International Journal of Ubiquitous Computing (IJUC)

ISSN : 2180-1355

Volume 2, Issue 1

Number of issues per year: 6

INTERNATIONAL JOURNAL OF UBIQUITOUS COMPUTING (IJUC)

VOLUME 2, ISSUE 1, 2012

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ISSN (Online): 1985-2312

International Journal of Ubiquitous Computing is published both in traditional paper form and in Internet. This journal is published at the website http://www.cscjournals.org, maintained by Computer Science Journals (CSC Journals), Malaysia.

IJUC Journal is a part of CSC Publishers
Computer Science Journals
http://www.cscjournals.org

INTERNATIONAL JOURNAL OF UBIQUITOUS COMPUTING (IJUC)

Book: Volume 2, Issue 1, December 2012
Publishing Date: 31-12-2012
ISSN (Online): 1985-2312

IJUC Journal is a part of CSC Publishers
http://www.cscjournals.org

Published in Malaysia

Typesetting: Camera-ready by author, data conversation by CSC Publishing Services – CSC Journals, Malaysia

CSC Publishers, 2012

EDITORIAL PREFACE

This is the *First* Issue of Volume *Two* of International Journal of Ubiquitous Computing (IJUC). The Journal is published bi-monthly, with papers being peer reviewed to high international standards. The International Journal of Ubiquitous Computing is not limited to a specific aspect of engineering but it is devoted to the publication of high quality papers on all division of engineering in general. IJUC intends to disseminate knowledge in the various disciplines of the Computer Science field from theoretical, practical and analytical research to physical implications and theoretical or quantitative discussion intended for academic and industrial progress. In order to position IJUC as one of the good journal on Computer Sciences, a group of highly valuable scholars are serving on the editorial board. The International Editorial Board ensures that significant developments in Ubiquitous Computing from around the world are reflected in the Journal. Some important topics covers by journal are architectures, middleware, tools designs, Experiments, Evaluation, etc.

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The coverage of the journal includes all new theoretical and experimental findings in the fields of engineering which enhance the knowledge of scientist, industrials, researchers and all those persons who are coupled with engineering field. IJUC objective is to publish articles that are not only technically proficient but also contains information and ideas of fresh interest for International readership. IJUC aims to handle submissions courteously and promptly. IJUC objectives are to promote and extend the use of all methods in the principal disciplines of Computing.

IJUC editors understand that how much it is important for authors and researchers to have their work published with a minimum delay after submission of their papers. They also strongly believe that the direct communication between the editors and authors are important for the welfare, quality and wellbeing of the Journal and its readers. Therefore, all activities from paper submission to paper publication are controlled through electronic systems that include electronic submission, editorial panel and review system that ensures rapid decision with least delays in the publication processes.

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Abstract

The paper describes playing experiences and features of mathematical mobile game *UFractions* developed for the South African context. We explore the role of culture in learning mathematics, and describe the phenomena of mobile gaming in a real-life developing educational context. Since *UFractions* applies concrete, tangible manipulatives (math rods) to permit deep understanding of mathematical concepts, we explore which aspects of combining manipulatives and a mobile game influenced the learning of mathematics. A prototype of *UFractions* was tested in five South African multi-cultural school environments during March 2009. A total of 105 Grade 8 mathematics learners and five teachers participated in the evaluation of the game. *UFractions* created the opportunity for the participants to learn the concept of fractions, as well as familiarize themselves with the main game characters, Mother Leopard and her cub Senatla, while playing the game. The empirical research indicates positive attitudes towards mobile gaming, and both teachers and students indicated they would like to use more mobile games in their teaching and learning. While the students engaged in playing *UFractions*, they actively interacted with math rods. By combining the *UFractions* mobile game and motivational manipulatives (math rods), the learning process in mathematics was effectively enhanced.

Keywords: Mathematics, Mobile learning, Tangible manipulative, Culture, South Africa.

1. INTRODUCTION

For more than a decade, achievement in school mathematics, as well as the number and quality of students pursuing university studies in mathematics, have been declining worldwide [1]. At the same time, modern people are confronted with increasingly complex life situations that require problem solving skills and practical knowledge of every-day mathematics [2]. Mathematics teachers and researchers have called for enhanced techniques to help students learn mathematical concepts and symbols better. Some of the difficulties in teaching mathematics are that teachers have to motivate students to spend more time on mathematical activities, as well as to assist them to cognitively construct mathematical understanding [3].

South Africa faces many challenges regarding mathematics education. The 2003 Trends in International Mathematics and Science Study (TIMSS) shows a need to improve the foundation of mathematics in schools. South African Grade 8 students scored the lowest for most indicators amongst the 46 participating countries [4]. The low number of students majoring in mathematics at South African universities and inadequate mathematical background of university students are serious concerns for the socio-economical development of the country [5]. A possible reason for the unpopularity of mathematics could be that the teaching of mathematics has not kept abreast with the rapid advances in technology. Students are of the opinion that mathematics is old-fashioned and redundant [5].

Advances in mobile technology open new possibilities to improve and enhance mathematics teaching. Although the actual level of access to mobile phones in South Africa is unknown, the use of mobile phones is exceptionally high amongst the South African youth. The South African pilot study of Kreuzer [6] conducted among grade eleven students at a low-income urban township school in Samora Machel, Cape Town, shows that practically all students use mobile phones daily. Students also like to play games with their mobile phones; almost all (92%) of these respondents have previously played mobile games, and more than half of them (53%) play games daily [6]. Examples of mobile games used in South African schools is the Dr Math system on MXit (a text based chat system), a tutoring system for mobile phones having over 6,000 users [7].

Instead of just testing and evaluating already existing learning technology, this paper focuses on developing new technology by explaining the features of contextualized *UFractions*, describing a math mobile game with tangible manipulatives, and discussing the evaluation of *UFractions'* prototype game in South-Africa. We start by describing the South-African context and the role of culture in learning mathematics. We present the fundamentals of mobile games, the motivation for using tangible manipulatives with games, as well as a description of the *UFractions* game. The section on research methodology provides background for the findings. Discussions and conclusions address the research questions.

2. THE SOUTH AFRICAN CONTEXT

South Africa is located in the southernmost part of the African continent and has a diverse population of more than 47 million people living in nine provinces (Figure 1). Approximately half of the population lives in rural areas [8]. South Africa counts among the world's upper middle-income countries according to its average level per capita income. Actual income distribution is one of the most unequal in the world and many South Africans live in poverty. There are significant differences between urban and rural areas, as well as variation by ethnic group and province [9]. Life expectancy at birth is about 50 years and 42.2% of the total population is 19 years or younger [10]

Education is compulsory for all South Africans from ages 7-15 and general education includes Grades from R to 9. More than 90% of South Africa's potential students are in school—a high enrolment rate for a developing country. About half of the adults have completed Grade 9 and three-quarter of adults have completed at least Grade 6. Illiteracy rates are around 24% of adults over 15 years old. Further education and training involves Grades 10-12. Grade 12 pass rates are disappointing at a rate of below 70% [10, 11].

The recognition of eleven official languages challenges the education system. The most spoken languages are isiZulu and isiXhosa, which together, forms the home language of more than 40 % of the population. Afrikaans is third common (13.3%), followed by Sepedi (9.4%), and English and Setswana (8.2% each). English is the second language of most South Africans [8]. Multilingualism is an important feature of South Africa's Language-in-Education Policy [12]. In Grades R (pre-school preparation year) to 3, students receive education in their home language. In Grades 4 to 12, the official school language is mostly English, and in some schools Afrikaans [13].

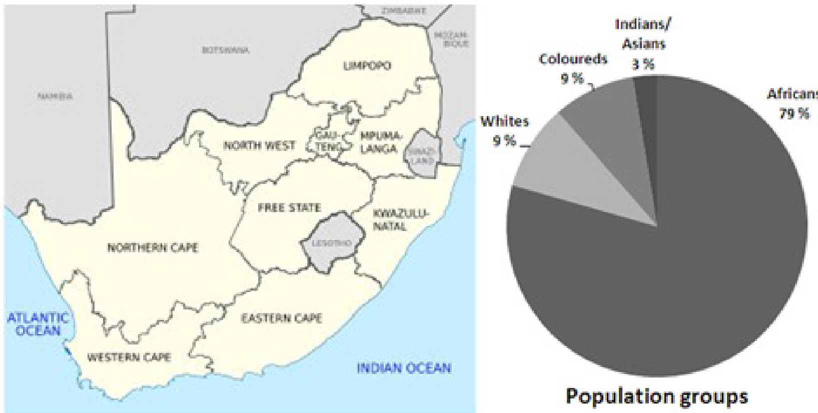

FIGURE 1: Map and Population Groups of South Africa

There is a huge demand for improving the quality of teaching and learning in South Africa. Both local and international measures of learning achievements show that South African learners perform poorly, especially in mathematics and literacy [10]. The test scores of South African Grade 8 students in mathematics and science were the lowest in the TIMMS studies compared to 46 countries in both the 1999 and 2003 studies [4]. These results indicate a significant number of South African students do not acquire basic mathematics skills during the general education phase necessary for the next phase of schooling. Barriers to learning achievement are inadequate teacher preparation, a lack of qualified teachers, language issues, shortages of learning materials and other basic resources [10]. Almost six percent (5.6%) of children aged 2-18 and 12.7% of educators test HIV positive. Many young students are orphaned and have to take care of their siblings. Hunger and long distances to school complicate students' schooling and most children travel to school by foot [10]. The first democratically elected South African government commits itself to transformation and invests heavily in education [14] to recover the imbalances in education caused by the years of apartheid when students from different cultures were taught according to different curricula [11, 13].

3. CULTURE AND LEARNING MATHEMATICS

As a result of 16th century colonization, the Eurocentric cultural system spread over the world and the term "mathematics" became associated with European culture. Mathematics education has become the teaching of mathematical notations. The terminology of measuring, counting and modelling is associated with mercantile arithmetic and geometry of constructions, invented during Mediterranean civilization, and also influenced by Islamic civilization [2]. Since the 1950s, industrialized nations influenced developing countries through modernization theory. This included support for education, especially for mathematics regarded as essential to industrialization. Developing countries adopted curricula in accordance with the western point of view, and schools received books from the USA and European countries [15, 16]. In the 1970s and 1980s scholars began to oppose this imported school mathematics model for developing countries and proposed other forms of mathematics education [16].

The research field of *ethnomathematics* aims to identify culturally embedded mathematical competences, and encourage self-development instead of importing curricula [15]. Learning of mathematics is a unique process and school mathematics is only one form of person's mathematical experience [2]. Personal, social and cultural views of students should be taken into account in mathematics teaching [2, 17] and instead of looking at the background of the students, we should look at their achievable foreground, indicating their possibilities, their future, and the student's social context [15].

In the South African Revised National Curriculum Statement for Mathematics [18], mathematics is seen as a product of multicultural investigation. It is defined as a purposeful activity in the context of social, political and economic goals and constraints. Emphasis is on the equality that mathematics offers for students, so that the mathematically literate person can participate in political, social, environmental and economic activities, as well as in developing and reconstructing society. Furthermore, it states that "the teaching and learning of Mathematics can enable the learner to: develop an awareness of the diverse historical, cultural and social practices of Mathematics", and it also recognises "that Mathematics is a creative part of human activity" [18].

4. EDUCATIONAL GAMES

The slogan *"Learn and Have Fun!"* advertises one of the dozens educational gaming sites on internet. Multiple studies have consistently found that digital game-based learning is an engaging and effective approach for learning [19-21]. At its best, educational gaming offers students enriching knowledge, fosters skills, and stimulates motivation and interest towards learning [21, 22]. However, games' educational strength depends on a variety of factors and creating an effective educational game requires more than just creating an engaging game and building in age-appropriate educational content [22]. According to Alessi and Trollip [19], educational games have to meet three basic requirements: (i) they must have worthwhile learning objectives; (ii) they must be fun; and (iii) the game's goals must reinforce the learning goals. Fisch [22] points out that the feedback structure should support both game play and student's learning of unfamiliar educational content. Malone's [23] empirical research on computer games has shown that the intrinsically motivating environment should offer challenge, elicit curiosity and involve fantasy. Students are therefore challenged by good, personally meaningful goals, uncertain outcome and randomness. Players' curiosity can be elicited through interesting audio and visual effects, well-defined knowledge structures and informative feedback. Fantasy relates to intrinsic and extrinsic motivation, cognition and emotion.

Csikszentmihalyi [24] presents the concept of *flow* that relates to a person's preoccupation on the task at hand. In the flow experience students fully concentrate on a determined task, thereby losing track of time and space. Good educational games provide flow experiences to students [20]. Empirical studies of Habgood and Ainsworth [25] show the importance of *intrinsic integration*: delivering "learning material through the parts of the game that are the most fun to play, riding on the back of the flow experience produced by the game, and not interrupting or diminishing its impact" and embodying "the learning material within the structure of the gaming world and the player's interactions with it" [25]. Habgood and Ainsworth designed intrinsic, extrinsic and control versions of a mathematical 3D action adventure game *Zombie Division*. Players of intrinsic *Zombie Division* use different attacks to mathematically divide enemies (numbered skeletons) in combat. Archaic weapons are used for visualization, for example dividing by 3 is illustrated with a barge with a triangular shield. Each game level contains about 20 enemies and divisions become more complicated while the game progresses. In an extrinsic *Zombie Division*, instead of numbers there are pictures of the weapons dividing the skeletons, and players answer a separate division quiz of the learning content. The control version of *Zombie Division* does not involve mathematics at all. Series of empirical research showed that the intrinsic relationship with the learning content of the game is important both for motivational and learning aspects: The learning outcomes of the group that had played intrinsic version of *Zombie Division* were the best while compared to other two experiment groups. Children also spent seven times longer playing the intrinsic version than other versions when they were provided with a free choice of which game to play [25].

Furthermore, research on computer gaming highlights the potential of game-based learning for mathematics. A study of Sedighian and Klawe [26] confirms that games invokes not only positive responses to learning, but also towards students' attitude towards mathematics. The study of Ke [27] indicates that cooperative goal structures promote positive mathematics learning attitudes in students. Empirical studies list examples of effective and motivating educational games in mathematics, like *Prime Climb* for learning number factorization [28], *Super Tangrams* for learning geometry and transformations by moving traditional Chinese Tangram puzzles in the screen [26], *DimensionM*, a multiplayer video game for learning algebra [29], as well as a handheld software program, *Skills Arena,* designed to teach basic arithmetic skills [30].

5. MANIPULATIVES

Concrete mathematics manipulatives, like pattern blocks, tangrams, colourful rods and geoboards, are often used in the classrooms to support the understanding of abstract concepts. Clements [31] indicated that the long-term use of concrete manipulatives improve students' achievements in mathematics. According to Kamii et al [32], manipulatives encourage students thinking and conclusions during mathematical problem solving. Sowell [33] points out that manipulatives improve students' attitudes towards mathematics if teachers know how to use them.

Scudder *et al*. [34] suggest that the use of concrete manipulatives can be effective, but the use of the concrete objects does not guarantee better understanding of the concept. To use manipulatives successfully, teachers should take into account students' ideas and perceptions of what the manipulatives represent. The use of concrete manipulatives are not always effective and the role of teacher remains important [31, 32]. According to Clements [31] manipulatives should be used before the introduction of formal symbolic instruction and "in the context of educational tasks to actively engage children's thinking with teacher guidance."

Objects on a computer screen can be also become valid and meaningful manipulatives [31]. Digital manipulatives are computationally enhanced versions of physical objects and offer opportunities for interaction and serious play [20]. The idea of digital manipulatives came about in 1970s when Papert combined concrete manipulatives and computers to assist in the learning of mathematics, mathematics language, and mathematical concepts by doing. Papert designed his famous Logo-programming language to move a turtle across coordinates on the floor [35]. Since Papert's turtle moved from floor to the computer screen in 1980s, much development took place in terms of Graphical User Interfaces (GUIs). The introduction of computers in classrooms have focused mainly on screen-based activities [36]. GUIs do not offer the possibility to really touch, feel and interact with the physical world. There is now a tendency to consider Tangible User Interfaces (TUIs) that facilitate direct manipulation of physical objects to bring together digital and physical worlds. For example, the MIT laboratory has demonstrated the value of a hands-on approach by developing a graphical programming language Scratch in 2007. A script with Scratch can be created by snapping graphical blocks together into stacks, much like LEGO bricks or puzzle pieces. Scratch is highly interactive and unlike traditional programming languages, there is no complicated syntax. Scratch has become popular - users share 1,500 new stories, animations, games, music, and art projects in the Scratch web site each day [37].

6. UFRACTIONS

UFractions is a mathematical game that combines mobile phones and tangible manipulatives. The content of the game is proportions and fractions — mathematical concepts that students often assimilate with difficulty [38]. *UFractions* operates on most phones that support Java and WLAN through the *Myst* learning platform developed at the University of Joensuu, Finland. Myst-based mobile games have earlier been successfully used and tested in Finland at the SciFest science festivals in Joensuu (SciMyst) [39], at the Museum of Technology in Helsinki (TekMyst), and at the Museum of Pielinen in Lieksa (LieksaMyst) where learning areas of the games comprised technology, history and science [40]. The Myst platform uses a client-server approach where the server pushes all content to the clients in XML format.

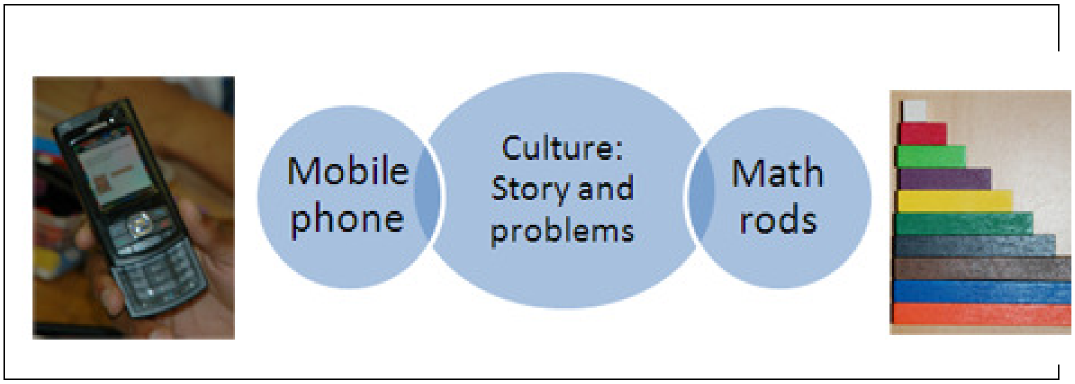

FIGURE 2: Story and problems connect the mobile phones and math rods in UFractions

UFractions mobile game is a story-based game whose story and mathematical problems are contextualized for the South African context with the assistance of cultural experts and local school teachers [41]. While playing *UFractions*, players help "Mother Leopard" to raise her cub "Senatla" in the harsh conditions of the South African Savannah. The story line involves mathematical problems relating to the leopards' lives and the players of *UFractions* earn points by solving these problems. Fraction problems can be solved with the help of mathematical rods, a collection of sticks of twelve different colors and lengths (Figure 2). The players have to understand the problem and concept of fractions to be able to solve the tasks. Players enter their solutions with the keyboard of mobile phone as either numbers, letters (color codes of the rods) or as a choice from a menu list. The story and the problems are in simple English so that students with limited English can also participate in the game. Learning activities concerning fractions are complementary to the normal learning outcomes expected for Grades 7 and 8 mathematics in South Africa [18].

In the beginning of the game players are introduced to the leopards and guided to the use the rods by solving four introductory problems. After the introduction they can select either "Feeding the cub: 0-16 weeks" (concepts of fractions), "Lessons to hunt: 4-12 months" (adding and substracting) or "Whole year" (both parts). Figure 3 shows the story line for the "Feeding the cub"-part. Players choose different story paths as the game progresses. Alternative paths represent different difficulty levels.

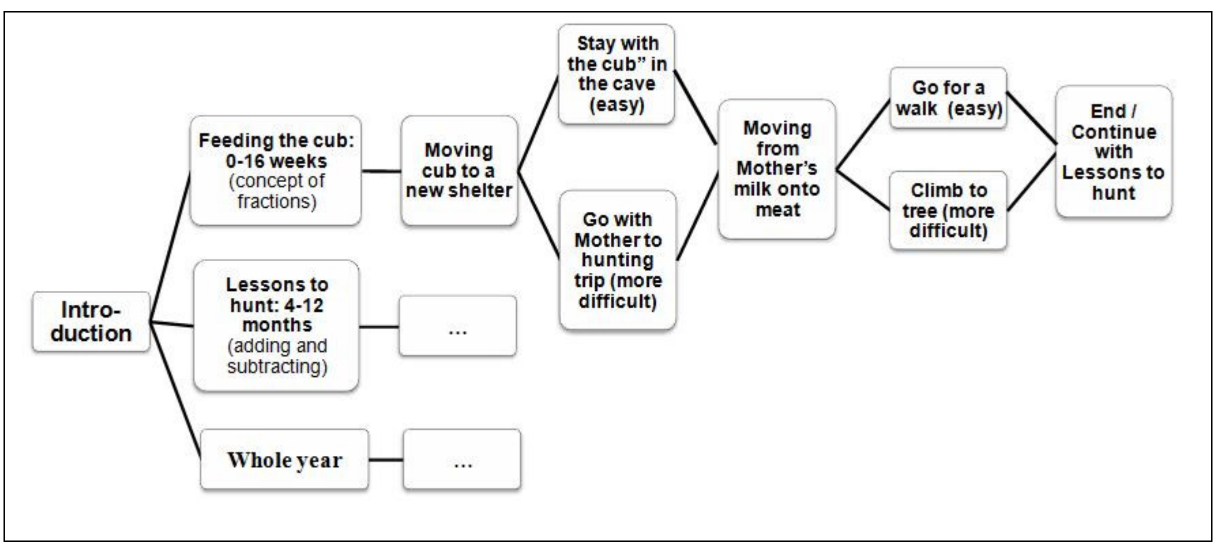

FIGURE 3: Example of storyline, "Feeding the cub"-part

For example, the "Moving from Mother's milk onto meat"-activity starts with Mother Leopard's comments: "*Congratulations –Senatla has survived over the hardest weeks and is now 14 weeks old. He has moven from Mother's milk onto meat and is eating so much! I really work hard to get him food.* " Figure 4 shows two screenshots with a fraction problem related to this part of the story and the picture of mathematical rods that can be used to solve this problem.

Mother Leopard can be prompted for a hint if a player cannot solve a problem, or when a player answers incorrectly. Hints do not provide immediate answers, but lead players on to the right path to solve the problem, e.g. choose the red coloured rod. Leopards provide appropriate feedback to players' input and their images display happy or sad faces according to the type of feedback they provide.

The joint effort of all players is used to fight hunger and danger. The *UFractions*' website displays the scores of the teams, as well as the total scores of players against the enemies' scores they accumulate during the game play (Figure 5). The current status of the leopards' struggle against hunger and enemies can be followed looking at the circle diagram where red marks indicate hunger and enemy scores, and green color indicates the scores of assistance to the leopards. The status is updated in real-time while the game is active.

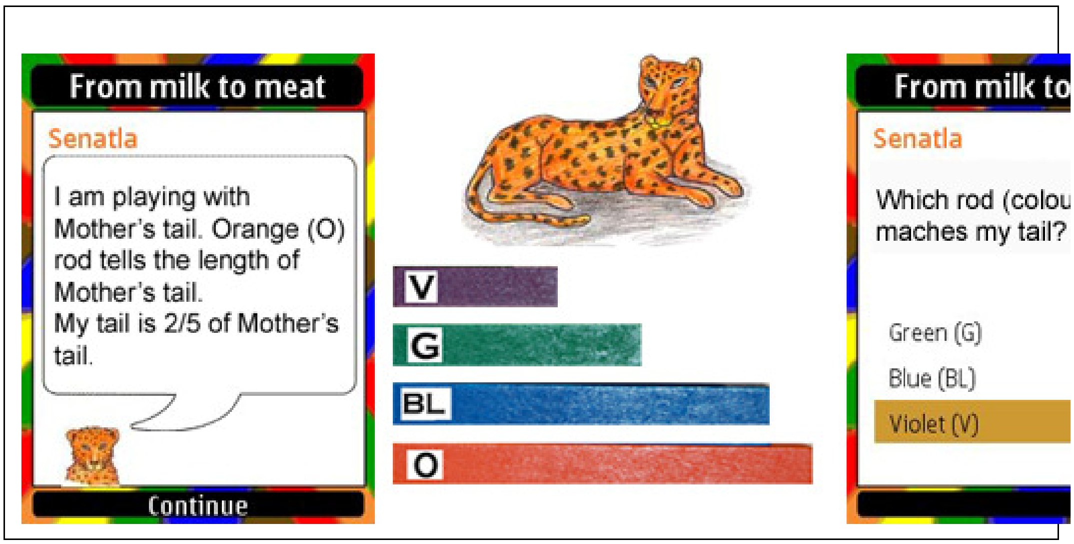

FIGURE 4: Example of math problem in UFractions game

UFractions also involves a game-like feature that allows players to record impressions. This second game approach is played after the first approach and players search for examples of fractions from the physical environment. They save discovered *evidence* by taking digital pictures with the mobile phones and adding comments to them. Through this evidence, the players can demonstrate their competencies of fractions from capturing examples from surprising places. This feature also allows the players to take a picture of the group and send greetings to the leopards.

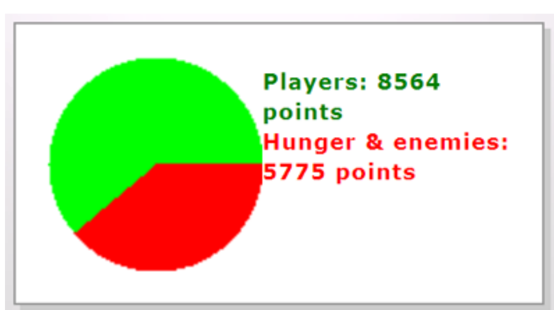

FIGURE 5: Circle diagram in the website presenting the the current status of the Leopards' struggle

7. RESEARCH METHODOLOGY

The aim of the study was to explore, describe and explain the occurrences of mobile gaming in a real-life developing context and to test the prototype of the *UFractions* game. Specific questions addressed in this paper are:

- *How does combining manipulates and mobile game work in real class room situation?*
- *What kind of aspects culture, language and educational technology brings to the playing experience?*
- *What are the challenges of mobile games for educational purposes in South African context?*

The evaluation employed a multi-method approach comprising qualitative and quantitative research strategies. The dominant method was a qualitative case study. Quantitative methods were used to extend the qualitative approach. Students and teachers completed questionnaires during the evaluation sessions, comprising of both open-ended and Likert-type questions (Strongly Disagree; Disagree; I don't have an opinion; Agree; Strongly Agree) related to the UFractions game.

The student' questionnaire also included fraction exercises to test the mathematical competency of students. The qualitative dataset consists of interviews with teachers and students, narrative answers to the open-ended questions on the questionnaires, researcher observations, artefacts (photographs), and group game scores. The game playing experiences of students were quantitatively measured through the Likert-type items of the questionnaire. Because the questionnaires consisted of independent items and no sub-scales were calculated, reliability and validity of the instrument are not relevant. For further triangulation of the data, observations and interviews of students and teachers extended the integrated dataset. Not all collected data is used in this paper.**Demographic characteristics**

Evaluating the *UFractions* game targeted Grade 8 students at five purposefully selected secondary schools in the North-West province, South Africa. Table 1 indicates the demographical characteristics of the five schools.

North-West Province School	Region	District	Municipality	Nearest Town or City	Total Number of Students
Alabama Secondary (Grades 8 to 12)	Southern	Matlosane	Matlosane	Klerksdorp	1300
Lebone II (Grades 1 to 12)	Bojanala	Rustenburg	Pokeng	Rustenburg	255
Seiphemelo Secondary (Grades 8 to 12)	Southern	Potchefstroom	Tlokwe	Potchefstroom	1063
High School Zeerust (Grades 8 to 12)	Central	Zeerust	Ramotshere-Moiloa	Zeerust	573
Zinniaville Secondary (Grades 8 to 12)	Bojanala	Rustenburg	Rustenburg	Rustenburg	987

TABLE 1: Demographical characteristics of the five schools.

Table 2 shows the descriptive statistics of the teachers who participated in the experiments. Table 3 provides descriptive statistics of the student sample. A total of 105 students participated in the research and the group sizes varied from 16 to 27 students. The researchers decided to use language as a cultural variable to distinguish between different groups within the study population because language is often regarded as a salient component and indicator of cultural identity [42]. Nine different language groups were encountered within the total sample, i.e. Sesotho, isiZulu, Setswana, isiXhosa, Afrikaans, Sepedi, SiSwati, English, and isiNdebele. One student did not specify his cultural language group.

The respondents' comprised 61 females and 44 males and their ages varied from 12 to 16. Sixty six students own a personal mobile phone and 39 did not have a mobile phone. Owning of mobile phone does not affect this study because researchers provided the phones to students for the duration of the experiment.

School	Cultural Language Group	Gender	Age	Mobile Phone
Alabama Secondary	Afrikaans	Male	42	Yes
Lebone II	isiZulu	Male	44	Yes
Seiphemelo Secondary	English	Female	50	Yes
High School Zeerust	Afrikaans	Male	57	Yes
Zinniaville Secondary	English	Female	50	Yes

TABLE 2: Descriptive statistics of the Grade 8 Mathematics teachers.

School Divided into Cultural Language Groups	Male (n)	Female (n)	Total (n)	Average Age	With Mobile Phones	Without Mobile Phones
Alabama Secondary	**8**	**13**	**21**	**14.3**	**8**	**13**
Sesotho	4	3	7		2	5
isiZulu	2	0	2		0	2
Setswana	1	8	9		4	5
isiXhosa	1	0	1		1	0
Afrikaans	0	2	2		1	1
Lebone II	**11**	**11**	**22**	**13.5**	**17**	**5**
Sesotho	0	1	1		1	0
Setswana	9	6	15		10	5
Sepedi	0	1	1		1	0
English	1	2	3		3	0
SiSwati	0	1	1		1	0
Not Specified	1	0	1		1	0
Seiphemelo Secondary	**6**	**10**	**16**	**14.4**	**4**	**12**
Sesotho	2	3	5		0	5
isiZulu	0	1	1		0	1
Setwana	2	3	5		3	2
isiXhosa	2	3	5		1	4
High School Zeerust	**11**	**16**	**27**	**13.9**	**21**	**6**
Setswana	4	13	17		13	4
English	5	2	7		6	1
Sepedi	1	0	1		1	0
Afrikaans	1	0	1		1	0
SiSwati	0	1	1		0	1
Zinniaville Secondary	**8**	**11**	**19**	**13.4**	**16**	**3**
Setswana	4	5	9		7	2
English	3	6	9		8	1
isiNdebele	1	0	1		1	0

TABLE 3: Descriptive statistics of the student sample.

7.2. Experiment Procedure

Experiments were held in the premises of the schools. Every evaluation session started with dividing the students into seven groups. Their first task was to choose a game name for the group. Thereafter the students completed the informed research permission forms to take part in the study, as well as the pre-study questionnaires including questions related to demographic data, mobile phone usage, students' attitudes toward mathematics, normal study methods and fraction skills. Before playing the *UFractions* game, the researchers presented the game idea with a presentation slides, explaining the different functions of the game and the use of the mobile phones that researchers provided for the students to play on during the experiment. Examples of the problems demonstrated to the students how to use the colour codes of the rods.

The students played the game for about forty minutes. During the game playing the researchers observed the players' reactions to the game, paying special attention to: (1) problem solving with the help of rods; (2) phone usage; (3) discussions among students; (4) the players' general reactions to the game. They involved the class teachers in observing the game play, as well as to observe their students' reaction to the game.

After playing the game, students and teachers reflected on their game playing experience while completing the questionnaires. By semi-structured interview method, researchers interviewed the teachers and three to five students per evaluation site to collect data on their unique experiences and attitudes. They also probed questions on technical aspects and the usability of the game.

8. RESULTS AND DISCUSSION

The results relates to the participants' experience on combining tangible manipulatives and mobile phones; the influence of culture, language and educational technology, as well as the challenges for mobile gaming in South Africa.

8.1. Tangible Manipulatives

To our knowledge, *UFractions* is the first mobile game using concrete math rods. Therefore, we found it important to test how the novel way of combining manipulates and mobile game work in real class room situation. The participants considered playing with the rods as the most liked activity among problem solving, reading the story, and using mobile phone [41]. Quantitative data shows that students liked playing with the math rods (96.2%) and almost all the participants (92.4%) felt that they wanted to play more with the math rods. The majority of players (96.2%) also indicated that math rods helped them to understand fractions (Table 4).

	Strongly agree	Agree	Disagree	Strongly disagree	I don't have an opinion
I wanted to play more with math rods	68	29	4	2	2
I liked playing with the math rods	69	32	2	2	0
Math rods helped me understanding the fractions	78	23	1	1	2

TABLE 4: Questions related to the use of mathematical rods.

Qualitative data obtained from interviews support the view that rods are helpful to the students, like the following students' answers show:

- *"When we are using Cuisenaire rods it is much easier to answer questions."*
- *"They helped me in the way that understanding. "*
- *"They helped to getting the number of fractions, getting the number of numerator and denominator."*

Students explained various ways in which math rods helped them to solve problems:

- *"I didn't have to think and like… in my brains something, I could just have the rods and like do it in front of my eyes. It was like the evidence was there. So it was easy to get the answer."*
- *"… sometimes you just use your fingers in your hands which you don't get the part of the picture of what you are doing. Rods give you the certain size. And I got to understand if 3/4 then you know that the blue rod is smaller, and then you have to add one light blue for you to get a right fraction. So they were very useful."*

The teachers indicated that the use of maths rods is effective and motivational:

- *"I wish I had them, I wouldn't do a lesson without them. Very very nice, I'm really impressed… It does make them [fractions] visualize, because it is hands-on experience."*
- *"It [math rods] really increases the effectiveness."*
- *"Concrete tools… they are quite... they are more powerful than abstract."*
- *"It is more interesting for the learners, it can motivate them. They will be, you know…they can be more attentive when you do things like this. By the time we are using the chalk board, which is boring, kind of boring. This can motivate the children."*

Teachers also indicated that combining manipulates and the game enhanced the learning process in mathematics:

- *"Well, together they will enhance the learning. It will make it much easier for the learner. Easier, exciting and on top of it they are using modern technology."*

- *"It [combining manipulatives and games] enhances the learning process. It makes the learning process much easier. The learners find it really easy to see the connection between what is being taught and what the outcomes of the certain lesson should be."*

8.2. Influence of Culture, Language and Educational Technology

To investigate role of culture, language and educational technology in playing experiences on the quantitative level, we calculated Spearman Correlations (R) for the multiple choice questions of the questionnaire to students (Table 5).

	I liked using cell phone	**Game helped me when I got "stuck"**	**I wanted to know what will happen next**	**Language was easy to understand**	**Leopards' comments after solving problems encouraged me**	**I enjoyed playing together with my classmates**
I learned better by playing than in usual mathematics lessons	0.273	0.250	0.359	**0.500**	0.200	**0.500**
Compared to ordinary class this was exciting	0.257	0.089	0.392	**0.471**	**0.518**	0.211
Rods helped me understanding the fractions	**0.542**	0.260	0.282	**0.531**	0.280	0.300
The size of the text was big enough	0.071	**0.475**	0.353	0.237	0.112	0.320
It was easy to use the phone as a tool for playing	**0.511**	0.191	**0.488**	0.360	0.223	0.250
I want to try again this kind of game	0.340	0.360	0.445	0.581	0.380	0.226
Note: Spearman correlations (R)≥0.5 are indicative of practical significant correlations						

TABLE 5: Spearman Correlations (R) of questions related to playing experiences

Concerning the use of mobile devices, math rods and learning of fractions, the following practical significant correlations were found:

- Participants who found the math rods helpful to understand fractions, liked using cell phones (R=0.542). This emphasises the tool-based use of cell phones in mathematics education.
- Participants who thought that the size of the text in the cell phone screen was big enough, also experienced that *UFractions* helped them in "stuck" situations during the game play (R=0.475). This finding underscores the importance of the text size for game developers to ensure that the application would assist learning. The limited screen size has been considered as one of the main technological constraints of mobile learning [43]
- Participants who indicated that the phones were easy to use, also liked using them (R=0.511). This finding indicates to educational game developers and educators that users like games that are easy to use.
- Participants' curiosity of the story correlated with easy phone use (R=0.488). This finding suggests that the easier the tool is to use, the more the users are curious to see what will happen next.

Understandable language practically correlated with the following constructs:

- Students experienced *UFractions* more exciting than normal classes (R=0.471). This suggests that the learning content and strategies of the game are more exciting for the study population, than traditional learning content strategies, when the language of instruction is understandable.
- Students want to again interact with mobile games (R=0.581). This shows that the more students thought that the language of the game is understandable, the more students are willing to use educational technology.
- Rods helped students to understand fractions (R=0.531). This finding shows that the more language is understandable, the more useful tools rods are to learn and understand fractions.
- Students learned better by playing *UFractions* than traditional Mathematics lessons (R=0.500). This suggests that the learning content and strategies of the game are more effective for the study population than traditional learning content and learning strategies, when the language of the game is understandable.
-

Students who felt that *UFractions* was more exciting than ordinary classes, also experienced the leopards' comments as encouraging to solve problems (R=0.518). This finding shows that encouragement from game characters is a practically significant contributor of students experiencing *UFractions* more exciting than traditional classes. This finding also hints to the lack of individual encouragement and support of students in South African schools due to large class sizes. Considering social dimension, students who enjoyed group work, also indicated that they learned better than usually (R=0.500).

8.3. Challenges for Mobile gaming in South African Context

In general, teachers considered the use of mobile gaming effective and a good way of learning. Their attitudes towards games were positive:

- *"I feel that they [games] are very powerful in a sense that motivation usually comes from game, from doing and also in that the retention, the knowledge in game becomes practical, and it last long. It's different than when being taught by teacher."*

According to the teachers, the learners were engaged and motivated while they played UFractions:

- *"It was motivating, you saw they didn't want to stop playing. They wanted to continue because they enjoyed it."*

The active participation of players was mentioned by many teachers:

- "*I liked it and they were all enjoying it. What I liked about it, that they were all active. They were all participating, they were all active. Unlike in a classroom, you cannot always get the attention…"*
- *"…the most of the children were involved from the beginning and they stayed involved right through the whole game. There was no one that was disappearing in the group, they were all arguing.."*

However, the teachers were suspicious of the practicality of mobile gaming in South African schools. The biggest challenges according to teachers are *time, big class room sizes, lack of resources, lack of relevant games* and *language*. Figure 6 shows examples of teachers' comments related to these five challenges. These challenges are slightly different from the general barriers of mobile learning comprising technological constraints (like small screen), a fragmented learning experience, cost, and security [43].

As a whole, these findings are partly the same as the findings of MobilED (Mobile EDucation), a 3-year international collaborative project in South Africa that ran two pilot studies of using mobile learning related to HIV/AIDS. During MobilEd, learners were motivated and energized and enjoyed the learning process. The attitudes of teachers were positive, but they needed a lot of support to develop the lesson plans for using mobile learning and some of them were used to banning mobile phones from school premises due to distracting influences of phones [44].

The positive findings are also supported by the Nokia Mobile Learning for Mathematics Project, which used mobile technology to support mathematics learning at 30 public secondary schools among approximately 3200 teenagers in South Africa. Teachers who participated in the project thought that using the Nokia Mobile Mathematics service would motivate and inspire learners in mathematics. In addition, they felt that the project impacted positively on their role as a mathematics teacher and their learners' mathematics results and attitude to mathematics. Teachers also valued the ubiquitousness of mobile learning; their students could work on mathematics anytime and anywhere, which was different from UFractions experiment situation. [45]

Similarly to our research, the Nokia Mobile Learning for Mathematics Project notices lack of resources as a challenge, because not all learners had access to mobile telephones that could access MXit essential for the Nokia Mathematics service. Unlike UFractions, the Nokia Mathematics service uses social networking, so the teachers were worried about the risk of using MXit and anti-social behaviour in social networking. [45]

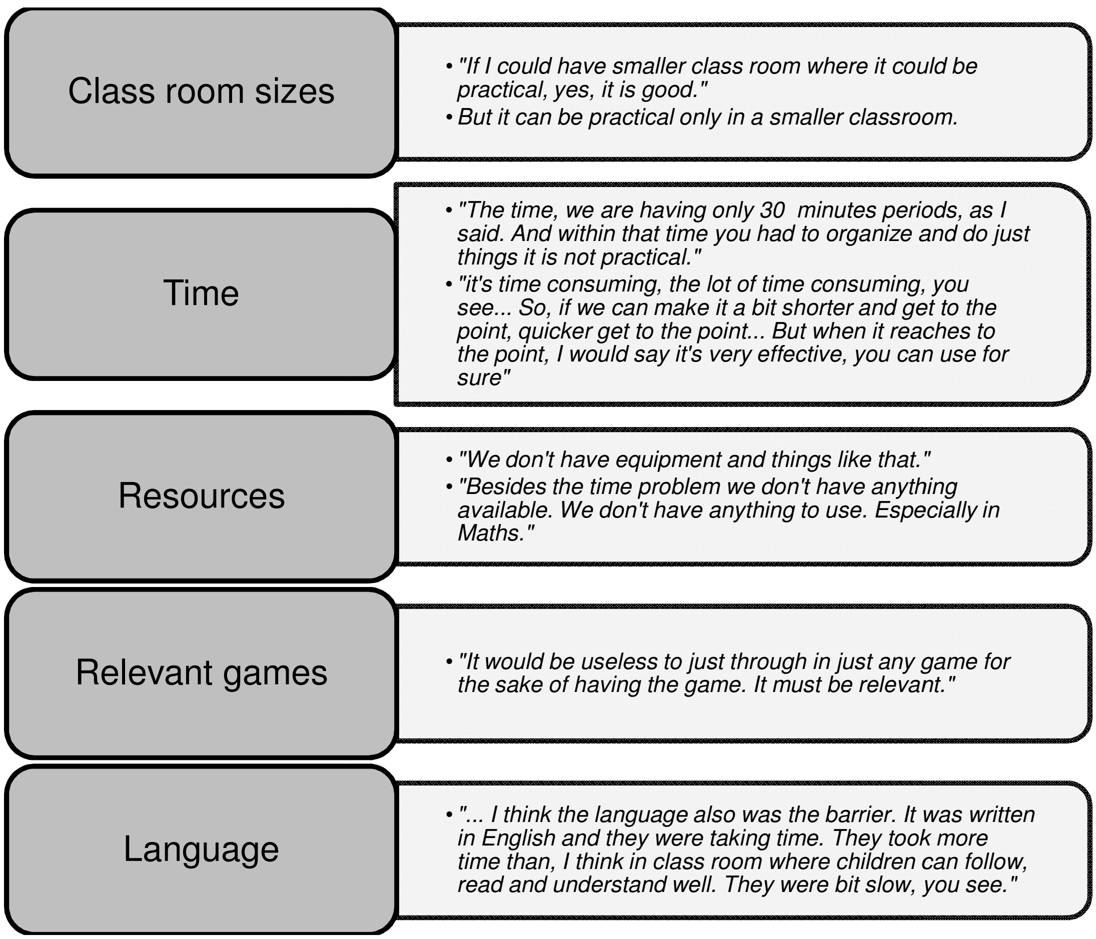

FIGURE 6: Teachers' comments about the challenges for mobile gaming

9. CONCLUSION AND FUTURE IMPLICATIONS

The first evaluation of *UFractions* shows that South African Grade 8 learners engaged in mobile gaming, and mobile gaming could become a suitable learning strategy for South African schools. The South African school curriculum for mathematics encourages to the use of "manipulatives as well as electronic and other technology effectively" [18]. According to this empirical study, teacher's attitudes towards mobile gaming are also positive, and that they would like to use more mobile games in their teaching and learning.

Combining concrete manipulatives and mobile phones seems to be an effective way to learn abstract concept of fractions in developing contexts. The students participated actively and their teachers indicated that hands-on learning-while-doing motivated students and helped them to understand mathematics concepts. Mobile gaming together with manipulatives increased active participation of students. A teacher commented: *"You know, that is what we are aiming these days, the learner's standard."*

South Africa has adopted mobile telephones. The question is why mobile learning is not used more in South African class rooms? From a teachers' point of view, mobile gaming is not yet practical in South African schools because of the following five major challenges: *time, big class room sizes, lack of resources, lack of relevant games* and *language*. However, this kind of challenges will most probably change over time - for example technology becomes cheaper. Creating well designed, practical educational games that can be used in affordable mobile devices, is an important step in implementing mobile games in South African schools towards active and holistic learning.

The findings of this investigation provide clues for future research on the development and combined use of mobile games and manipulatives to effectively enhance the teaching and learning of mathematics in classrooms. Examples of research questions that arise, include:

- Are there any practically significant differences between the experiences of individuals (solitary) vs. groups using the UFractions Mobile Manipulative Game?
- What strategies can be developed to promote mobile learning in South African schools?
- What pedagogical strategies can be developed to effectively facilitate the use of UFractions in classrooms with large numbers of students?
- Can a framework be developed for the implementation and integration of UFractions as a suitable learning strategy for South African schools?
- How can the design of mobile manipulative games be enhanced to make them even more trans-culturally user friendly?

The UFractions game could be improved by updating the game to run on state-of-the-art smartphones, possibly utilizing on-board sensors and augmented reality to increase the convergence of the real world and the leopards' world. For example, augmented reality technology would allow the player to see a three-dimensional model of a leopard sitting on the table next to the rods, giving hints as to which rod could be useful. The game could be integrated with smart fraction rods that would allow the game to follow the player's progress and give scaffolding aids so as to keep the players in the zone of proximal development [46]. The platform of UFractions' also enables extending the game by new content with different animals and educational topics. Investigation of the game's pedagogical and motivational affordances for different player types (like the *Killers*, *Achievers*, *Socializers* and *Explorers* defined by Bartle [47]) would allow us to adapt the game content not only for different skill levels but also for different player profiles.

10. ACKNOWLEDGEMENTS

Acknowledgement to: (i) Dr. Suria Ellis from Statistical Consultation Service, North-West University for statistical support; (ii) Carolina Islas-Sedano and (iii) Mikko Vinni for developing the Myst platform and helping to design UFractions game.This work was partially supported by the new faculty research fund of Ajou University and by the Academy of Finland (project number 128577).

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