Using Gamification to Teach Foundational Fractions in the Third Grade: Year One

Prepared by

Makeba McCray, Ed.D. Educational Leadership, Kean University Class of 2020

With

Soundaram Ramaswami, Ph.D , Kean University

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Introduction

Ever since its inception in 1994, the Internet has provided an avenue for information gathering, data sharing, and gaming experiences at incredible speeds. The Internet has paved the way for new educational endeavors, such as online learning and gamification (Anderson & Rainie, 2012). This has led to the emergence of innovation in educational technology and has opened the door for online learning as a serious contender to traditional education (Erenli, 2013). The progression of “nationalizing” 21st-century education with new standards set by Common Core Standards and online assessments has increased the necessity for K-12 institutions to think “digitally” regarding student learning and academic success. This is even more relevant with the current scenario presented by the pandemic, and the debate about online learning for K-12 students.

The adoption of online learning has led to innovative ways to incorporate technology into the classroom. One such modality is to infuse gaming into instruction and learning. Online learning, coupled with gamification mechanics, has evolved into a multi-dimensional sophisticated platform that hinges itself on the academic success of students, instructional design, and game mechanics. The word “gamification” has emerged in recent years as a way to describe interactive online design that plays on people’s competitive instincts and often incorporates the use of rewards to drive action–these elements include virtual rewards such as points, payments, badges, discounts, and gifts; and status indicators such as friend counts, re-tweets, leaderboards, achievement data, progress bars, and the ability to progress to the next level (Anderson & Rainie, 2012; Nacke & Deterding, 2017). There have been numerous research studies on the gamification of instruction regarding post-secondary, professional institutions and industries; however, few research studies have been conducted to apply the principles of gamification in an eLearning environment on an elementary level (Anderson & Rainie, 2012). Despite this fact, training through gamification is an evident reality in primary education (Marín et al., 2015). This study explored the impact of gamification on student motivation (from a teacher perspective), problem-solving skills in mathematics, and achievement levels of third-grade students learning foundational fractions in an online learning environment.

Gamification

Gamification is a topic of interest that currently spans industries from the private to the public sector, including areas such as Education, Psychology, Game Theory and Design, Human-Computer Interaction, Digital Information Systems, Business, and Medical Science (Mora et al., 2017). Teachers have used games and gaming methods since the beginning of human history. Humans and non-humans alike learn basic knowledge and survival skills through play (Seaborn & Fels, 2015). Children learn social skills, foundational knowledge, conceptual strategies through role-play and game-based activities. Also, societal conditioning has developed people's competitive natures by announcing the first-born baby in January of a new year, athletic competitions, the best schools, and neighborhoods, to name a few examples (Seaborn & Fels, 2015). Collectively, every facet of Western society has been gamified from Electoral College's votes to law and order.

Gamification is a term used to describe the features of an interactive system that aims to motivate and engage the user through game mechanics and elements, in other words, the use of game elements and mechanics in non-game contexts (Seaborn & Fels, 2015). Gerber (2014) offered a variation in the definition by protesting that gamification is "the use of game mechanics and thinking to engage audiences and solve problems" (p. 45). The elements of gamification can invoke "feel-good chemical reactions, alter human responses to stimuli-increasing reactions times and in certain situations can improve learning, participation and motivation" (Anderson & Rainie, 2012, p.1). Games and gamification are not synonymous; while gaming or full-fledged games are immersive environments most often enveloped in a fantasy setting with the sole purpose of entertaining, gamification integrates the mechanics of games such as levels, badging, points, leaderboards, and rules to invoke the physiology and behavioral impulse similar to a full-fledge game to perform serious actions (Gerber, 2014).

Education has been slow to adopt the concept of utilizing gaming and gamification to deliver instruction, partly because of increased initiatives to drive academic rigor, dwindling budgets, and lack of instructional designers to implement gamification (Bruder, 2014). However, in the last 15 years, gamification has become a "trending concept in online courses," and gamification usage has increased due to the rise in online learning technologies (Sturges et al., 2015, p. 23). Integrating game-mechanics into instruction can motivate and engage disenfranchised learners and ignite cognition with elements such as levels, badges, achievements, and points with the opportunity to individualize learning (Cohen, 2011). Given the benefits of gamification, Cohen (2011) suggested that math and science are more accessible to being gamified than other content areas such as English Language Arts (ELA) essay-based activities. Most recently, Georgia deployed a gamified assessment program and piloted with first and second graders ("How Digital Games Take the Stress Out of Formative Tests," 2019), where the student was at the center of design and application, a critical detail in the development process. According to the initial studies, the students were unaware that they were assessed; however, the students were able to engage with the experience while also displaying competency in the concepts. In the current study also, the student was at the center of design and application of an eLearning math program, *Fractionville.* The Fractionville math app was developed and designed by the main author (the Assistant Principal of the school), to engage and motivate third grade students to learn fractions, which has been a critical challenge for teachers and students at this urban elementary school.

Rationale and significance of the study

Even as early as the 2013-2014 school year, the district in this study scored only 31% proficiency on the third-grade state assessment in the Number and Operations–Fractions cluster. Furthermore, these math deficiencies propagate to the fourth and fifth grades in the Numbers and Operations–Fractions and Operations and Algebraic Thinking clusters. The first administration of the Partnership for Assessment of Readiness for College and Careers assessment (PARCC) in 2015 also displayed the continuity of difficulties with fractions. According to the PARCC Evidence Statement Analysis Report, a 56-question analysis that measures the percentage of students who answered various items correctly, the lowest percentage were in Number and Operations–Fractions and Operations and Algebraic Thinking, with less than 20% of students being proficient in each category. Also, nationwide there is a challenge for learning fractions (Braithwaite et al., 2017). Fractions are an abstract mathematical concept that is best learned by application and visual instruction. Shin and Bryant (2015) attested that mastering algebraic concepts, such as fractions, facilitates the learning of more advanced mathematical ideas. In addition, the authors claim that American students underperform in mathematics; given the importance that competence with fractions represents an integral part of the learning progression for algebra (Shin & Bryant, 2015). As a result, there are two elements at play: fractions challenge children, and understanding fractions is required to learn complex algebraic mathematics. Fractions can be a challenging mathematical concept to teach to third graders because fractions essentially break all the rules of multiplication and division. For example, when fractions are multiplied, the fraction gets smaller than either multiplicand, and when fractions are divided, they get larger than either dividend, which is contradictory to the laws of multiplication (Lortie-Forgues, Tian, & Siegler, 2015). With such complexity, teachers face an instructional dilemma as to how to create a motivational environment where fractions are fun, interactive, and induce problem-solving skills through real-time application. Striking a balance between gamification, and content delivery, while also providing effective instructional learning objectives for knowledge mastery without overloading students with information and digital "noise" can be a challenge, especially at the third-grade level. Hence, the design and development of Fractionville program used the principles of "User-Centered Design," where the student user was at the center of the design, with a focus on benefiting the user (Nicholson, 2012). The primary theory behind User-Centered Design is that the learner's goals and needs are at the center of every stage of development of a gamified learning process. The following brief discussion focuses on the seminal features of the Fractionville program.

Fractionville App and Development

Fractionville uses a story about a town that has outgrown its space. The Mayor of the town decided to buy new land but needs a Fraction Master (the student) to divide the new land among the Food, Fashion, and Housing Districts. The program provides a "cheat sheet" page that informs the student about the meaning of the icons on a typical page and the location of items for future use. Once selected, the avatars remained on-screen at the top left-hand corner.

Fractionville contains three learning modules/levels: Food, Housing, and Fashion District. Each level has several types of questions ranging from matching, drag-and-drop, and input to highlighting, and animation interaction features. Once a student successfully passes each sublevel with 70% or better, the badges and points earned appear in their award tracker at the top right of the screen, which the student can view at any time during the experience.

After the introduction in each level, there is also a short instructional animation or static page that re-teaches the fraction concept. A point structure of 100 points for correct answers and -50 points for incorrect answers was created. The points were programmed to accumulate during the experience, and there was also feedback given to students once they submitted their answers to be evaluated by the program. The question attempts in the math program were set to “Unlimited” after discussion with the team on learner fatigue, students becoming discouraged, and ultimately “giving up” on the experience from not being able to progress through levels. At the end of each level, the student received a summary and a badge. Fractionville program was delivered for three weeks during math center time in 15-minute rotations according to the district’s mandated pacing guide and instructional schedule. Students were able to continue Fractionville at home; however, the instructor did not require home use because some students did not possess Internet access.

Methodology

The project was assessed by the Kean University Institutional Review Board. The study used a quasi-experimental approach to analyze the effects of gamification on the differences in the achievement levels between students receiving traditional education on fractions and those students receiving the gamification treatment. The study used multiple data points such as district benchmark assessments, pretest, posttest, and third grade PARCC Content Standard scores on the Numbers and Operations–Fraction band.

In the study school, the classes were homogeneous according to the academic level of the students. The class levels were: Low-Response to Intervention (RTI), Low, Middle-High, and High. In the first year of implementation (2016-2017), there were two classes selected as the treatment group for the study, the Low-RTI and Low classes, while the Middle-High and High classes continued the traditional method of learning fractions (see Table 1). In the classes receiving the gamification treatment, students were between the ages of 8 and 9, with eight students classified with learning disabilities (mildly learning disabled; Mild LD), within an inclusion class setting. Also, 92% of students received Free and Reduced Lunch and Title I funding. Table 1 displays the class level breakdown and gender distribution for the 2016-2017 school year.

Table 1

2016-2017 Third Grade Class Levels by Gender

Class Level	Low-RTI	Low	Middle-High	High
	n = 19	n = 16	n = 17	n = 19
Males	7 (37%)	6 (38%)	7 (41%)	8 (42%)
Females	12 (63%)	10 (63%)	10 (59%)	11 (58%)

Validity and Reliability of the Assessments

Pre and Post Assessment

To test the fraction assessments' reliability, 58 fourth grade students who had already experienced the content in the previous grade, were recruited and piloted with the pre and post- tests. Cronbach's alpha for the 26 fraction questions was .782 (α = .782), which indicated good reliability.

Benchmark Assessment

To test the district's benchmark assessment reliability, once again a Cronbach's alpha test of the assessments was used. In the 2016-2017 school year, 66 third grade students took the benchmark assessment at the end of the fraction unit and the Cronbach's alpha for the 2017 benchmark assessment was .867 (α = .867), showing high reliability.

PARCC Assessment

According to the PARCC consortium, the average scale score reliability for third-grade mathematics was .94 for the computer-based test (CBT) and .93 for the paper-based test (PBT) (PARCC, 2018). Likewise, the mathematics full summative tests have four subclaim scores—Major Content (MC), Mathematical Reasoning (MR), Modeling Practice (MP), and Additional and Supporting Content (ASC). The reliability estimates ranged from .67 to .89 for these subclaims. The validity measures for the subclaims tested ranged between .70 and .90. As a result of the high intercorrelations, the assessments are likely to be considered unidimensional, meaning that the assessment is testing for mathematical skills on the third-grade level, which also supports the validity of the math portion of the assessment for Grade 3.

The data analyses consisted of several analyses related to different assessments that were used to triangulate the effectiveness of the Fractionville program. A paired *t* -test, and one way ANOVAs were conducted. The paired t-test was used to compare the pretest and posttest (fraction assessment) scores of the first cohort's lower-level students (Low RTI & Low groups), to elicit Fractionville's treatment effect. One way ANOVAs were employed to compare the differences in achievement on the benchmark and PARCC assessments, among the different groups.

Findings

The first analysis looked at the effects on learning, understanding and applying fraction skills, specifically for the lower-performing third-grade students from the treatment group that received this eLearning math program. The pretest was given before the students began the unit on fractions, and the posttest was given after the fraction unit ended. A paired t-test analysis showed that there was a statistically significant difference between the pretest and posttest scores of the lower performing students who utilized Fractionville in 2017 (t (32) -3.95, p = .000). The significant increase between the pretest (M=50.09 and posttest scores (M=62.45) further revealed a mean difference of 12.36 (see Table 2). This increase in academic performance is evidence that the Fractionville assisted lower-performing students with learning and mastering fractions. This result is even more noteworthy that gamification benefited this Low-RTI class with special need students.

Table 2

A Paired t-test Analysis: Pretest and Posttest Fraction Content Scores of the Lower Performing Groups

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper	*t*	*df*	Sig. (2-tailed)
Pair 1	Pretest Grade % - Posttest Grade %	-12.36	18.01	3.13	-18.75	-5.98	-3.95	32	.000

However, a comparison of the posttest assessment performance (mastery of fractions) of the lower-performing students (treatment group) and the higher-performing students (control group) did not yield statistically significant results (f (3, 65) = 2.38, p = 0.78).

To further examine the mastery of these fraction skills, a one-way ANOVA was used to investigate the differences in academic performances of all the four groups on the district benchmark assessment. Table 3 provides the means and other related statistics for all the four groups.

Table 3

Descriptive Statistics: Benchmark Assessment on Fractions

Groups	*N*	Mean	Std. Error
Low-RTI	18	79.00	1.60
Low	13	30.15	4.02
Middle-High	13	56.62	7.13
High	19	65.47	4.53
Total	63	60.22	3.08

The one way Analysis yielded a significant result, (f (3,59) = 20.25, p = .000), A Tukey post hoc analysis further revealed that the Low-RTI group (M = 79.0) significantly outperformed the Low group (M = 30.15, p=.000) and the Middle-High group (M = 56.62, p=.005) on the benchmark assessment. Once again, Low RTI students who had the gamification experience outperformed the Middle-High students who were taught through the traditional method. However, it is interesting to note that the High group (M=65.47) even without gamification experience performed significantly better than the Low group (M=30.15, *p*=.000) which had the treatment.

To further triangulate the gamification effect, performance on the state assessment (PARCC) was analyzed for these cohort 1 third graders. Specifically, Number and Operations–Fractions strand was the measure of interest. However, a one way ANOVA did not yield any significant result (f (3, 66) = 2.22, p = .094), showing no differences in student performance between the traditional and the online learning of fractions, on the state assessment. One can only speculate that the skills learnt did not produce the desired results on the state assessment.

Discussion & Conclusion

Looking at the effect of gamification of fractions on mastering fraction skills of lower-performing third-grade students clearly showed that the lowest performing students benefited the most from this eLearning math program. It is even more of the essence and encouraging to note here that gamification benefited students who were classified with special needs in the Low-RTI class, as these students usually struggle to comprehend this complex mathematical concept. These results are in alignment with the literature, which states that students who interact with a gamified learning experience tend to perform better academically and it helps to engage these students (Light & Pierson, 2014). Also, gamification allows the students to be active learners of knowledge and provides opportunities to practice problem solving, decision-making, and inquiry (Arnab et al., 2012).

Although it advanced the learning of the lowest group, and leveled the academic performance field between the Low-RTI, Middle-High, and High classes, the Low group produced the lowest average scores of all the classes on the benchmark assessment. This raises the question of how effective gamification is on this Low group? On the other hand, one could speculate that if the Low class did not have gamification, how much lower would they be without this treatment? It is valid to recognize here that the academic gap lessened with the application of gamification.

Although these differences did not carry over into the state assessments, and the academic performances did not show any significant differences among these groups, the third graders from this school outperformed the district and state on fraction questions on the state assessment which could further evidence the effectiveness of the program, and these results are similar to the ones noted by Çeker and Özdaml (2017) in their study.

It is unrealistic to believe that a single math program will tip the scales for the lower group to outperform their higher group counterparts. However, these results are promising, and the school and district should further explore and understand the impact of gamification by expanding the research on gamification to include at-risk students learning math on all levels. Further, the district should expand Fractionville to include the next progression of fractions, which is the Algebraic Thinking standard. Approaching the math deficiencies by standard and intensive data collection, the district can sustain academic progress, as students' advance through more difficult fraction concepts such as simplifying, dividing, and multiplying fractions in the fourth, fifth, and sixth grades. Fractionville should continue to be utilized during the math rotation center schedule daily and administered in 15-20-minute segments to ensure students have ample time to complete the levels. District should employ data analysis reporting to track user data during the usage of the gamified experience which can further throw light on the usage and time requirements in developing/modifying this program for other primary and middle grade levels.

Since the results did not show that the lower-performing students were able to transfer their skills and knowledge to the PARCC assessment, the district should incorporate PARCC-like questions and activities/interactions to match the rigor of the PARCC assessment to counter this issue. To close the performance gap even more, the district should focus on maximizing the effectiveness of the math program by evaluating the continuous models and question types used within the online math program to replicate the expectations of the math standard and the PARCC assessment. Interaction models should also promote and increase critical thinking skills required for success on the state assessment.

One of the best features of Fractionville is that the program did not require additional training and/or professional development for the teaching staff. Most of the development focus emphasized creating a user-centered environment geared toward the supplemental instruction of fractions. The program was built for easy teacher implementation, seamlessly integrating with the math center rotation. Conversely, with the pending expansion of Fractionville, instructors will need more information regarding the features and implementation, along with solid infrastructure and security protocols, as the program expands to include student data analysis and increased assessment features.

The results of this study supplied valuable information and data that would benefit the expansion of gamification in the school district and the education field. This information is also beneficial to other academic institutions and organizations regarding the implementation of gamified learning. The study is especially instrumental in educational institutions with at-risk populations. Future research should have a broader scope to improve gamification, knowledge, practicality, and deployment. This study increased the knowledge base on gamification; however, it is encouraged that the continuity of research progress into a wider area.

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