Story-based UFractions Mobile Game in South Africa: Contextualization Process and Multidimensional Playing Experiences

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Abstract. To increase more applied and transferable learning of mathematics we present mathematical mobile, story-based -game UFractions and its contextualization for the African cultural context. The prototype of UFractions was tested during March 2009 on 105 Grade 8 learners in five South African schools and 20 students and teachers of the University of Pretoria, South Africa. A multi method approach comprising qualitative and quantitative data collection strategies was employed. Based on the empirical research, story-based mobile gaming brings many dimensions into learning. Students identified themselves with the story of the Mother leopard and her cub Senatla and the story induced ethical, physical and cognitive rationales. Participants solved actively real-life fraction problems using mathematical rods and gave affective, functional and action-oriented arguments for liking the mathematics in the game. Players' constructive feedback helps future development of UFractions.

Keywords: Contextualization, educational games, manipulatives, mobile gaming, tangible manipulatives, South Africa

1 Introduction

Most IT (information technology) learning tools are developed in Western countries for use of learners with this cultural background. The technological tools may not necessarily have the same success when used in other cultural contexts as the tools are often *dumped* without hardly any adaptations. However, *planting* of IT tools to the new environment would elicit more sustainable technology. Modifications of the technology according to the cultural context would guarantee a better understanding and utilization of the tools [1-3]. We present a learning tool, designed in Finland, but contextualized in South Africa to facilitate learning of mathematics for secondary school pupils in an engaging and motivating way.

UFractions (Ubiquitous Fractions) is an educational mathematical mobile game that utilizes Myst platform [4, 5] and applies concrete, tangible manipulatives to permit deeper understanding of mathematical concepts. The idea of using physical objects to support learning is not new. Pestalozzi (1746-1827) argued that students learn best through physical activity, using their own senses. Froebel (1782-1852) and Montessori (1870-1952) created different kinds of concrete manipulatives to assist children in starting reasoning, facilitate more advanced abstract and critical thinking, and foster creativeness [6]. Psychologist Piaget's (1896-1980) research on the development of children's intelligence showed the necessity for actual manipulation of objects when learning formal, abstract mathematical ideas [7]. Recent research indicated that the long-term use of manipulatives improve students achievements in mathematics [8], and concreteness can be used to encourage thinking and conclusions while solving mathematical problems [9]. Manipulatives [10] as well as games [11] invoke not only positive response with respect to learning but also attitude towards mathematics, so we suggest to combine them.

2 South African Context

South Africa is located in the southernmost part of the African continent and has a complex and diversified population of more than 47 million inhabitants. Although there are eleven official languages, teaching generally takes place through English, and some other languages after Grade 3. About half of the population lives in rural areas [12]. There are significant differences between urban and rural areas as well as variation by race and by province in terms of poverty. Income distribution is one of the most unequal in the world, mainly as a legacy of apartheid [13]. South Africa faces amongst others, the effects of criminality, unemployment and HIV/AIDS [14].

Although the new democratically elected South African government invests heavily in education, there is a huge demand for improving the quality of teaching and learning across South African schools. Both local and international measures and studies of learning achievements show that South African learners perform poorly, especially in mathematics, literacy and ICT skills. The main barriers to learning achievement relate to poverty, insufficient qualified teachers, learning materials and other basic resources [14]. To support educational transformation and effective learning, the Department of Education drafted a policy paper on e-education: *Transforming Learning and Teaching through Information and Communication Technologies (ICTs)* in 2004. The policy shares the view that ICTs are central to the changes taking place throughout the world. The strategical goal of the policy is to have ICT enable all students and educators by 2013 [15]. This includes not only building technical skills, but also enriching educational experiences through ICTs. The objectives of the policy are hard to achieve, but fast advancing mobile technology may improve and enhance teaching and learning.

While many schools have only few computers available, the cellular phone saturation is high and most adolescents have access to mobile phones [16]. Few pilots have already tested different technical possibilities to use cellular phones for learning mathematics in South Africa like Mobile Learning for Mathematics Project using mainly SMS-solutions [17] and DrMath on Mobile Instant Messenger MXit [18].

3 UFractions and its contextualization

In this section we (i) describe the features of the *Myst* pervasive mobile learning platform that UFractions utilizes, and (ii) present the process of creating a storyline with appropriate mathematical problems to UFractions for the South African context.

3.1 The Myst Platform

The Myst platform (no relation to the commercial Myst game) offers quick deployment of pervasive m-learning environments for different contexts. It was developed at the University of Joensuu, Finland, and previously used for several pervasive m-learning games at different locations in Finland (e.g. SciMyst [4] and LieksaMyst [5]). The Myst platform is built on top of Nokia's MUPE software [19] which allows rapid development of multi-user, networked mobile applications on Java-enabled mobile devices. A main feature of the Myst platform is its usability in various locations with minimal customization. The flexible design of the platform makes it possible to design games for a variety of contexts, content types (e.g. different media types), players (e.g. age, language) and interactions between players and non-player characters. The Myst platform offers the following game-like features:

1. Context-sensitive problems or *enigmas* as we call them that can involve queries with multiple choice or open answers, or 'take-a-picture' tasks.
2. *Battle-mode* in which the player solves enigmas against a count-down timer. The battle is to be played at the end of the game as a drill.
3. Interactive *help-feature* which allows a player to request help from another player through the mobile device. Context-sensitive hints are also available for enigmas.
4. Recording of data, *impressions*, through the mobile device's camera and text input mechanism. Sound and video recording features are also available.
5. *Story-based structure* that has one or more virtual characters – each having its own characteristics and ways to respond to the player.
6. *Guest book* which allows players to leave their comments and ideas of the learning experience. Guest book entries can be published on the game's website.
7. Synchronous integration between the players' activities and the *game's website*.

Some of these features may be used for applications. For example the designer of an application can decide if players get points from correctly solved enigmas or impressions, both of them, or neither of them. In addition to text, story-based structure can contain images, sounds and video. The storyline can be divided into a network of paths and various narrators can be created to interact with the player. Mobile devices' interaction with the game website makes it possible to create common goals for a group of players. The game website presents statistics of the players' performance. Contents of Myst-based learning environments are authored by editing XML files.

3.2 Contextualization process

When we commenced on developing a game for the South African context, we had an idea for a game with a story related to animals as a starting point. We thought to

use ants as characters because we had suitable graphics from the previous game. The subject of the game was identified as fractions so that the problems could be solved with the help of Hungarian mathematical manipulatives, i.e. a collection of twelve colored rods, each having a different color and length.

The contextualization process of the game started with school visits. The main designer of the game interviewed secondary school teachers in the North-West province about mobile games and the use of manipulatives in their classes. A suitable level of mathematics for the game was defined with the help of teachers and the Revised National Curriculum Statement Grades R-9 [20]. Because of the challenges with learners' language skills, we used simple and clear English in the game.

Considering cultural matters, we consulted a researcher in Indigenous Knowledge Systems, Mpobe Letsholo of the North-West University and Satsopa Johannes Shole, a professor in Setswana at the University of South Africa. They maintained that although the ant is universally acknowledged for its hard-working characteristics, ants are not ideal role models for use in educational games in South Africa, as they are not considered significant in the African culture. These researchers recommended that we use the leopard, as it is regarded as the symbol of strength and royalty in African culture. According to Mpobe Letsholo *"The chiefs use the skin of a leopard as a symbol of chieftaincy. No other person can wear that skin, because it will be taken as an offense. The hard working part of leopard is when it defends itself, when it takes care of its young ones, and also when defending its territory".*

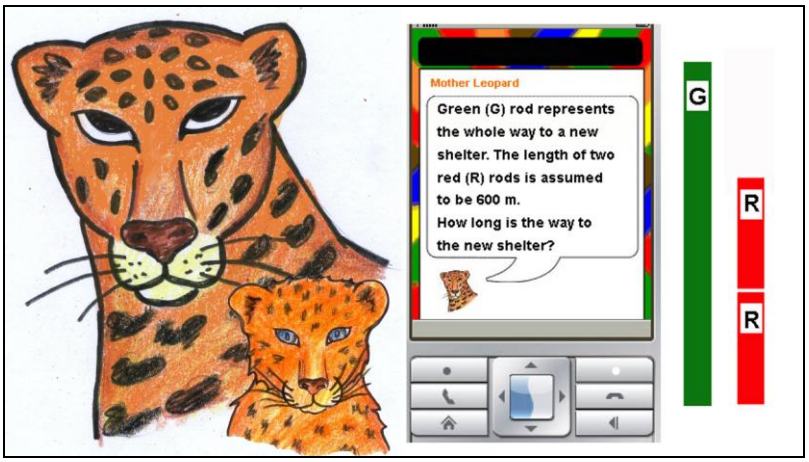

Fig. 1. Mother Leopard, her cub Senatla, example of mathematical problem and the use of rods

Consequently, the UFraction designers decided to use "Mother Leopard" and her cub "Senatla" (Fig. 1.) as role model characters for the game. The word "Senatla" means strong and powerful in the Setswana language. In the UFractions game learners assist Mother Leopard to raise her cub and fight against hunger and enemies living in the South African savannah territory. Players earn points by solving enigmas related to the two leopards' life. To make the storyline and problems more authentic, we explored the characteristics and behaviour of leopards in their natural habitat by studying literature [21] and visiting the Predator Park and Pilanesberg Game Reserve.

We created enigmas as fraction problems that can be solved with the help of math manipulatives. This goes beyond mere calculations — the game players have to understand the problem and concept of fractions. The solutions to the enigmas are numbers, letters (color codes of the rods) or choices from the list of different answers, so players interact with the mobile device using keys of cellular phones.

At the start of the game players are introduced to the leopards and challenged to solve four introductory problems that guide them how to use the rods. After the introduction they can select either "Feeding the cub: 0-16 weeks", "Lessons to hunt: 4-12 months" or "Whole year". The storyline involves different paths that players can choose while the game develops further. Alternative paths have different difficulty levels. Figure 2 shows the storyline for the "Feeding the cub"-part, and for example, the "Moving the cub to a new shelter"-activity starts with Mother Leopard's comments: *"I have to move Senatla to a new shelter every two or three days to confuse the enemies like lions, baboons and hyenas that may come looking for an easy meal. Now I will carry Senatla in my mouth to a nice peaceful cave where I can leave him while I am hunting during the night. Now your task is to answer some problems, so that moving Senatla to a new shelter succeeds."* A fraction problem connected to this part of the story and the use of mathematical rods is shown in Figure 1.

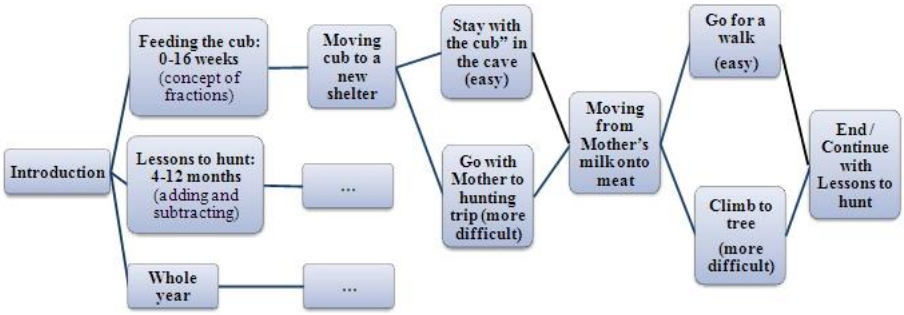

Fig. 2. Example of storyline, "Feeding the cub"-part

Creating an effective educational game is more than creating an engaging storyline and designing an age-appropriate educational content. We designed the layout of the game and drew pictures of leopards. We created suitable hints for every problem that could be asked from leopards after an incorrect answer. Hints do not provide the answer immediately, but lead players on the right path to solving the problem. Positive feedbacks were tailored for each problem and negative feedbacks were randomly picked from a pool of negative feedbacks. We involved the feature that allows players to record impressions after the first part of the game. By taking pictures of the surrounding information and adding a comment on the pictures players can show their knowledge of fractions and identify mathematics from their everyday environment, or simply send greetings to the leopards. Finally, we created a website that displays the current status of the leopards' and players' struggle against hunger and enemies — the two main threats of the leopards. The website also presents the scores of the teams, recorded impressions and guest book entries.

4 South African experiences with UFractions

4.1 Research methodology

A multi method approach comprising qualitative and quantitative strategies was employed. The aim of the study was to explore and explain the phenomena of mobile gaming in a developing country context and to test the prototype of the game. The dominant method was a qualitative case study and quantitative methods were used to extend the qualitative approach. Participants responded to a questionnaire that comprised open-ended and multiple choice questions. While the open-ended questions formed part of the qualitative data, multiple choice questions offered extensive quantitative data. Triangulation of the observation and interview data of students and teachers extended the integrated dataset. Testing of the UFractions game targeted 105 Grade 8 students at five secondary schools in the North-West Province, i.e. Alabama Secondary in Klerksdorp (21 participants), Lebone II in Rustenburg (22 participants), Seiphemelo Secondary in Potchefstroom (16 participants), High School Zeerust in Zeerust (27 participants) and Zinniaville Secondary in Rustenburg (19 participants). In every school students played the game in groups of two to four students. Additionally 20 students and teachers from the University of Pretoria, mainly from the department of Informatics, tested the UFractions game.

4.2 Playing experiences

According to the observations all the students engaged in playing UFractions and researchers had even to ask them many times to stop playing. The level of engagement is visible for example from one student's comment: *"Would want to go on and on… and just never stop… like when you said that we have to stop I was so angry".*[1]

Table 1. Frequency table of questions related to the contentment and usability

	Strongly agree	Agree	Disagree	Strongly disagree	I don't have an opinion
It was fun to play with the phone	102	17	3	0	3
Compared to ordinary class this was exciting	100	17	3	0	5
It was easy to use phone for playing	90	28	4	1	2
Game helped me when I got stuck	70	40	9	0	6
Typing the colour codes was easy	75	38	1	1	10
The size of the text was big enough	77	36	9	0	3

[1] Quotations are directly from the players' texts, including mistakes and spelling errors.

All students took intensively part in the game play and quantitative data shows participants' contentment to the game; almost all the participants thought that it was fun to play with mobile phones and, compared to ordinary mathematics class activities, game play was exciting (Table 1). Students argued actively about the math problems and the team spirit was most visible after the correct solutions: groups cheered happily (Fig.4). After game play students were eager to view the web pages to determine if Senatla had survived, and how their group's totals compared to others.

Fig. 3. Students' reactions to learning the correct answers were cheerful

4.3 Most players liked game activities

Relative frequency from the quantitative data related to the different game activities was calculated and the frequencies of strongly agree and agree answers were added together (Fig. 4) to get the most liked game activities. This quantitative analysis of multiple choice questions shows that most liked game activities were problem solving, using mobile phone, playing with the rods and reading the story.

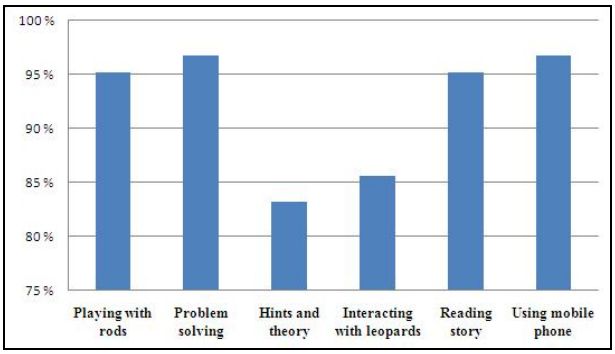

Fig. 4. Most liked game activities according to quantitative analysis

Qualitative analysis of open question "What did you like/enjoy about playing with Leopards" shows more precisely what kinds of dimensions different activities bring into the playing experience. Most answers relate to the story of leopards. Answers like

"I will take care of her child that she is eating well" and *"When I saw the forest and the catch that mother leopards got"* shows players' profound identification with the story. By doing cluster analysis we found three different rationales related to the storyline; ethical, physical and cognitive (Table 2). Many participants mentioned that they liked mathematics in the game. Comments considering mathematics can be divided into three arguments; affective (intrinsic motivation to mathematics), functional and action-oriented (Table 2). Playing with the rods as well as playing with the mobile phone was mentioned as an enjoyable activity, like for example: *"It was nice to play around on a phone and getting educated at the same time".* The way of learning was thought by several players and typical comments related to this theme are for example: *"Fun way to learn", The way it is presented is very interesting"* and *"Its more nice to learn maths by playing a game unlike learning it in class".*

Table 2. Rationales related to the story and different arguments about mathematics in the game

Ethical rationale	Cognitive rationale	Physical rationale
"I enjoy playing with leopard because I was helping them" *"I really enjoyed playing the game, because I want to help the wildlife"*	*"I enjoyed knowing and learning about them."* *"I enjoyed learning how they survive in the wild and what they eat".*	*"I enjoyed feeding Senatla and playing with him"* *"When they run fast I want to compite with them"*
Affective argument	**Action-oriented argument**	**Functional argument**
"I liked the fractions a lot" *"Adding the things together"* *"I do like more think like fractions cm, kg, km and so on."*	*"Hands on"* *"I enjoyed solving the problems"* *"The problem solving was great!"*	*"It enabled my with my maths"* *"It exercise your brain"* *"To make use of my mathematical brain."*

4.4 Usability of UFractions and improvement suggestions

Participants were asked multiple choice questions about the usability of the game in the questionnaire; 94,4% agreed that it was easy to use phone for playing, 88,0% felt that phone helped them when they got stuck, 90,4% thought that typing the colour codes was easy and 90,4% agreed that the size of the text was big enough (Table 1).

Players were asked what they disliked or found difficult about playing with the leopards and how they would like to improve the game. Answers to the open-ended questions in the questionnaire and interviews show that one of the most disliked characteristic was the mathematics in the game. Typical comments considering math problems were:*"I didn't like the fractions. Some of the questions were tricky to answer.", "The fraction part where you got to find your own answer.", "They were a stage when I got confused with fractions.", "I dislike when I have to divide so I have to find the right answer."* The level of mathematics was considered both too difficult and too easy. Students' suggestions for improving the questions were like: *"Make a little harder questions.", "There should be easier questions for smaller children.", "Put more stuff other than fractions."* Although the story of leopards was liked a lot, it also got some critique: *"Dislike the hahienas eating the cub.", "I didn't like when I heared that mother leopard is struggling to feed Senatla and keep him from a safe place.", "I dislike the dangers the Leopards face and how they mark their territory.", "That they eat a lot of meat. Why they like to kill?",* Players suggested adding another baby to take care of, involving the father of the cub and other characters. Also making of longer storyline and adding more chapters to the leopard story was suggested.

Participants paid also attention to the technical features of the game and suggested to add more functions like going back on the menu to repeat questions. Few players would prefer a computer game because the screen is larger. Some argued that one cellular phone for three students was too few. Students also wanted to have the game for more phone models and commented that *"Get it out soon"*. Some players mentioned that they would like to increase their control in the game: *"...for us to be able to direct the leopard and when we come to a problem figure it out and proceed"*. Development ideas related to the graphics of the game considered adding of 3-D pictures, music, sound and speech. One student wanted *"to make it faster and more realistic, like say u' do sumthing rong the lion crys and right the u can help the lion".*

5 Conclusion and future research

This paper has presented contextualization of UFractions mathematical mobile game and a qualitative case study of its testing in a real-life context. The design process of the game started from the available Myst platform and contents to the game were contextualized by exploring behavior of leopards in their natural habitat and interviewing South African teachers and culture experts.

Identifying the new opportunities that mobile gaming together with tangible manipulatives gives to a more applied and transferable learning and teaching of mathematics: Game playing extends and enriches education by bringing many dimensions into the learning process. Story of the leopards induce ethical, physical and cognitive rationales, meaning that leopards as role models provoked feelings that are not typical in an ordinary mathematics classes like urge to help and feed the cub, run with him or learn interesting things about leopards' lives. Reasons to like mathematics in the game are affective (intrinsic motivation to mathematics), functional and action-oriented. Playing the game in the groups is effective in sense of argumentation considering mathematical problems and learning by doing together. Every student is able to participate and proceed at their own level, aiming at common goal. The theory and hints in the game helps with solving the mathematical problems and phone gives immediately feedback after players' answers to the questions.

Playing experiences show that usability of UFractions is good and students are able to use phone easily as a playing tool. In the future designers of Ufractions will take into consideration players' suggestions about technical aspects, like back button to repeat the questions, improvements to graphics and more levels and paths to the story. We will also consider different techniques for better adaptation to the knowledge level of the students as well as use more pervasive features of mobile devices to connect mathematics to students' every-day environment.

UFractions has only been tested on Nokia N80 and N95 devices but it should run on any phone supporting Java and WLAN connectivity. However, we would like to develop and test the game further so that it could be conveniently used over the Internet and with the most popular phone models. Next step in our research is to bring UFractions back to Europe and test how Finnish students experience the story of leopards and let them use their imagination to extend the story of leopards or create completely own story to mathematical mobile game. Myst platform will also be used in other contexts and subjects –all you need is a good story and a context.

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