Continuance Use Intention of Primary School Learners Towards Mobile Mathematical Applications

Marisa Venter
Information Technology Department
Central University of Technology
Bloemfontein, South Africa

Lizette de Wet
Department of Computer Science & Informatics
University of the Free State
Bloemfontein, South Africa

***Abstract*—Mobile educational applications include some of the most useful learning tools that have ever been developed. Games for learning are most effective when multiple sessions are involved, in other words, when users replay the games. Previous research on the use of educational games in mathematics education have focused primarily on the learning potential of these games and have not adequately addressed the continuance use intention, or the replay value, of these games. This is a serious gap in literature due to the fact that mobile mathematical applications will only be able to assist primary school learners to improve their math skills if they continue to use these apps on a regular basis. The purpose of this paper is to address this gap by investigating the continuance use intention of primary school learners towards mobile educational mathematical applications. This study adopted the Flow Theory, GameFlow and EGameFlow model, Game Based Learning model and the Technology Acceptance Model adapted to mobile gaming as theoretical base. A mixed method research methodology was employed where qualitative and quantitative data was gathered through surveys, individual observations and focus groups. Twenty-six children, aged 10 to 13, from selected schools in one of South Africa's provinces, participated in the study. The results indicate that the fun, fantasy, immersion and sensation constructs were the most influential in terms of the continuance use intention. The findings of this study could be used by educators and designers of educational mathematical applications in the evaluation of the re-use potential of these applications.**

Keywords— mathematical applications, mathematical games, mobile games, continuance use intention, primary school learners

I. Introduction

There is mounting concern in developed countries about the declining number of students that meet the entry requirements for university-entrance level mathematics (math) [1]. The state of math education in developing countries warrant even more concern, but the situation in South Africa (SA) is particularly disturbing. Here the performance of learners in math is the worst of all middle-income countries in the world, and even worse than many low-income African countries, according to international studies [2]. In addition, according to a report published by The World Economic Forum in 2014, SA also has the worst quality of math and science education of all 148 countries surveyed [3].

Consequently, the poor performance of learners in math in SA is seriously hampering the ability of Higher Education Institutions (HEI's) to provide science and engineering graduates that are needed for a range of key roles in society [4]. Science and engineering faculties, in particular, are plagued by very low participation rates due to the fact that 90% of high schools in SA fail to meet the minimum performance standards necessary for a tertiary education in mathematics and science [5]. Dr. Sam Ramaila from the Department of Applied Physics and Engineering Mathematics at the University of Johannesburg (UJ), believes that it is the responsibility of universities to search for innovative ways to improve the overall quality of math and science education of school learners [6].

In an attempt to find a solution to the low performance of learners in math, the authors have been investigating several aspects regarding the use of mobile math applications (apps) in their community. It has been confirmed by various studies that the use of mobile math apps offer a wide range of benefits to children [7],[8],[9],[10]. Preliminary research that was conducted by the authors in 2015 found that both teachers and parents had a very positive perception towards the use of math apps at school and at home. Furthermore, they found that 30% of parents have downloaded mobile math apps for their children to use at home [11]. The aim of this paper is to report on a follow-up study regarding the continuance use intention of primary school children towards mobile math apps.

Previous research on the use of educational games in math education have focused primarily on the learning potential of these games [7],[8],[9],[10] and have not adequately addressed the continuance use intention, or the replay value, of these games. To the authors' best knowledge, little scientific research exists that can shed light on the factors that influence learners to replay educational math games. This gap needs to be filled in order to fully understand the role that math educational games could play in the enhancement of the math skills of learners.

The contribution of this study towards higher education in engineering is that it is exploring mobile technology as a means to improve the performance of learners in math. For engineering and science faculties at HEI's to operate efficiently, they need students with adequate performance levels in math. Various international studies indicated that the problem with math originates in primary school [12] and that

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the best approach to improve math performance is to concentrate on primary school learners [2]. Mobile math apps will only be able to assist primary school learners to improve their math skills if they continue to use these apps on a regular basis.

The objectives of this study are, therefore, to attempt to obtain answers to the following research questions:

- Do primary school learners enjoy playing mobile educational math games?
- Do primary school learners want to continue using specific mobile educational math games after being exposed to it?
- Which constructs have an influence on the continuance use intention of primary school learners towards mobile educational math games?

The paper is structured to firstly provide the theoretical framework for the study. Secondly, the research methodology is discussed followed by the results, discussions and conclusions.

II. Theoretical Framework

The repetitious use behavior of individuals (referred to in literature as continuance use intention) towards video games is one of the main features that attracted educators to make use of game based learning [13]. Games for learning are most effective when multiple sessions are involved and users are motivated to play again with a new strategy or approach, and not only repeating the same action [14]. The potential for learning through the repeated play of games is attractive to promoters of game-based learning, but it is even more attractive to funders and designers of games. Games are expensive to develop, and the notion that learners could engage several times with a well-designed game is an exciting prospect for both the designers and funders of these games [15]. With this said, little work has been done to explore the reasons why learners replay educational games. Existing studies of consumer behaviors in mobile games have largely focused on the pre-adoption phase while ignoring the post-adoption behaviors.

The first of only a few studies that could be found that focused on the continuance use intention of mobile games was conducted by Chinomona (2013) among SA university students. This study investigated the influence of students' perceived mobile gaming enjoyment and ease of play on mobile gaming continuance intention. Both perceived enjoyment and ease of play were found to be significant predictors of continuance intention [16]. The second study that could be found by the authors was conducted in 2015 by Nguyen. This study examined the role of perceived enjoyment as the driver for mobile game continual use and also explored the antecedents of perceived enjoyment in mobile games. Nguyen found that design aesthetics and perceived ease of use were significant predictors of perceived enjoyment of mobile games, while perceived enjoyment was a significant predictor of continuance intention [17]. It is important to note that the mentioned studies investigated mobile games and not mobile educational games, and focused on adult users of mobile technology.

In order to develop a theoretical framework for this study, the authors have evaluated several theoretical models and studies. Due to the fact that perceived enjoyment proved to be a strong predictor of continuance intention of mobile games in the studies discussed previously [16],[17], as well as the fact that perceived enjoyment is often reckoned as one of the most important factors affecting consumer behavior in gaming contexts [18], the authors reviewed theoretical models that were geared towards explaining perceived enjoyment in a game context. Malone [19] determined that perceived enjoyment is also an important aspect of software when developing educational learning material. Without the technology providing a positive experience, children are unlikely to interact or accept it, let alone re-use it [20]. Although the goal of an educational game is to provide a functional benefit rather than to entertain the player, enjoyment is an essential game component, since enjoyable educational games result in an improved functional outcome and have a higher replay value [21]. The following theoretical models and studies were revised in the development of the theoretical framework for this study:

a) Flow Theory of Csikszentmihalyi (1997), with dependent variable flow, and independent variables goals, feedback, challenge, skill, concentration, control, loss of self-consciousness, time distortion, autotelic or self-rewarding experience [22];

b) GameFlow model of Sweetser and Wyeth (2005), with dependent variable player enjoyment of video games, and independent variables concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction [23];

c) Game-based learning (GBL) model of Shi and Shih (2015), with dependent variable enjoyment in digital game based learning systems, and independent variables game goals, game mechanism, interaction, freedom, game fantasy, narrative, sensation, game value, challenges, sociality, mystery [24];

d) Technology Acceptance Model (TAM) adapted to mobile gaming by Chinomona (2013), with dependent variable mobile gaming continuance intention, and independent variables perceived mobile gaming enjoyment, perceived ease of play, and attitude towards mobile gaming intention [16];

e) EGameFlow model of Fu, Su and Yu (2009), with dependent variable enjoyment of e-learning games, and independent variables immersion, social interaction, challenge, goal clarity, feedback, concentration, control, and knowledge improvement [25].

The adapted theoretical framework used for this study is shown in Fig. 1.

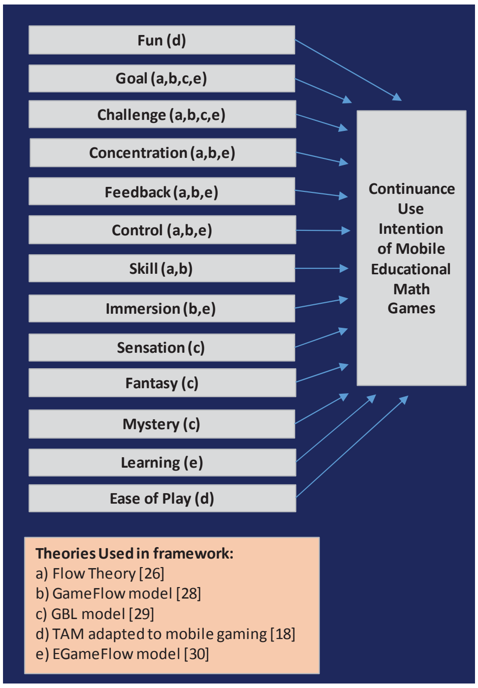

Fig. 1. Theoretical framework

III. Mobile Educational Math Games Used in the Study

Over a period of one year the authors have downloaded and evaluated a large number of mobile educational math apps in order to find the best quality and most engaging games available on the Google play store. The authors made use of several reputable rating organizations who rate educational apps based on various criteria, for example Balefire Labs, Common Sense Media, Graphite, Moms with apps and Teachers with apps [26]. The search for games focused particularly on available apps that were engaging, motivating and fun, while also being educational. One key requirement for a game to be included in the study, was that the game had to be available on the Google Play store. This was necessary due to the fact that Android tablets and cell phones are the most popular devices used by the SA population as a result of their affordability [27]. The following games were consequently selected for the study: 10 Monkeys Multiplication, Bubble Pop Multiplication, Dragon Box 5+, King of Math Junior, Math Duel, Math Evolve, Math vs Zombies, Monster Numbers, Motion Math Fractions, Pet Bingo - by Duck Duck Moose, Slice Fractions, Squeebles Fractions, Squeebles Math Race. The authors included one app in the evaluation as a control, namely Math Pro. This was not a game per se, but a straight forward drill app with no music, graphics or reward system - it consisted only of sums displayed on a green background.

IV. Research Methodology

A. *Research paradigm*

The interpretivist/constructivist research paradigm was used in this study. Interpretivist/constructivist approaches to research have the intention to understand the world of human experience and propose that reality is socially constructed [28]. The constructivist researcher is likely to depend on qualitative data collection methods and analysis, or a combination of both quantitative and qualitative methods (mixed methods) [28]. In this study the authors, therefore, made use of a mixed methods methodology.

B. *Mixed method methodology*

As mentioned, the authors have selected the mixed method methodology for the study. A mixed method approach should add understanding and insight that might be missed when only a single method is employed. A broader and more complete range of research questions could also be answered if one is not limited to a single approach or method [29]. In this light, surveys, personal observations and focus groups were used to gather data for the study.

C. *Sampling*

The population for the study consisted of primary school learners in the Free State province of SA. A purposive or purposeful sampling technique was employed due to the fact that it enables the researcher to choose cases that will best answer the research questions and address the research objectives [30]. When using purposive sampling, the researcher must determine the criteria that are essential in choosing who is to be included in the sample. Stake (1994) advises that age, gender, and previous exposure to technology should be used as the characteristics to select a sample from the population. In addition, the amount of time that the researcher will be able to gain access to participants should also be integrated in the sampling strategy [31].

The sampling strategy that was used resulted in the following sample: 26 learners of which 42% were girls and 58% were boys, 51% were 10 years old, 14% were 11 years old, 33% were 12 years old, and 2% were 13 years old. All the learners in the sample were regular mobile technology users, and had access to a mobile device at home.

D. *Data Collection Methods*

Learners were exposed to 13 mobile educational math games over a period of 5 weeks. Two 45 minute sessions per week in the afternoon after school were arranged in a classroom at one of the local schools. The apps were installed on 7-inch Android tablets. The data collection methods that were employed in the study are discussed next.

1) *Survey instruments*

The Fun Toolkit, a survey instrument that was developed to help developers and researchers to collect opinions about technology from children, was used in the study [32]. Two tools from the toolkit, namely the Smileyometer and the Again-Again table, were used. The Smileyometer has been widely applied and adopted in studies with children, is easy to complete and requires no writing on behalf of children [20],[33],[32],[34]. An example of the Smileyometer employed in this study is shown in Fig. 2. The feedback from the Smileyometer was coded in SPSS as follows: Awful (1); not very good (2); ok (3); really good (4); and brilliant (5). The Again-Again table was designed to capture an indication of engagement by asking the children whether or not they would engage in the activity again [34]. An example of an Again-Again table used is shown in Fig. 3. The feedback from the Again-Again table was coded in SPSS as follows: Yes (1); maybe (3); and no (5).

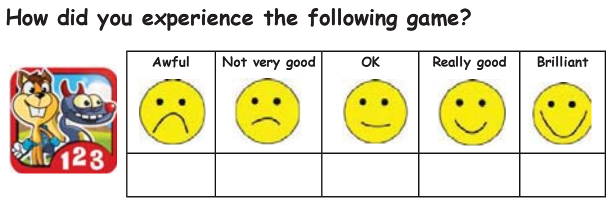

Fig. 2. Smileyometer

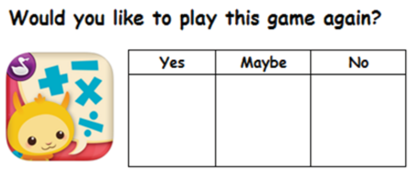

Fig. 3. Again-Again Table

In order to measure the correlation between each construct and continuance use intention of learners towards mobile educational math games, the authors made use of another visual research tool that was designed to obtain Likert-scale responses from children, namely the Ballometer [35]. An example of a Ballometer employed in this study is shown in Fig. 4. The questions that were asked in the Ballometer, as well as the scales used, were adapted from a questionnaire designed by Shernoff, Hamari and Rowe (2014) for the measuring of engagement in educational games and gamified learning environments [36], as well as from the GBL model [24]. The feedback from the Ballometer was coded in SPSS as follows: Not at all (1); a little (2); somewhat (3), pretty much (4); and very much (5).

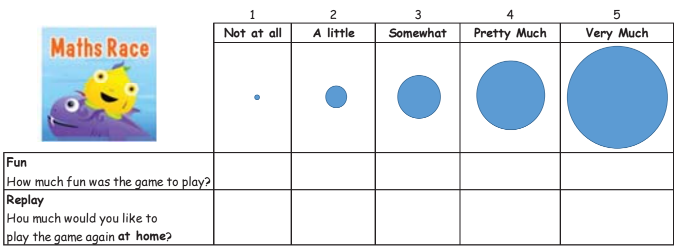

Fig. 4. Ballometer

Each learner completed a Smileyometer, an Again-Again table and a Ballometer (consisting of the 13 constructs in the theoretical framework) for every game he/she played. A total of 246 evaluations were completed by 26 learners.

2) *Focus groups*

Four focus group sessions were conducted comprising of 5 learners each. During these sessions each construct in the Ballometer was explained to the learners in detail. These focus group sessions were also used to complete one Ballometer together as a group, which served as a pilot study for the use of the Ballometer. Learners were asked to relate the constructs to experiences in their own lives, as well as to experiences while playing the games. For example, the fantasy construct was explained referring to the fantasy world that was created in the game [24], and children were asked to give examples of the fantasy worlds that were created in the games. From their explanations it was clear that they understood this construct. The immersion construct was explained to learners as the experience of losing track of time and also becoming very involved when doing something interesting, thereby forgetting about other things [25]. In order to ensure that the learners understood this construct, each of them were asked if they have ever experienced immersion when performing an activity. All the children related it to experiences they had while playing a game on a tablet, an Xbox or a PlayStation, and could relate very well to this construct. The sensation construct was explained to learners as the virtual world of the game, including images, animations and music in the game [24]. Similar discussions took place for the rest of the constructs in the Ballometer.

3) *Individual observations*

A total number of 7 learners were individually observed while playing the games during two weeks of a school holiday at the home of one of the authors, Marisa Venter from the Central University of Technology.

E. *Reliability and validity*

In order to ensure content validity of the measuring instruments, the authors made use of items and scales from past literature. The Smileyometer, Again-Again table and the Ballometer were also piloted before the data collection for the study began. From the pilot study it was clear that the learners understood these measuring instruments and the constructs that were measured by these instruments. In order to ensure convergent validity, a principal component analysis (PCA) was conducted on the 13 constructs of the Ballometer. All constructs had high loadings on the extracted factor, resulting in 3 constructs with factor loadings between 0.60 and 0.69, 7 constructs with factor loadings between 0.70 and 0.79 and 3 constructs with factor loadings between 0.80 and 0.89. The results of the PCA indicated good convergent validity. In order to determine the reliability of the Ballometer used in this study the Cronbach's α was calculated. The resulting value of 0.934 was above the accepted level of 0.8 [37] and indicated that the Ballometer was a reliable measuring instrument for replay intention.

F. *Ethical considerations*

Due to the fact that the participants of this study were small children, special consideration was given to the ethical aspects. A detailed consent form was obtained from the parents of every participant, and every participant completed a consent form as well. The formal ethical clearance procedure of the University of the Free State in SA, from where the research took place, was followed and ethical clearance was obtained for this study in 2015. The authors paid special attention to observe learners in an environment that was non-threatening, comfortable and familiar to them.

V. Results

A. Survey instruments

The first two research questions of the study were: 1) Do primary school learners enjoy playing mobile educational math games? and 2) Do primary school learners want to continue using specific mobile educational math games after being exposed to it? The results of the Smileyometer, Again-Again table, and Ballometer were used to attempt to answer these two questions.

Table I contains a summary of the mean scores for the Smileyometer and the Again–Again table for every game. Table II contains a frequency table for the fun, replay and learning constructs obtained from the Ballometer, and Table III contains the mean scores for each construct obtained from the Ballometer. The results displayed in these tables will be discussed next.

As was expected, the score of the Smileyometer and the Again-Again table as shown in Table I, was the lowest for the Math Pro app. This app was included in the study as a control, and contained no game elements (as discussed earlier). This indicates that the children had a clear preference for the games that were selected for the study based on being engaging, motivating, fun, and educational. Of the 13 games evaluated, 6 games (Slice Fractions, Math Vs Zombies, Dragon Box 5+, Pet Bingo, King of Math Junior and Monster Numbers) had mean scores of more than 4. An additional 3 games (Squeebles Math Race, 10 Monkeys Multiplication, Math Duel) had scored very close to 4 for the Smileyometer. The mean score for all the games (excluding the Math Pro app) was 3.90, indicating that overall the learners had a good experience while playing these games. In addition to the results obtained from Table I, according to Table II, a total of 73.2% of the learners experienced high levels of fun while playing these games with 18.7% of learners enjoying the games “pretty much” and 54.7% enjoying the games “very much”. The mean score of the fun construct measured by the Ballometer, as shown in Table III, was 3.96 and almost the same as the mean score of 3.9 for the Smileyometer. This indicated that the Smileyometer was a valid tool for measuring the fun construct. From the results it can be seen that learners did enjoy playing educational mobile math games, therefore answering the first research question.

The means for 9 of the 13 games for the Again-Again table shown in Table I were also above 4 (or close to 4), and the mean score for all the scores (excluding the Math Pro app) was 3.87. In addition to the results obtained from Table I, according to Table II, a total of 71,5% of the learners really wanted to play these games again, with 22.2 % of learners wanting to play these games again “pretty much” and 49.3% wanting to play it again “very much”. The mean score of the replay construct measured by the Ballometer, as shown in Table III, was 3.82 and almost identical to the mean score of 3.87 obtained from the Again-Again table, indicating that the Again-Again table was a valid tool for measuring the replay intention. The high scores obtained from the Again-Again table and from the Ballometer indicated that learners wanted to continue to play a large percentage of the tested games, thus answering question 2.

TABLE I. MEAN SCORES OF THE SMILEYOMETER AND AGAIN-AGAIN TABLE

Name of mobile educational math game	**Mean of Smileyo-meter**	**Mean of Again-Again Table**
Slice Fractions	4.57	4.74
Math Vs Zombies	4.43	4.52
Dragon Box 5+	4.35	4.29
Pet Bingo	4.33	3.93
King of Math Junior	4.11	3.67
Monster Numbers	4.06	3.63
Squeebles Math Race	3.94	3.94
10 Monkeys Multiplication	3.74	3.74
Math Duel	3.70	4.20
Motion Math Fractions	3.29	3.67
Bubble Pop Multiplication	3.18	3.24
Math Evolve	3.12	2.88
Math Pro	2.62	2.90
Mean for all games excluding Math Pro	**3.90**	**3.87**

In addition to experiencing high levels of fun, as well as wanting to replay the games, learners also found these games educational. In the Ballometer, learners were asked how much math they learnt while playing these games. From Table II it can be seen that the majority of learners (72,9 %) reported that they were learning math while playing these games, with 44% reporting they were learning “very much”, 18,2% “pretty much”, and 10,7% that they were learning “somewhat”.

TABLE II. FREQUENCY TABLE FOR BALLOMETER

	Fun [a]		**Replay** [a]		**Learning** [a]	
	n	***%***	***n***	***%***	***n***	***%***
Not at all	19	8.4	21	9.3	40	17.8
A little	13	5.8	14	6.2	21	9.3
Somewhat	28	12.4	29	12.9	24	10.7
Pretty Much	42	18.7	50	22.2	41	18.2
Very Much	123	54.7	111	49.3	99	44.0
Total	225	100.0	225	100.0	225	100.0

[a] Values excluding Math Pro App

A Spearman correlation analysis and regression analysis were performed in SPSS in order to answer the third research question, namely: Which determinants have an influence on the continuance use intention of primary school learners towards mobile educational math games? A Spearman correlation analysis was selected due to the fact that all variables in the Ballometer were ordinal scale variables and not interval scale variables, which is a prerequisite for performing a Pearson correlation analysis [37]. In order to measure the continuance use intention of learners, the following question was included in the Ballometer: “How much would you like to play the game again at home? The correlations reported in Table IV are between this construct (that will be referred to as replay intention in the rest of this section), and the constructs in the theoretical model (Fig. 1). The results of the Spearman correlation analysis are shown in Table IV.

TABLE III. MEAN SCORES OF BALLOMETER

Construct	N	Mean	Std. Deviation
Skill	246	4.15	1.210
Ease of Use	246	4.03	1.230
Fun	246	3.96	1.367
Control	246	3.87	1.276
Goal	246	3.86	1.330
Replay	246	3.82	1.427
Feedback	246	3.81	1.387
Challenge	246	3.78	1.438
Sensation	246	3.73	1.395
Concentration	246	3.70	1.336
Mystery	246	3.66	1.398
Fantasy	246	3.59	1.453
Learning	246	3.55	1.558
Immersion	246	3.44	1.526

The following guidelines, presented by Evans (1996) [38], were used to interpret r_s: Very weak (0 - 0.19); weak (0.20 - 0.39); moderate (0.40 - 0.59); strong (0.60 - 0.79); very strong (0.80 - 1.00).

As can be seen from Table IV, all the correlations listed are significant ($p = 0.000$). The authors expected to find the very strong correlation (r_s =0.805) between replay intention and fun, and this finding is in line with several international studies on the correlation between perceived enjoyment and the continuance use intention of mobile games [18], [20]. The strongest observed correlations, besides fun, are between replay intention and immersion (r_s =0.646), fantasy (r_s =0.643), sensation (r_s =0.591), learning (rs=0.575), concentration (rs =0.567) and feedback (rs =0.555). The authors were surprised by the strong positive correlation between fun and learning and this finding is also in contrast to studies that found no correlation between fun and learning in educational software [39].

TABLE IV. SPEARMAN'S CORRELATION COEFFICIENTS (REPLAY INTENTION)

Construct	r_s	p	Strength of correlation Evans (1996)
Fun	0.805	.000	Very Strong
Immersion	0.646	.000	Strong
Fantasy	0.643	.000	Strong
Sensation	0.591	.000	Moderate
Learning	0.575	.000	Moderate
Concentration	0.567	.000	Moderate
Feedback	0.555	.000	Moderate
Goal	0.537	.000	Moderate
Control	0.505	.000	Moderate
Ease of Use	0.497	.000	Moderate
Mystery	0.497	.000	Moderate
Challenge	0.451	.000	Moderate
Skill	0.363	.000	Weak

In addition to a correlation analysis, the authors wanted to find out what proportion of variance in the replay intention was explained by the various constructs combined in a model. A multiple linear regression was calculated. Using the stepwise method, a significant model emerged ($F_{4,241}$= 218, $p < 0.001$). The adjusted R square value is 0.7804. Significant variables are shown in Table V.

TABLE V. COEFFICIENTS OF SIGNIFICANT VARIABLES OF THE REGRESSION MODEL

Predictor Variable	B	SE B	β	p
Fun	0.631	0.047	0.605	.000
Fantasy	0.142	0.047	0.144	.003
Immersion	0.124	0.041	0.133	.003
Sensation	0.109	0.046	0.107	.018
Dependant variable: Replay intention				

In terms of the regression model, 78.04% of the variance in replay intention was explained by the fun, fantasy, immersion and sensation constructs. The fun construct on its own could explain 73.24% of the variance in replay intention, with fantasy (3.4%), immersion (0.97%) and sensation (0.43%) explaining the remaining 4.80 % of variance.

The collinearity statistics also show that multicollinearity for the model is well within the acceptable range [37], with all the tolerance values above 0.2 (fun = 0.442) (fantasy = 0.388) (immersion = 0.473) (sensation = 0.450) and VIF values below 5 (fun = 2.261) (fantasy = 2.579) (immersion = 2.112) (sensation = 2.220). This indicates that there is not a high correlation of one independent variable with a combination of the other independent variables in the derived model.

From the correlation and regression analysis the third research question can be answered. From both the correlation analysis and the regression analysis it can be deducted that the fun, fantasy, immersion and sensation constructs appeared to have the most important influence on the continuance use intention of primary school learners towards mobile educational math games. These 4 constructs had the highest correlation with replay intention, and also had the greatest combined predictive ability towards replay intention.

B. Focus groups

During the focus group sessions, it became clear that boys and girls had different game preferences when it came to the fantasy worlds that were created in the various games. Boys enjoyed the fantasy environment of the Math vs Zombies game more where the player has to fight zombies by shooting at, and jumping on them. On the other hand, girls enjoyed the fantasy world created in the Math Bingo game more. In this game players interacted with a variety of adorable characters and had to do math in order to collect very cute pets. The girls did not like the Zombie fighting fantasy world of the Math vs Zombies game and the boys did not like the fantasy environment of the Pet Bingo game, commenting that it was too "girlie" for them. This observation is consistent with literature that shows that girls and boys have different motivations for using computers, and have different preferences [22].

C. *Individual observations*

The following data was gathered during personal observations. A total number of 7 learners were individually observed while playing the games during two weeks of school holidays. At the end of each individual observation session, interviews were used to gather data for each game the learner played by making use of a Smileyometer, Again-Again table and Ballometer. A total of 60 game evaluations were completed by the 7 learners.

1) *Challenge*

What was very interesting was the fact that the majority of learners selected the easiest math options in all the games, except for two games where players received more rewards for more difficult math problems. When these learners subsequently had to answer how challenging the game was, they would select the "not at all" option on the Ballometer. This lack of challenge, however, did not negatively influence the fun or replay intention of learners.

2) *Sensation*

The sensation construct in this study refers to the representation of the virtual game world to players, by using animation, audio, aesthetics, as well as the simulation of game elements. Sensation is regarded to be a key element in the design of educational games [24]. During the individual observations, the authors observed that learners particularly enjoyed the simulation experience in the Motion Math game. In this game the user interacted with a falling ball on the screen by tilting the device in order to steer the falling ball towards the correct math answer.

3) *Social interaction*

The social interaction construct could not be included in the theoretical framework of this study due to the fact that the authors could only find three multiplayer mobile educational math games, and the fact that the tablets used in the study could not connect to the internet. This made the play of multiplayer social network games impossible. The authors, however, did make some noteworthy observations while learners were playing three multi-player math games, namely Math Duel, Sqeeubles Math Race, and Equator. Learners only seemed to enjoy the game when they won. If they lost to another learner, they gave the game a low rating, indicating that achievement is an important factor for learners when playing games. All the learners also enjoyed the game, Equator, more than the other two selected multi-player games. In this game players co-operate with each other to construct a math equation with the same answer as opposed to competing against the other player in the other two games.

VI. Discussions

The purpose of this study was to explore if primary school learners enjoyed playing mobile educational math games and whether they wanted to use these games again. In addition, this study also sought to understand which constructs had an influence on the continuance use intention of primary school learners towards mobile educational math games. To achieve this, the study developed and tested a research framework based on the Flow Theory, GameFlow and EGameFlow model, GBL model and the TAM adapted to mobile gaming. Surveys, individual observations, and focus groups were used in order to gain insight into the objectives of the study.

The main contribution of this study towards higher education in engineering is that it is exploring mobile technology as a means to improve the performance of learners in math. The contribution of this study towards math education can be explained as follows: First, the authors spent many hours over a period of one year to search for and evaluate hundreds of educational mobile math apps. A study conducted by the authors in 2015 found that the most important reason why parents and teachers are not using mobile mathematics applications is because they do not know where to find them, or they do not have time to search for appropriate apps [11]. The list of apps provided in this paper could solve this problem in providing parents and educators with tested apps that were perceived as both fun and educational by learners. Secondly, all the selected apps used in this study are available on the Android and Apple platforms. To the author's best knowledge this is one of very few studies (the authors could not find any other) that sheds light on the use of Android games for math education. All the other studies focused on i-Pad educational math apps [40],[41],[42] and most of these apps are currently not available on the Android platform. The third contribution of this study towards math education is that it has identified the fun, fantasy, immersion and sensation constructs as having the greatest influence on the continuance use intention of primary school learners towards mobile educational math games. Parents and teachers could use this knowledge to identify and evaluate suitable math games for learners.

A summary of the results for each research objective will be discussed next. The study has determined that learners enjoyed to play mobile educational math games, wanted to continue using it, and also learned math while playing it. The regression model that was derived from the fun, fantasy, immersion and sensation constructs predicted 78.04% of the variance in the continuance use intention of primary school learners toward mobile educational math apps. This is significantly higher than a study conducted by Nguyen (2015) where the model only explained 34% of continuance intention towards mobile games [17].

The study found that the fun construct had the most important influence on the replay intention and this finding is in line with several international studies on the correlation between perceived enjoyment and the continuance use intention of mobile games [18],[20]. The sensation construct was subsequently identified by the study as being one of the most influential determinants of replay intention. This finding correlates with research that found that the sensation construct was one of most important elements in the design of educational games [29], as well as a study finding it to be a predictor of continuance use intention of mobiles games [17]. This implies that parents and teachers should search for games with abundant audiovisual media as simulation, audio, and graphic elements are crucial factors for improving player motivation [31]. Parents and teachers must also make use of games that leverage the physical interaction features of the mobile device (for example the tilting of the device) to interact with the game, like the popular Motion Math series. This feature of games has been found to contribute to the understanding of abstract concepts [32][9].

The fantasy construct was furthermore identified as being one of most influential determinants of replay intention. Various studies confirm the importance of fantasy in game settings, and reports that game fantasy motivates players to participate in the game and is vital for game success [44]. The authors are not aware of the fantasy construct being used before in studies focusing on the replay intention of educational or any other games and therefore, provides an opportunity for researchers to incorporate it in future studies. This study, however, did find that boys and girls have distinct preferences towards certain types of game fantasy environments, which correlates with a study of Inal (2007) who found that boys preferred war and fighting games and girls preferred "Barbie-like games" [45]. The implication of this finding is that parents and teachers should ensure that they select gender appropriate math games. For example, one excellent math game available on the Android platform, "SMART Adventures Mission Math 1: Sabotage at the Space Station" was specifically designed for girls and was, therefore, not included in this study.

This study also presents some insight into the challenge construct. During the individual observations it became clear that learners avoided challenge in the game by choosing the easiest game options. The lack of challenge, however, did not influence the enjoyment and replay intention of learners. These findings were supported by data gathered by the Ballometer, as shown in Table II, where challenge had the second lowest correlation to replay intention. The preceding results are comparable to research that found that participants were more engaged and played longer when an educational math game was easier (which seems to contradict the generality of the Inverted-U Hypothesis that predicts that maximum game engagement will occur with moderate challenge) [24]. An implication of this finding is that the designers of educational games should deliberately design games that offer rewards to players for attempting more challenging levels, for example in the Math vs Zombies game where players earn more bullets for solving more difficult math equations. Parents and teachers should also be aware of this tendency in children and should search for apps where the parent or teacher can either lock the easier levels, or where incentives for doing more difficult math are provided.

Moreover, the study has also shed some light on the social interaction preferences of learners. Learners observed in the study tended to enjoy co-operative multi-player games more than competitive ones, and particularly disliked losing to another player. Parents and teachers using multi-player games should ensure that learners play against competitors with similar competence levels in math. Regardless of whether social interaction in a game is co-operative or competitive, most players prefer to play with humans instead of the computer [29], making multi-player math games specifically desirable for math education.

VII. CONCLUSIONS

This study has determined that primary learners enjoy playing mobile math educational games and want to keep playing it. In addition, this study has determined that the fun, immersion, fantasy and sensation constructs have the most important influence on the continuance use intention of primary school learners towards mobile educational math games.

Furthermore, this study provided insight into the use of educational mobile math games and suggested a list of tested mobile math games that could serve as a helpful tool for parents and teachers who wanted to tap into the vast opportunities presented by mobile educational technology.

A limitation of the study is the small sample size and the controlled environment in which the study took place. The authors are currently in the process of making more parents aware of the study in their province, and are inviting parents to download and test these games at home. Currently a total of 81 parents have already volunteered to test these games at home. On the basis of the promising findings presented in this paper, research will continue and findings of a larger sample of parents testing these games at home will be presented in future papers. A recommendation for future research could be to empirically test the same games used in this study for their educational potential.

REFERENCES

[1] A. Noyes and P. Sealey, "Investigating participation in Advanced level mathematics: a study of student drop-out," Res. Pap. Educ., vol. 27, no. 1, pp. 123–138, 2012.

[2] J. McCarthy and R. Oliphant, "Mathematics Outcomes in South Africa. What are the facts ? What should be done ?," CDE Insight, no. October, 2013.

[3] S. Writer, "SA has worst mathematics, science education in the world: World Economic Forum," 2014. [Online]. Available: http://mybroadband.co.za/news/general/103307-sa-has-worst-mathematics-science-education-in-the-world-wef.html.

[4] J. Case, D. Marshall, and D. Grayson, "Mind the gap: Science and engineering education at the secondary-tertiary interface," S. Afr. J. Sci., vol. 109, no. 7–8, pp. 1–5, 2013.

[5] A. Van Der Hoek, "Poor performance in Maths troubling," 2014. [Online]. Available: http://www.skillsportal.co.za/content/poor-performance-maths-troubling. [Accessed: 17-Apr-2016].

[6] S. Moodley, "Poor maths, science education at heart of SA's skills problem," Igarss 2014, 2014. [Online]. Available: http://www.engineeringnews.co.za/article/sa-industries-struggling-with-skills-shortage-owing-to-poor- math-science-education-2014-06-27.

[7] B. Bos and K. Lee, "Mathematics apps and mobile learning," in Society for Information Technology & Teacher Education International Conference, 2013, vol. 2013, no. 1, pp. 3654–3660.

[8] H. Pope, J. Boaler, and C. Mangram, "Wuzzit Trouble : The Influence of a Digital Math Game on Student Number Sense." 2015.

[9] M. M. Riconscente, "Results From a Controlled Study of the iPad Fractions Game Motion Math," Games Cult., vol. 8, no. 4, pp. 186–214, 2013.

[10] S. R. Subramanya and A. Farahani, "Point-of-View Article on: Design of a Smartphone App for Learning Concepts in Mathematics and Engineering," Int. J. Innov. Sci., vol. 4, no. 3, pp. 173–184, 2012.

[11] M. I. Venter, A. B. van der Walt, A. J. Swart, and L. De Wet, "An investigation of the use of mobile mathematics applications: An African perspective," in 2015 IEEE Frontiers in Education Conference, 2015.

[12] G. Cambell and M. Prew, "Behind the matric results: The story of maths and science," Mail and Guardian, 2014. [Online]. Available: http://mg.co.za/article/2014-01-07-behind-the-matric-results-the-story-of-maths-and-science. [Accessed: 11-Apr-2015].

[13] M. Prensky, "The Digital Game-Based Learning," New York: McGraw-Hill, 2001, pp. 1–19.

[14] K. Kapp, "Top 10 + 1 instructional game design best practices," 2013. [Online]. Available: http://karlkapp.com/top-10-1instructional-game-design- best-practices/. [Accessed: 09-Nov-2015].

[15] T. Owens, "Effects of learning from a civics video game," 2010. [Online]. Available: www.trevorowens.org. [Accessed: 16-Jan-2016].

[16] R. Chinomona, "Mobile Gaming Perceived Enjoyment and Ease of Play as Predictors of Student Attitude and Mobile Gaming Continuance Intention," vol. 4, no. 14, pp. 237–248, 2013.

[17] D. Nguyen, "Understanding Perceived Enjoyment and Continuance Intention in Mobile Games," Master's thesis. Aalto University, 2015.

[18] H. Wang, C. Shen, and U. Ritterfeld, "Enjoyment of Digital Games What Makes Them ' Seriously ' Fun ?," Serious games Mech. Eff., pp. 25–47, 2008.

[19] T. W. Malone, "Toward a Theory of Intrinsically Motivating Instruction *," vol. 4, 1981.

[20] G. Sim, M. Horton, and N. Danino, "Evaluating game preference using the Fun toolkit across cultures," in Proceedings of the BCS HCI 2012 People & Computers XXVI, 2012.

[21] A. Nagle, P. Wolf, R. Riener, and D. Novak, "The Use of Player-centered Positive Reinforcement to Schedule In-game Rewards Increases Enjoyment and Performance in a Serious Game," Int. J. Serious Games, vol. 1, no. 4, pp. 2384–8766, 2014.

[22] M. Csikszentmihalyi, Finding flow: The psychology of engagement with everyday life. New York: Cam bridge University Press, 1997.

[23] P. Sweetser and P. Wyeth, "Revisiting the GameFlow Model with Detailed Heuristics," J. Creat. Tech-nologies, vol. 2012, no. 3, 2012.

[24] Y. Shi and J. Shih, "Game Factors and Game-Based Learning Design Model," Int. J. Comput. Games Technol., vol. 2015, 2015.

[25] F. Fu, R. Su, and S. Yu, "EGameFlow : A scale to measure learners ' enjoyment of e-learning games," Comput. Educ., vol. 52, no. 1, pp. 101–112, 2009.

[26] K. Costanza, "App Reviews to Help Choose Ed Tech this Holiday Season," 2014. [Online]. Available: http://www.joanganzcooneycenter.org/2014/12/19/app-reviews-to-help-choose-ed-tech-this-holiday-season/. [Accessed: 15-Jan-2016].

[27] Mybroadband, "Android versus Apple in South Africa – the winner is clear," 2016. [Online]. Available: http://mybroadband.co.za/news/cellular/155060-android-versus-apple-in-south-africa-the-winner-is-clear.html. [Accessed: 20-Apr-2016].

[28] N. Mackenzie and S. Knipe, "Research dilemmas: Paradigms, methods and methodology," Issues Educ. Res., vol. 16, no. 2, 2006.

[29] R. B. Johnson and A. J. Ogwenguzie, "Mixed methods research: a research paradigm whose time has come," Educ. Res., vol. 33, no. 7, pp. 14–26, 2004.

[30] M. Saunders, P. Lewis, and A. Thornhill, Research methods for business students, 4th ed. London: Prentice Hall, 2007.

[31] R. E. Stake, "Case Studies," in Handbook of qualitative research, N. K. Denzin and Y. S. Lincoln, Eds. Thousand Oaks,LA: Sage, 1994, pp. 236–247.

[32] J. C. Read, "Validating the Fun Toolkit: An instrument for measuring children's opinions of technology," Cogn. Technol. Work, vol. 10, no. 2, pp. 119–128, 2008.

[33] G. Sim, G. Sim, and M. Horton, "Investigating children ' s opinions of games : Fun Toolkit vs . This or That Investigating Children ' s Opinions of Games : Fun Toolkit vs . This or That," in IDC 2012, 2013.

[34] J. C. Read and S. MacFarlane, "Using the fun toolkit and other survey methods to gather opinions in child computer interaction," Proceeding 2006 Conf. Interact. Des. Child. IDC 06, p. 81, 2006.

[35] R. Rebane and K. Roost, "Design and Development of Virtual Environments," 2014.

[36] D. Shernoff, J. Hamari, and E. Rowe, "Measuring Flow in Educational Games and Gamified Learning Environments," in EdMedia, 2014, no. June 23–26.

[37] A. Field, Discovering statistics using SPSS. London,: SAGE., 2009.

[38] J. Evans, Straightforward statistics for the behavioral sceinces. Pacific Grove: CA:Brooks/Cole Publishing, 1996.

[39] G. Sim, S. MacFarlane, and J. Read, "All work and no play: Measuring fun, usability, and learning in software for children," Comput. Educ., vol. 46, no. 3, pp. 235–248, 2006.

[40] C. Bonnington, "iPad a solid education tool , study reports.," 2012. [Online]. Available: http://edition.cnn.com/2012/01/23/tech/innovation/ipad-solid-education-tool iPad. [Accessed: 11-May-2015].

[41] K. Larkin, "Mathematics Education: Is There an App For That?," Math. Educ. Yesterday, today tomorrow (Proceedings 36th Annu. Conf. Math. Educ. Res. Gr. Aust., vol. 0, pp. 426–433, 2013.

[42] K. Larkin, "iPad apps that promote mathematical knowledge? Yes, they exist!: Discovery Service for University of the Free State," Aust. Prim. Math. Classr., vol. 19, no. 2, pp. 28–32, 2014.

[43] International Data Corporation, "Smartphone OS Market Share, 2015 Q2.," International Data Corporation, 2015. [Online]. Available: http://www.idc.com/prodserv/smartphone-os-market-share.jsp.

[44] M. Masters, "What makes a great game ? The key elements of successful games," 2014. [Online]. Available: http://blog.digitaltutors.com/what-makes-a-great-game-the-key-elements-of-successful-games/.

[45] Y. Inal and K. Cagiltay, "Flow experiences of children in an interactive social game environment," Br. J. Educ. Technol., vol. 38, no. 3, pp. 445–464, 2007.