectures methodology with elementary school students. One hundred second grade students from the same school participated in this experiment, with 50 participants each assigned to the experimental group and control group. In terms of the independent variables, the experimental group engaged in RPG-based assessment in the computer classroom, where each student was provided with a computer. Traditional lectures methodology was employed for the control group in this teaching experiment. In this passive teaching method, the teacher typically explains the unit content according to the textbook, with students listening at their seats. Teaching tools, such as the blackboard or flash cards, are used. In terms of dependent variables, academic performance refers to the pre- and post-test results of a self-compiled test regarding mathematical academic performance. To establish expert validity, this test was reviewed by a university professor and three experienced elementary school teachers from our school. Suitability of the content was assessed and some items were revised. Then, a pre-test was administered to 27 third grade students who had already studied the module; items with a discrimination index above 0.25 were retained. Finally, internal consistency was tested, resulting in Cronbach's α of 0.892—a measurement validating that the test could be used formally. In terms of learning attitude, the proposed "Probability Learning Attitude Scale" by Tan et al. (2011) were modified to give the "Fractional Learning Attitude Scale" that was adopted in this study. As mentioned previously, it includes five dimensions in sequence: learning attitude, learning interest, learning concepts, learning anxiety, and learning confidence. The Learning Attitude Scale was scored using a Likert five-point scale, with a higher score indicating a more positive learning attitude. As for satisfaction with the learning environment, the proposal entitled "Key Factors Influencing Students' E-Learning Satisfaction" (Sun et al., 2008) was modified to an "RPG-based assessment Satisfaction Questionnaire" with the following six dimensions: "attitude," "anxiety," "self-efficacy," " acceptance of digital convenience," "flexibility of RPG-based assessment curriculum," and

"RPG-based assessment satisfaction." A Likert five-point scale was used, and a higher score indicated a higher satisfaction toward the learning system. Among the control variables, the teaching duration for both groups was three classes (a total of 120 minutes); other variables, such as school grade, teaching progress, teacher, and educational material, were the same for both groups.

Data collection

The framework of the experimental design is shown in **Table 1.** which shows the symbols represent the following: A represents the academic performance pre-test performed before the experiment; A1 represents the academic performance post-test performed after the experiment; B represents the learning attitude scale pre-test; and B1 represents the learning attitude scale post-test. O indicates that the group received RPG-based assessment; X indicates that the group did not receive RPG-based assessment; and C refers to completion of the RPG-based assessment Satisfaction Questionnaire after the experiment.

Table 1. The framework of the experimental design

	Control group	Experimental group
academic performance pre-test	A	A
learning attitude scale pre-test	B	B
experimental treatment	X	O
academic performance post-test	A1	A1
learning attitude scale pre-test	B1	B1
RPG-based assessment Satisfaction Questionnaire		C

Data analysis

Before the formal experiment, homogeneity testing was performed on the academic performance of the experimental and control groups, and the result was not significant ($F = -0.66$, $p = .797 > .05$). This finding indicates that an understanding of fraction concepts for both groups was similar at the pre-test phase; thus, the next step of the experiment could be carried out. Similarly, this study performed the "paired samples t-test" for analyzing whether there were significant differences in the "learning attitude" of the two groups of students. Lastly, the study divided the students in the experimental group based on their achievement test posttest results, where students with the top 27% and bottom 27% scores were grouped into the high score and low score groups, respectively. The total number of students in the high score group, the low score group, and the medium score group were 12, 12, and 26, respectively. A covariance (ANCOVA) analysis was then conducted to analyze the differences among students with different learning achievements in the satisfaction survey on RPG-based assessment.

Intervention

The RPG-based assessment gaming software developed by Unity 3D. Users played virtual characters in the game while mission tips were provided by virtual instructors shown at the bottom of the screen. The virtual characters' movements were controlled by the arrow keys on the keyboard, while the mouse was used to change the viewing direction (**Figure 1.a**). Once a target object was found, it could be selected using a single left click on the mouse (**Figure 1.b**) and the object could be moved while holding down the left button of the mouse (**Figure 1.c**). Once the target object was moved to the designated location, releasing the left mouse button would drop the object and thus complete the mission (**Figure 1.d**). The entire game designed the textbook contents into 10 game levels (show in **Table 2.**), and the completion of a level signified the mastering of a concept of the fraction unit.

(a) Search target in the scene

(b) Select the correct part

(c) Drag to the designated area

(d) Mission accomplished

Figure 1. The interface of RPG-based assessment gaming software

Table 2. The 10 game levels from assessment target

Game levels	Assessment target
Round 1	Understand the concept of half and bisected
Round 2	Understand the aliquot concept
Round 3	Understand the concept of fractional (denominator < 12)
Round 4	Splitting into equal parts or groups
Round 5	Understand half means 1/2
Round 6	Understand the concept of Part / Total
Round 7	What the numerator and denominator of Part / Total
Round 8	Compare two fractions which large which small
Round 9	Compare two fractions which large which small when different denominator
Round 10	Understand the concept of discrete quantity and continuous quantity

RESULTS

The pretest and posttest data of the academic performance and learning attitude of the experimental group and the control group are shown in **Table 3.** Results of the "paired samples t-test" analysis showed significant difference (p<.001) between the groups in both academic performance and learning attitude. In terms of progress, the experimental group showed significant progress in academic performance and learning attitude compared with the control group. The control group, on the contrary, showed almost no differences in learning attitude between the pretest and posttest. This indicated that the application of RPG-based assessment was effective in promoting significant progress in academic performance and learning attitude.

Table 3. The pretest and posttest data of the academic performance and learning attitude

Item	Control group n=50			Experimental group n=50			Difference	T test
	pre-test (%)	post-test (%)	Progress (%)	pre-test (%)	post-test (%)	Progress (%)	2 group (%)	*p*
Academic performance	37.68	66.48	28.80	41.28	82.40	41.12	12.32	.000***
Learning attitude	56.36	57.24	0.88	57.46	74.81	17.35	16.47	.000***

***P < .001

As for the analyses of the satisfaction survey on RPG-based assessment, students in the experimental group rated the various subcategories with high satisfactory scores of above 3.9. This study further divided students in the experimental group into the high score group (top 27%), medium score group, and low score group (bottom 27%) based on their posttest results for achievement test. The results of the covariant analysis are illustrated in **Table 4.** The results showed significant difference in learning attitude (p<.01) and learning anxiety (p<.05), indicating that students with different academic achievements differed significantly in their learning attitude and learning anxiety, while their opinion on other subcategories were consistent.

Table 4. The results of the satisfaction survey on RPG-based assessment

Item	overall		Different Learning Achievement ANCOVA	
	Average	Standard Deviation	*F*	*P*
Attitude	4.15	1.421	7.543	.001**
Anxiety	3.9	1.437	4.184	.021*
Self-efficacy	4.22	1.321	2.941	.063
Acceptance of digital convenience	4.04	1.444	2.471	.095
Flexibility of RPG-based assessment curriculum	4.16	1.394	1.749	.185
RPG-based assessment satisfaction	4.68	0.783	1.402	.256

*$P < .05$, **$P < .01$

DISCUSSION

The study discussed three aspects. First, in terms of academic performance, the data and interviews revealed that compared with the traditional method of narrative learning, the content of RPG-based assessment was more lively and interesting, through which a dynamic learning environment was created with the use of sound, and animation and interaction; such an environment provides students the opportunity to proactively engaged in learning to reduce their anxiety in learning mathematics and increase their willingness to learn, which in turn helped them improve their academic performance. In terms of learning attitude, the control group also underwent the same traditional narrative learning before participating in the experiment; therefore, the pretest and posttest results of their learning attitude were almost the same, whereas the experimental group displayed significant differences; this confirmed the feasibility of this study in terms of learning attitude. Lastly, in terms of the level of satisfaction toward RPG-based assessment, the overall direction was affirmative; however, more in-depth analysis conducted on the high score, medium score, and low score groups revealed significant differences in learning attitude and learning anxiety among the three subgroups. Interviews revealed that the initial cognitive load for the mathematical fraction concept was positive among students in the high score group, and the use of RPG-based assessment made the learning content more interesting. Therefore, the learning attitude items were rated very high comparatively, the initial cognitive load for the mathematical fraction concept may have been positive among students in the low score group. Although the use of RPG-based assessment made the learning content more interesting, students in this group made several mistakes before they could complete the mission. Factors, such as frustration and the loss of confidence, had therefore resulted in the difference in the learning attitude items. In terms of learning anxiety, the significant difference between students in the high score and low score groups may be a result of family factors, as most of the students in the high score group were very familiar with computer operations compared with students in the low score group who had limited experience using computers.

CONCLUSION

Following observation of and reflection on the entire experiment, this study found that most of the students regarded RPG-Based learning as refreshing, exciting, and adventurous. As indicated in the literature (Shih et al., 2010), they thought that it possessed the characteristics of self-learning and was capable of stimulating interest for learning. For some students with low achievement, such an innovative way of conducting classes changed their view toward mathematics class, such that they found mathematics lessons to be more enjoyable and interesting. Compared with the more entertaining RPG, RPG-based assessment was designed based on the content of textbooks, so that students could master mathematical concepts after learning and achieve actual learning through playing. On the other hand, RPG-based assessment required each student to have a computer, which was a major challenge for teachers and required thorough planning for various unanticipated challenges. Further, the 3D game look very realistic (Maratou, Chatzidaki, & Xenos, 2016), students may become over excited during RPG-based assessment, teachers need to specify class rules to manage the order of classes. It is hoped that the innovative learning method provided by this study will make learning contents more vivid, lively, and interesting, in order to help change students' learning attitude and reduce their learning pressure, thereby helping toward enhancing their liking for mathematics and capabilities to a higher level.

ACKNOWLEDGEMENTS

This study was supported by the Ministry of Science and Technology (Project Number: MOST 104-2420-H-134 -004 -MY3 and MOST 103-2511-S-134-009).

REFERENCES

All, A., Castellar, E. P. N., & Looy, J. V. (2015). Towards a conceptual framework for assessing the effectiveness of digital game-based learning. *Computers & Education, 88*, 29-37

Behr, M., Harel, G., Post, T., & Lesh, R. (1992). Rational number, ratio and proportion. In D. Grouws (Ed.), *Handbook on research of teaching and learning* (pp. 296-333). New York: McMillan.

Borthwick, A. C., Anderson, C. L., Finsness, E. S. & Foulger, T. S. (2015). Special Article Personal Wearable Technologies in Education: Value or Villain? *Journal of Digital Learning in Teacher Education, 31*(3), 85-92.

Buń, p., Górski, F., Wichniarek, R., Kuczko, W., Hamrol, A., & Zawadzki, P. (2015). Application of Professional and Low-cost Head Mounted Devices in Immersive Educational Application. *Procedia Computer Science, 75*, 173-181.

Chua, H. C., Yang, K. H., & Chen, J. H. (2015). A time sequence-oriented concept map approach to developing educational computer games for history courses. Interactive *Learning Environments, 23*(2), 212-229.

Cornillie, F., Clarebout, G., & Desmet, P. (2012). The role of feedback in foreign language learning through digital role playing games. *Procedia - Social and Behavioral Sciences, 34*, 49-53

Empson, S. B. (1999). Equal Sharing and Shared Meaning: The Development of Fraction Concepts in a First-Grade Classroom. *Cognition and Instruction, 17*(3), 283-342.

Johnson L. F., & Levine, A. H. (2008). Virtual Worlds: Inherently Immersive, Highly Social Learning Spaces, *Theory into Practice, 47*(2), 161-170.

Kuliga, S. F., Thrash, T., Dalton, R. C., & Hölscher, C. (2015). Virtual reality as an empirical research tool - Exploring user experience in a real building and a corresponding virtual model. *Computers, Environment and Urban Systems, 54*, 363-375.

Liu, C., Xin, Z., Lin, C., & Thompson, C. A. (2013). Children's mental representation when comparing fractions with common numerators. *Educational Psychology, 33*(2), 175-191.

Liu, M., Rosenblum, J. A., Horton, L., & Kang, J. (2014). Designing Science Learning with Game-Based Approaches. Computers in the Schools: *Interdisciplinary Journal of Practice, Theory, and Applied Research, 31*(1-2), 84-102.

Maratou, V., Chatzidaki, E., & Xenos, M. (2016). Enhance learning on software project management through a role-play game in a virtual world. *Interactive Learning Environments, 24*(4), 897–915.

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2013). Math Anxiety, Working Memory, and Math Achievement in Early Elementary School. *Journal of Cognition and Development, 14* (2), 187-202.

Shih, J. L., Shih, B. J., Shih, C. C., Su, H. Y., & Chuang, C. W. (2010). The influence of collaboration styles to children's cognitive performance in digital problem-solving game "William Adventure": A comparative case study. *Computers & Education, 55*(1), 982–993.

Sun, P. C., Tsai, R. J., Finger, G., Chen, Y. Y., & Yeh, D. (2008). What drives a successful E-Learning? An empirical investigation of the critical factor influencing learner satisfaction. *Computers & Education, 50*(4), 1183–1202.

Tan, C. K., Harji, M. B., & Lau, S. H. (2011). Fostering positive attitude in probability learning using graphing calculator. *Computers & Education, 57*(3), 2011-2024.

Tsai, F. H., Tsai, C. C., & Lin, K. Y. (2015). The evaluation of different gaming modes and feedback types on game-based formative assessment in an online learning environment. *Computers & Education, 81*, 259-269.

Vandercruysse, S., Vrugte, J. T., Jong, T. D., Wouters, P., Oostendorp, H. V., Verschaffel, L., Moeyaert, M., & Elen, J. (2016). The effectiveness of a math game: The impact of integrating conceptual clarification as support. *Computers in Human Behavior, 64*, 21-33.

Watt, S. J. & Therrien, W. J. (2016). Examining a Preteaching Framework to Improve Fraction Computation Outcomes Among Struggling Learners. *Preventing School Failure: Alternative Education for Children and Youth, 60*(4), 311-319.

Wubbena, Z. C. (2013). Mathematical fluency as a function of conservation ability in young children. *Learning and Individual Differences, 26*, 153–155.