## Ubiquitous Mathematics from South Africa to Finland: Does Reverse Transfer Work?

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### Abstract

Ubiquitous learning spaces are inherently context adaptive: their context-aware features allow an educational system to be automatically configured to a set of aspects of a given context. UFractions is a ubiquitous mobile game that combines a storyline with manipulatives for learning fractions, and in which context adaptation is limited to the set of manipulatives. UFractions was created for a South African context and then reverse-transferred to a Finnish context. In reverse transfer, a technology designed in and for a technology-alien context is taken as such to a technology-familiar context. An evaluation of UFractions in the two contexts indicates that the game needs to be adapted to the pedagogical and cultural context of its users. Hence, reverse transfer is not enough for a successful learning environment; context adaptation is required. For ubiquitous learning games, such as UFractions, our findings indicate that learning contents and activities need to be re-contextualized.

### 1. Introduction

New technologies offer new educational opportunities, and the increasing availability of affordable mobile devices, in particular mobile phones, allows the educational benefits to be available in communities which have hitherto not had access to those new technologies.

A particular approach which may be effective is game-based learning, not least because the engagement of students with playful activities in the learning process can be highly motivational.

In this paper, we consider a technology developed to support mobile game-based educational software, and present a case study of a game developed using the technology. This game --- UFractions --- was written to support learners in South Africa who are learning fractions as part of their mathematics curriculum, and has been deployed in South African schools. The same game was subsequently delivered to a class of Finnish learners on the same grade level who were also learning about fractions. We call this delivery *reverse transfer*, in contrast to a typical technology transfer which takes a technology created in a technology-familiar environment (like Finland) to a technology-alien environment (like many places in South Africa).

We hypothesized that the two groups of learners would react differently to the technology and to the educational content, and we wished to explore how those differences would manifest themselves and what underlying reasons might account for them.

The paper proceeds as follows. We first outline the technical and the theoretical foundations for our approach. We then describe the contextualization and reverse transfer together with the UFractions game, including the game design, its implementation, and how we evaluated it when we tested it with learners. This is followed by a discussion of the evaluation results and, before concluding the paper, we outline how the results of this paper inform the development of future ubiquitous learning spaces.

## 2. Background

### 2.1. Research contexts

UFractions game was designed in and for South African context, and then reverse-transferred to Finnish context. Specifically, North West Province in South Africa, and North Karelia Province in Finland were the geographical areas of this research (Figure 1). In this section we describe the key aspects of these contexts, which are summarized in Table 1.

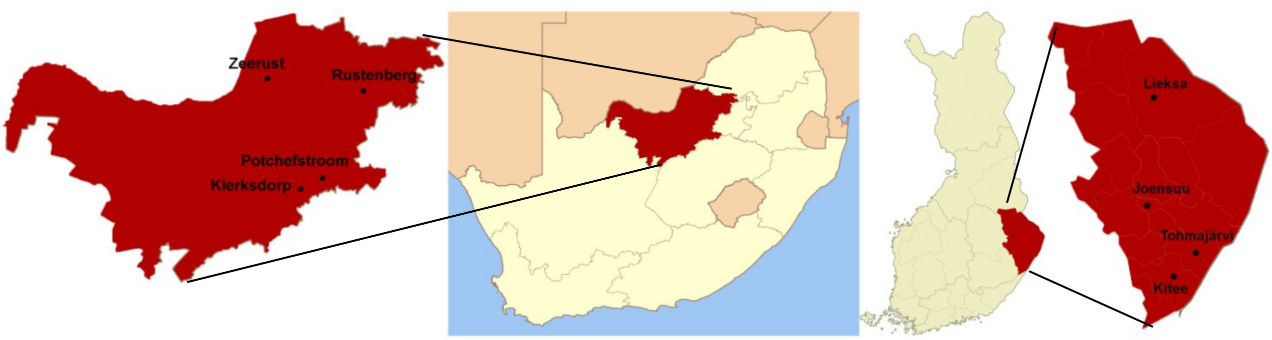


Figure 1: Locations of the North West Province in South Africa and the North Karelia Province in Finland

Table 1: Comparison of key statistics of Finland and South Africa

| Finland | South Africa |
|---|---|
| Population : 5 400 000<br>Density: 15.7 inhabitants/km² | Population: 49 320 500 (Statistics South Africa, 2009)<br>Density: 40.4 inhabitants/km² |
| Area: 338 145 km² | Area: 1 221 037 km² |
| Official languages: Finnish and Swedish | Official languages: Afrikaans, English, isiNdebele, SeSotho, Sepedi, siSwati, Setswana, Xitsonga, Tshivenda, isiXhosa and isiZulu |
| Literacy rate: 99.0%[1] | Literacy rate: 82.4% [1] |
| Mobile cellular subscriptions per 100 inhabitants 2008: 128.76<br>Ratio of mobile cellular subscriptions to fixed telephone lines: 4.1:1<br>Compound Annual Growth Rate (%) in mobile cellular subscriptions 2003 – 08: 7.5<br>(International Telecommunication Union, 2008) | Mobile cellular subscriptions per 100 inhabitants 2008: 90.60<br>Ratio of mobile cellular subscriptions to fixed telephone lines: 10.2:1<br>Compound Annual Growth Rate (%)in mobile cellular subscriptions 2003 – 08: 21.7<br>(International Telecommunication Union, 2008) |
| The Second Information Technology in Education Study (SITES 2006)<br>- Level of access to computers: 100%<br>- Level of access to internet: 100%<br>- The amount of computers per school is approximately 64, of which 72% was used by pupils, 13% by teachers and 6% by administrative personnel.<br>- The number of computers per school varied from 11 to 304.<br>- Mobile devices were used for learning in 11 % of schools<br>- Ratio pupil/computer: over 70% of schools had less than 10 students per computer<br>- Educational software in 66% of schools (Kankaanranta *et al*., 2008) | The Second Information Technology in Education Study (SITES 2006)<br>- Level of access to computers: 38%<br>- Level of access to Internet: 67%<br>- Computer access at schools: 38%<br>- Only 15% of mathematics and science teachers use ICTs for teaching and learning |
| **North Karelia** | **North West Province** |
| Population : 166 000<br>Density: 9,34 inhabitants/km² | Population : 3 450 400<br>Density: 32,39 inhabitants/km² |
| Area: 21 584 km² | Area: 106 512 km² |

### 2.1.1 South Africa

South Africa is situated at the most Southern tip of Africa and consists of nine provinces with huge differences in size, economical viability and population density. Each province has its own legislature, premier and executive council, distinctive landscape, population, and climate. They are the Eastern Cape, the Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, the Northern Cape, North West, and the Western Cape. South Africa can be described as a medium sized country consisting of total land area of slightly more than 1.2-million square kilometers. The North West province is one of the smaller and less affluent provinces. The over 49-million people have a wide variety of cultures, languages and beliefs. Although KwaZulu-Natal has the most people, Gauteng is most densely populated province. Of the eleven official languages, English is the most spoken in commercial public life. IsiZulu is the mother tongue of 23.8% of South Africa's population, followed by isiXhosa at 17.6%, Afrikaans at 13.3%. South Africa's first democratic election took place in April 1994, with victory to the African National Council (ANC) with Nelson Mandela as president (Southafrica.Info, 2010).

[1] http://en.wikipedia.org/wiki/Literacy (accessed April 27, 2010)

South Africa has 12.3-million learners, about 386 600 teachers and 26 292 schools. About 6 000 are high schools (grade 7 to grade 12) and the rest primary schools (grade 0 to grade 6). The national Department of Education is responsible for education across the country as a whole, while each of the nine provinces has its own education department. The central government provides a national framework for school policy, but administrative responsibility lies with the provinces. School life spans 13 from grade 0 through to grade 12. Under the South African Schools Act of 1996, education is compulsory, but not free in all cases for all South Africans from age 7 (grade 1) to age 15, or the completion of grade 9 (Southafrica.Info, 2010). Very poor schools are excluded from school fees and are subsidized with feeding schemes.

South Africa is rich in diversity in terms of income, culture, languages, and technology. On the one hand, South Africa is renowned for its technological innovation and development; and on the other hand, the majority of South Africa's learners do not share in the expectations of the information age. These inequalities become obvious in educational delivery where only about 65% of learners that enter the final school examination, pass it. South Africa performed less than adequate in the most recent International Mathematics and Science Study (TIMMS) where its learners bottom ranked (Gonzales et al., 2004). The Progress in Reading Literacy Study (PIRLS) indicated that grade 3 and 4 learners' reading skills by far do not meet international standards (Edac Wowe, 2008). The results of the most recent Second International Technology in Education Study (SITES 2006) — a longitudinal large-scale international comparative survey on the use of Information and Communication Technologies (ICTs) in schools (Law et al., 2008) indicated that South Africa was the only country in the SITES 2006 study that could not provide students with full access to computers. South African schools' overall computer access (38%) remains dismally low when compared to other education systems in developing countries such as Estonia (100%), Chile (96%), and Israel (96%) (Blignau*t et al*., 2010b). Only about 15% of South Africa's mathematics and science teachers' used ICTs in their teaching and learning (Blignau*t et al*., 2010a).

To consolidate and guide diverse initiatives towards the educational transformation, the Ministry of Education published the White Paper on e-Education: Transforming Learning and Teaching through Information and Communication Technologies during August 2004 (Department of Education, 2004). This initial, and to date the only ICT policy for South African education, presents a framework for the strategic, political, pedagogical, and developmental facets of implementing e-education in South Africa. The unobtainable strategic objective of this e-Education policy states that, "Every South African manager, teacher and student in the general and further education and training bands will be ICT capable, that is, use ICTs confidently and creatively to help develop the skills and knowledge they need as lifelong learners to achieve personal goals and to fully participate in the global community by 2013" (Department of Education, 2004: 17). The e-Education policy framework supports four key elements of ICT use in teaching and learning: *equity, access to ICT infrastructure, capacity building,* and *norms and standards.*

### 2.1.2 Finnish context

Finland is located in northern Europe between Russia and Sweden, and the majority of the 5,400,000 population reside in southern Finland (about 1,000,000 in the metropolitan area of Helsinki). The geographical area of Finland is 338,145 $km^2$, and is the most sparsely populated country in the European Union with 15.7 inhabitants per $km^2$. Official languages are Finnish and Swedish, although Finnish is the most common language spoken by 91%

of inhabitants (Statistics Finland, 2009). Following 700 years of rule by Sweden, and latterly Russia, Finland became an independent parliamentary democracy in 1917 and is now a member of European Union (Finland Promotion Board, 2010).

Finnish students are highly placed in international comparisons of science skills, such as the OECD PISA (Programme for International Student Assessment) surveys which test the mathematics, science, reading literacy and problem-solving skills of 15 year old students in over 40 countries. PISA tests address essential knowledge rather which are not specific to any curriculum (Ministry of Education, 2007), and Finnish students' scores have been among the best in all subjects in all three PISA surveys (Oecd, 2007).

Finnish students' performances in PISA tests have been consistent and the differences between the strongest and weakest results in Finland are small as well as differences between schools and regions. Socio-economic background and language group have a lower impact on Finnish students' performance than in the other PISA countries. The Ministry of Education identifies reasons for success which include equal opportunities, comprehensiveness of education, competent teachers, student counseling and special needs education, encouraging evaluation, a flexible system based on empowerment, co-operation and a student-oriented, active conception of learning, rather than financial expenditure on education (which is the OECD average) (Ministry of Education, 2007).

The Finnish education system consists of one year voluntary pre-primary education, nine-year compulsory basic education (comprehensive school), followed by upper secondary education and higher education. Students start their compulsory schooling at the age of seven years and continue until they have accomplished all nine grades or are aged 17. Almost all Finnish students (99.7%) complete the basic education syllabus (Finnish National Board of Education, 2010).

Basic education in Finland is free of charge including books, school meals and health care. Most comprehensive schools are public schools and compulsory education is monitored by local authorities. Basic education providers construct their own curricula according to the instructions in the national core curriculum given by Finnish National Board of Education. Generally teachers are highly qualified and a Master's degree is required at all school levels (Finnish National Board of Education, 2010).

The Second Information Technology in Education Study (SITES) assessed the use of ICT in lower secondary schools in 2006 in different countries (Kankaanranta *et al*., 2008). Although the use of ICT in Finnish schools is quite high (Table 1), not all Finnish students have equal possibilities to use ICT for learning and developing good ICT literacy skills. SITES research also showed that 61% of science teachers and less than 48% of mathematics teachers had used ICT during a specific period during the school year and there are many teachers have never used ICT in their lectures, suggesting that pedagogical opportunities of ICT are still untapped (Kankaanranta *et al*., 2008).

### 2.2 Mobile, Ubiquitous and Pervasive Learning

Mobile learning, or m-learning, is a form of informal learning where the learner traverses one or more physical contexts carrying a personal mobile device which provides learning materials and activities. Wireless networks can enable content sharing among learners as well as retrieval of learning materials from the server and support for collaborative activities. The key benefit of m-learning is that it enables learning experiences regardless of location and time. Affordable mobile technology is appealing for learning applications, and is particularly useful in informal settings outside classroom environment also in addition to use in classrooms (Eschenbrenne*r et al*., 2007; Naismit*h et al*., 2004; Trifonova, 2003).

The Merriam-Webster dictionary defines the word *ubiquitous* as "existing or being everywhere at the same time", i.e. being all around us. The term *ubiquitous computing* was coined by Marc Weiser with a popular phrase:

> *The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.* (Weiser, 1991: 94-104)

Weiser also accurately predicted that ubiquitous computing would become the dominant mode of computer access 20 years following the article's publication. In particular, wearable computers (e.g. augmented reality visors, smart clothes, body sensors) and wireless sensor networks (e.g. environmental monitoring, vehicle monitoring, area surveillance) are increasingly being researched and deployed.

*Ubiquitous learning*, or *u-learning*, is a subcategory of mobile learning with an emphasis on embedded, ubiquitous computing and context-awareness. In addition to anywhere-any time properties inherited from m-learning, the context-aware nature of ubiquitous learning takes into account aspects of the learner's context, e.g. who else is with the learner, what resources are nearby, what the learner is doing, and what the environmental parameters are. In other words, "context is all about the whole situation relevant to an application and its set of users" (Dey, 2001).

So, how can ubiquitous learning utilize available ubiquitous computing devices? Context-awareness enables the technologies to be used to provide the richest possible set of contextual information. The extent to which context-awareness can be supported depends largely on the available technical resources as well as on the requirements of the application. At its simplest, context-awareness can be mere location-awareness (e.g. GPS). Include the learner's direction (compass), nearby peers interconnected client devices), weather (temperature, humidity, wind sensors), body awareness (heart rate, body temperature, stress level) and information on the learner's preferences (user profile management and background data elicitation), and the possibilities to provide highly relevant learning content increase rapidly. In addition to context-awareness, ubiquitous technologies address the shortcomings of client mobile devices used in learning applications. A small screen can be complemented, for example, with a touch screen installed at a bus stop, interacting with the learner's mobile device. Poor input capabilities can be enhanced by moving from text-only input towards providing alternative ways of recording the learner's status via for example, voice or face expression recognition, or bio-sensors affixed to the learner's body. Finally, the restraint set by the low processing power can be tackled by using high-capacity servers to perform computationally complex operations.

*Pervasive learning*, or p-learning, is another subcategory of m-learning and closely related to ubiquitous learning. Although the phrases pervasive learning and ubiquitous learning are sometimes used interchangeably, we make a distinction between the two at the level of the learner's mobility (Lyytine*n et al*., 2002). In ubiquitous learning the learner is traversing different contexts and the embedded technology supports this transition, whereas in pervasive learning the learning process and the learner are typically attached to a particular context such as a museum. Both ubiquitous learning and pervasive learning have a strong connection to context-awareness. A ubiquitous learning equivalent for a pervasive learning application in a specific museum could be a city-wide learning environment where the learner would be able to traverse several museums, receiving context-sensitive learning activities at each location. However, in ubiquitous learning context-sensitiveness is more limited than in pervasive learning where the learning technology is specifically designed for a particular context and the more there are differences between the contexts the harder it becomes for ubiquitous learning environment to provide deep contextual information from each target context.

Context-aware learning environments that support ubiquitous and pervasive learning are referred to as a *ubiquitous learning space* (ULS) and a *pervasive learning space* (PLS), respectively.

### 2.3 Game-based learning

There exists considerable interest in the use of technology for gaming, due to the ubiquitous nature of technology in modern society and our natural human approach to play. Consequently, at the end of the 1990's research in digital games commenced.

The use of play as exploratory learning is not new (Reilly, 1974). Alessi and Trollip (2001) note that educators consider games suitable for children, and also highlight the use of games for business school students. Game researchers have categorized as *serious games* those games that have a purpose beyond entertaining (Michae*l et al*., 2006), and in particular Game Based Learning focuses on games with well-defined learning outcomes.

Kirriemuir and McFarlane (2004) identify a need for a better understanding of games as tools and the use of games within educational constraints (schools, teachers, parents, resources, curricula, student's time, etc.), and this study contributes to understanding requirements for educational games.

Despite the large number of different game genres and technologies, most current games are designed to be context-neutral; that is, they are played in any place by anyone. This applies particularly to mobile-based games which are confined to the screen of a mobile device and thereby disregard the richness of the surrounding environment. In this paper, we specifically focus on the ubiquitous side of game-based learning where mobile devices are used as learning tools, and on games designed to support context-awareness. In addition to mobile devices, game-based ULSs may use real world objects as part of the game play. Context-awareness in ubiquitous (and pervasive) learning games opens new possibilities for rich interactions with the physical environment.

### 2.4 Technologies for mathematics education

There exist various educational technologies to support the learning of abstract mathematical concepts. In this section we present two of them that are relevant to the UFractions game: concrete manipulatives and mobile applications for supporting mathematics learning.

#### 2.4.1 The Use of Manipulatives in Mathematics

Mathematical *manipulatives* are concrete objects designed to support the learning of mathematical concepts. The importance of involving physical senses in the learning process of formal, abstract, mathematical ideas is well understood (Piaget, 1969). Concrete manipulatives, like pattern blocks, fraction bars, tangrams, and geoboards are widely used in today's classrooms, although recent research has not shown unambiguously their effectiveness.

Proponents of manipulatives suggest that the long-term use of concrete manipulatives improves students' mathematical achievements (Raphael *et al*., 1989; Sowell, 1989), encourages students thinking during mathematical problem solving (Kamii *et al*., 2001) and improve students' attitudes towards mathematics (Sowell, 1989). Critics of concreteness suggest that using manipulatives does not automatically guarantee better learning outcomes and meaningful learning learning (Clements, 1999; Scudder *et al*., 1997). Many studies agree that the critical factor for the effectiveness of manipulatives is the manner in which they are integrated into the learning process (Clements, 1999; Kamii et al., 2001). To use manipulatives successfully, teachers should take into account students' ideas and perceptions of what the manipulatives represent, manipulatives must be chosen and used meaningfully (Scudder et al., 1997), and they should be used before the introduction of formal symbolic instruction (Sowell, 1989).

The use of concrete manipulatives especially helps the understanding and conceptualization process of students with learning disabilities (Brigham *et al*., 1996; Cass *et al*., 2003; Maccini *et al*., 2000). Concrete-Representational-Abstract (CRA) instructional approach suggests that mathematical concept development happens through three stages; 1) concrete, 2) representational (pictorial or semi-concrete) and 3) abstract. During the concrete stage of CRA, learners manipulate real objects to demonstrate a mathematical idea. In the representational stage, a concrete model is transformed into the representational level by representing relational statements, for example by drawing pictures or diagrams. Finally, during the abstract stage, a mathematical concept is modeled at the symbolic level, using only numbers, notations, and mathematical symbols (Maccini *et al*., 2000). Figure 2 presents how CRA strategy could be used for learning fractions with help of fraction bars (also called Cuisenaire Rods[2]).

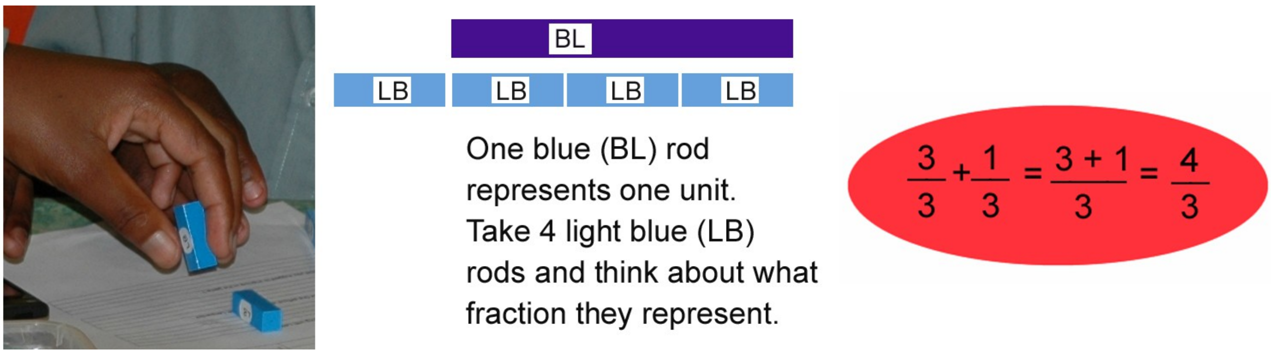


Figure 2: An example of the CRA instructional approach in learning fractions.

### 2.4.2 Mobile technology in mathematics

Much research has been done in the use of mobile devices for learning purposes, some applications having more game-like features than others. For mathematics education, there are several mobile-based tools of which a selection is presented in this section.

[2] The name Cuisenaire® as well as the special color sequence of the Cuisenaire Rods are registered trademarks of ETA/Cuisenaire®.

While the tools we present here have emerged from the scientific community, there are also commercial mobile-based learning tools for mathematics.

Dr Math (Butgereit, 2007) is a South African mathematics tutoring environment built on the mobile-based MXit instant messaging service which is highly popular among South African youngsters[3]. The key idea behind Dr Math is that teenagers using MXit can anonymously ask text-based questions related to mathematics from tutors behind the Dr Math avatar. The tutors in turn, from behind desktop computers, provide individual help to the teenagers. The service was set to run on certain days and times each week and advertisements were posted at a local high school. According to evaluations (Butgereit, 2007), Dr Math was an enjoyable and encouraging experience for the participants, although a drawback was the inability to use drawing and illustration tools. At the time of writing, Dr Math is being adapted to the Mobicents telecommunications platform, making it more scalable and accessible to a wider audience (Butgereit *et al*., 2010).

Sudoku[4] is a popular pastime activity that is very suitable for mobile devices due to its simple layout and operation. Nestler et al (2008) took the idea of a mobile-based sudoku one step further, combining it with a multi-touch table for collaborative game playing. Views on the table and on mobile devices are synchronized so an action performed by a player on a mobile device is immediately shown on the touch screen table, and vice versa. This research is an example of how the coupling of mobile devices and a tactile user interface could be used to support collaborative game play and learning.

Math4Mobile is a suite of Java-based graphical mathematics tools to support learning of mathematics at high school level and above. Learning materials can be constructed and shared with other users. Botzer and Yerushalmy (2007) studied the use of Math4Mobile for modeling real life scenarios and increasing collaboration between test participants. The study followed four students who were given a task to engage in mathematical modeling in their everyday life situations, using a camera to record the target situations. Created models and recordings were then shared between the participants and commented upon. This study shows that it is indeed possible to combine abstract mathematical concepts with concrete aspects of the real world.

The MOBI project is a South African initiative which aims to alleviate the South African science and mathematics education problem through the use of Java-based mobile applications (Matthee *et al*., 2007). The project has yielded a mobile learning environment which includes live tutoring (similar to Dr Math above), radio, chat, and mathematics training. Before using the environment, the user is assessed by a multiple choice test to determine their proficiency level in the subject so as to provide adapted content.

Skills Arena is a suite of mobile-based games for learning basic arithmetic skills. After creating an avatar, the player chooses a suitable game type and skill level for their ability and learning goals. There is a time limit for given tasks and immediate feedback is provided after answering. The use of Skills Arena and the use of flash cards in learning basic arithmetic skills have been compared, and results suggest that a mobile game such as Skills Arena has a positive impact on students' learning in mathematics, especially those with low-abilities skills (Shin *et al*., 2006).

## 2.5 Summary

[3]http://www.itnewsafrica.com/?p=2730 (accessed April 27, 2010)
[4]http://en.wikipedia.org/wiki/sudoku (accessed April 27, 2010)

While many mobile-based games for learning mathematics have been developed, to our knowledge nobody has yet combined concrete manipulatives and a mobile-based game to form a ULS that can be used in different contexts. In this paper we introduce UFractions, a ULS, which combines a story-based mobile game with fraction sticks. The game was designed for learning mathematics in the South African context. Our motivation to target South Africa stems from the fact that mobile devices are the primary computing and communication devices for many South Africans. Additionally, especially in developing regions of South Africa, the challenges in mathematics education are enormous. Finland, on the other hand, is a technologically advanced country with an excellent educational system. Technologies developed in countries like Finland are typically transferred to developing contexts. In this research we take the unexplored road of reverse transfer by designing the UFractions game in technology-alien South African regions and then taking it to technology-familiar Finland. In the next section, we define related concepts and describe UFractions. We then evaluate how well reverse transfer works from the perspectives of the cultural and pedagogical contexts, and identify the effects of technology integration.

## 3 Case Study on Reverse Transfer: UFractions

### 3.1 Contextualization and Reverse Transfer

In the design process of technologies, including educational games, there is a need for a contextualized approach (Vesisenaho, 2007). In short, contextualization refers to a design principle which takes seriously the expectations, needs and especially the strengths of the context that the proposed technology should serve.

Context has many aspects, such as cultural, pedagogical, physical or political. *Technology-alien* describes a context which uses relatively little technology, whereas a *technology-familiar* context is known for its high exploitation level of technology.

Needs-based design is a conventional approach to creating contextually relevant technologies. However, when basing the design on existing lists of needs or demands, the needs-based approach does not take into account the resources of a particular context.

Strength-based design (Sutinen, 2010) starts the contextualization stage by exploring the strengths and resources of the intended user context of the technology. Compared to the deductive needs-based approach, the strength-based approach requires creativity and induction.

Whereas conventional needs-based design is quite straightforward, the strength-based approach to contextualization requires participatory design which embeds the potential users of the technology into the design process. An example of strength-based design is the design process of HIV/AIDS educational learning materials in Tanzania where youngsters used their own experiences to come up with meaningful educational content, based on their real-life experiences and stories (Duveskog *et al*., 2009).

*Re-contextualization* is a process that adapts a contextually designed technology into a new context (Bada *et al*., 2009). The aim is to design viable technologies that can not only sustain but also modify and reproduce themselves in a new environment.

Re-contextualization relates closely to context-awareness which is an inherent property of both ubiquitous and pervasive learning. A future highly context-aware technology could, in principle, be used to automatically adapt an educational system and material to a new context, i.e., to re-contextualize it. Until such a powerful technology emerges, contextual design remains a key factor for successful re-contextualization.

In this paper, we explore the process of reverse transfer of a ULS and the relevance of its outcome to the users of a new context. *Reverse transfer* refers to a process where a technology, designed for and within a technology-alien context, is transferred as such to a technology-familiar environment. Thus, reverse transfer does not re-contextualize the technology, and its outcome can be used to analyze the role of contextualization of technology.

### 3.2 Context adaptation

Being aware of the context is one of the key features both in ubiquitous learning and in pervasive learning. Even though pervasive learning is tied more to a specific context than ubiquitous learning, both utilize embedded technologies to provide the system with context-sensitive information about the learner's current context. *Context adaptation* refers to the ability of a system to adapt automatically to diverse aspects of context (e.g. physical, cultural, political, technological, social) when the system is being transferred to a new context. Figure 3 illustrates the levels of context adaptation in plain mobile learning, pervasive learning and ubiquitous learning. For example, when a context adaptive learning game is being transferred from context A to context B, it is expected to automatically adapt to the culture, available technological infrastructure, and pedagogical requirements of the target context B. In addition, the context-adaptive system may take into account other aspects such as the learner's identity, environmental conditions, financial constraints, and political reality. In case of reverse transfer, the importance of technological context adaptation is low because the users in the target (technologically-familiar) context are unlikely to have problems operating the transferred technology.

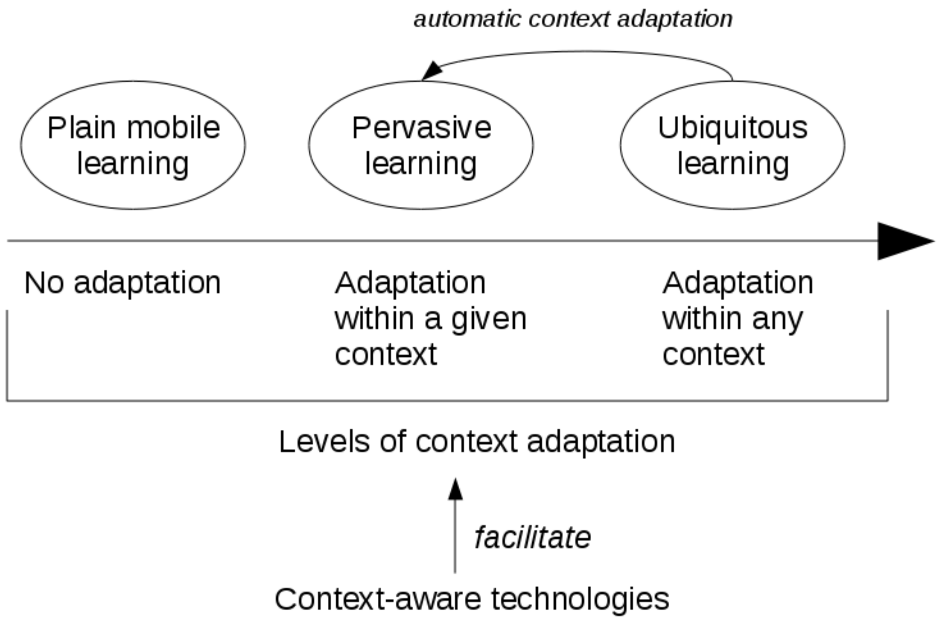


Figure 3: Levels of context adaptation in mobile-based learning approaches. Automatic context adaptation has a two-tier structure: a ULS is adapted into a PLS, which in turn is adaptive within its respective context.

Context adaptation is facilitated by context-aware technologies such as smart tags and wireless sensors. According to this view, a ULS is able to adapt automatically within any context that it is transferred to. For example, in the case of museums, a perfectly adaptive ULS would be able to transfer from one museum to another without requiring interventions from technical or design perspectives. To our knowledge, currently available technologies cannot yet perform completely automatic context adaptation, thus transferring the current ULSs across all possible contexts is not possible. In case of pervasive learning, this transfer is not required as a PLS is designed for a particular context. One could view a true ULS also as a set of context-specific adaptations of a generic system, and these adaptations could in turn be referred to as PLSs as they are automatically adapted, or designed, to a given context.

Context adaptation is evaluated through various aspects of context. In this paper we use cultural and pedagogical aspects in the evaluation of UFractions. Additionally, the role of technology integration is evaluated.

## 3.3 UFractions

UFractions is a ULS combining a story-based mobile game with fraction rods so as to motivate the pupils to learn fractions in a novel way. To our knowledge no work has yet been done in combining concrete manipulatives with mobile gaming. The combination of the two different learning tools provided us with new opportunities not only to motivate the pupils but also to create new connections between a fictitious story, fraction theory, and physical objects.

The ubiquitous nature of UFractions is not so much technical as it is conceptual – the context comprises the mobile game and the concrete manipulatives, and the game can be transferred from a table top to another. In terms of cultural and pedagogical contexts, however, UFractions lacks context adaptation, as we will find out in Section 3.4. Before that, the UFractions game is described from the perspectives design and implementation.

### *3.3.1 Design Process*

UFractions was designed within and for a technology-alien environment in rural South Africa. The design process started with an idea for a story-based game related to animals. The story for the game was made with help of South African cultural experts and a suitable level of mathematics for the game was defined with the help of secondary school teachers from North-West province and the Revised National Curriculum Statement Grades R-9 (Department of Education (Department of Education, 2002; Turtiaine*n et al*., 2009). We chose the game format to be similar to that of LieksaMyst (Lain*e et al*., 2009), so we had to adapt the content of UFractions to fit the same format.


Figure 4: Mother Leopard, her cub Senatla, an example of mathematical problem, and the use of rods

The main characters in the UFractions game are “Mother Leopard” and her cub “Senatla” (Figure 4), whose appearances were drawn during the design process. While playing the game, the learners assist Mother Leopard to raise her cub and fight against hunger and enemies living in the South African savannah. Players earn points by solving fraction challenges related to the lives of the two leopards' with the help of fraction rods. Therefore, the players must gain an understanding of the problem and the concept of fractions in order to be able to find the correct solutions.

The chosen game format (LieksaMyst) requires the answers to the problems to be numbers or choices from a list. The limited set of question types complicated the planning of meaningful mathematical problems, and because of the restricted screen space, explanations had to be concise. Suitable hints for every problem were also created, so players are able to ask for advice after an incorrect answer. Hints do not provide the answer immediately, but lead players to the right path of solving the problem instead. Positive feedbacks were tailored for each problem and negative feedbacks were randomly picked from a pool of negative feedbacks assigned for each character.

The game starts with an introduction, where players are introduced to the leopards and challenged to solve four introductory problems that guide them to using the rods. After the introduction the players can select a level: “Feeding the cub: 0-16 weeks”, “Lessons to hunt: 4-6 months”, “Pro hunting: 6-12 months” or “Whole year”. The storyline involves different paths that the players can choose (Figure 5).

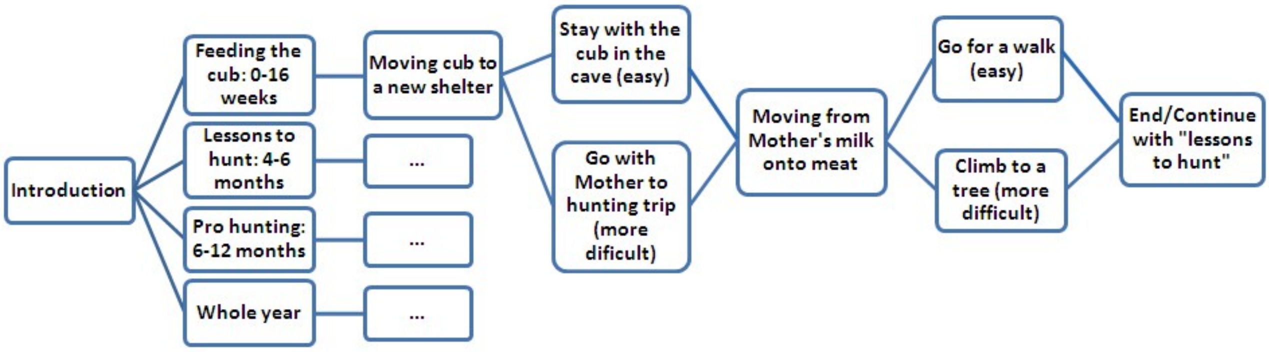


Figure 5: An example storyline fragment, “Feeding the cub”

In addition to the story-based game, UFractions can record evidence of the players showing their knowledge of fractions and identifying mathematics from their everyday environment by taking pictures and adding comments to the pictures. The game website[5] displays a real-time status of the leopards' and the players’ struggle against hunger and enemies — the two main threats of the leopards — and presents the scores of the teams, recorded evidence and guest book entries.

When UFractions was reverse-transferred to the technology-familiar environment in Finland, the storyline was not changed at all, but was translated to Finnish, although some sentences had to be shortened or split to fit to the mobile phone screen. Also color codes used in the game were kept intact so for example "Valkoinen" (white) remained coded with a letter "W".

### *3.3.2 Implementation*

The development process of UFractions was financially challenging and time constrained, so we decided to use an existing platform that would enable fast and easy game development. For this purpose, we analysed two pervasive games that were previously constructed at University of Eastern Finland (University of Joensuu). *SciMyst* (Islas Sedano *et al*., 2007) is a quiz-based competitive pervasive adventure game created for the annual SciFest science festival held in Joensuu, Finland, in which players use mobile devices to explore the festival arena by solving challenges related to the surrounding objects and phenomena, and answers to the challenges are found from the physical environment. *LieksaMyst* is a story-based game situated at the Pielinen museum, a large open-air living museum in Lieksa, Finland (Laine et al., 2009). In LieksaMyst, players use a mobile device to make a relaxed (non-competitive) journey back in time to meet and interact with fictitious characters from the past. The characters tell the player how life was like in their respective periods of time, and ask for assistance in performing various daily activities such as churning butter or warming up the house.

After analysing the applicability of both game types for learning mathematics in South African context, we chose LieksaMyst's story-based structure as a template for UFractions, and added competitive features from the SciMyst games. Merging features of the two games was easy because both are based on the Myst pervasive learning platform (Laine et al., 2010). It is important to note that in this process a pervasive learning platform was used to create a ULS. This activity provided us valuable experience on how the same technological foundation can be used to support both pervasive and ubiquitous learning.

[5]UFractions website: http://ubiquelab.joensuu.fi/ufractions (accessed April 28, 2010)

The Myst platform was developed on top of Nokia's MUPE (Multi-User Publishing Environment) software (Suomel*a et al*., 2004). MUPE uses a client-server approach where the Java-based server pushes game content to J2ME-based clients in a pre-defined XML format over a network connection. The advantage of this content delivery model is that if changes are made to the content, the clients do not need to be upgraded. Furthermore, the same client can be used to access several MUPE-based games and the player's status is stored on the server, i.e. the game can be resumed after a period of absence.

UFractions does not use any context-awareness technology (e.g. 2D bar codes, NFC, location input) because it is location-agnostic. The context in the case of UFractions is the table on which the fraction rods and the game content on a mobile device interact. This interaction is managed by explicitly expressed colour codes on the rods and in the story (e.g. 'W' for a white rod).

### *3.4 Evaluation*

The aim of the overall evaluation was to compare the differences between South African and Finnish school 8$^{th}$ grade contexts in the use of UFractions, particularly focusing on the effects of reverse transfer. A multi method approach comprising qualitative and quantitative strategies was employed to achieve the aim. In this paper we concentrate on results that measure how well the game is adapted to the cultural and pedagogical contexts, and how the integrated technology was accepted in the two countries. We do this to show the importance of re-contextualization rather than just reverse transfer of a ULS such as UFractions. The results are primarily derived from quantitative questionnaire data and the findings are supported by qualitative comments from the participants.

#### 3.4.1 Evaluation Setting

Evaluations were conducted in five South African schools and four Finnish schools during March 2009 (South Africa) and March 2010 (Finland). Key figures of the target schools and test groups are presented in Table 3.

Table 3: Key figures of the schools and test participants

| **North-West Province School (Grades)** | **Total Number of Students** | **Number of participants (males/females)** | **Percentage of mobile phone owners in test group** |
|---|---|---|---|
| Alabama Secondary (8 -12) | 1300 | 21 (8/13) | 38% |
| Lebone II (1-12) | 255 | 22 (11/11) | 77% |
| Seiphemelo Secondary (8-12) | 1063 | 16 (6/10) | 25% |
| High School Zeerust (8-12) | 573 | 27 (11/16) | 78% |
| Zinniaville Secondary (8-12) | 987 | 19 (8/11) | 84% |
| **North Karelia School (Grades)** | **Total Number of Students** | **Number of participants (males/females)** | **Percentage of mobile phone owners in test group** |
| Arppen Koulu (7-9) | 307 | 32 (14/18) | 100% |
| Lieksan Keskuskoulu (7-9) | 406 | 31 (16/15) | 100% |
| Joensuun Normaalikoulu (7- 9) | 201 | 18 (9/9) | 100% |
| Tietäväisen koulu (1-9) | 201 | 23 (14/9) | 100% |

Students and teachers filled in a questionnaire that included open-ended and multiple choice questions, where they selected the most appropriate option from: Strongly Agree (5), Agree (4), I don't have an opinion (3), Disagree (2), Strongly Disagree (1). Students' also made a few fraction exercises to test their mathematical competency. The qualitative data consists of open-ended questions, observations and interviews of students and teachers, and multiple choice questions offer extensive quantitative data. We performed a descriptive analysis of the quantitative data, using mean and standard deviation calculations. The findings were then supported by qualitative data. A previous cluster analysis of the qualitative data showed that South African students immersed themselves in the story, and that the story induced ethical, physical and cognitive rationales. The South African participants liked mathematics in the UFractions game for affective (intrinsic motivation to mathematics), functional and action-oriented reasons (Turtiainen et al., 2009).

Each school testing session started with filling in the first part of the questionnaire and dividing the students into groups; in South Africa the group sizes were 2-4 students and in Finland 1-3 students. The researchers showed a slide show presentation of UFractions to the students and explained the game idea, as well as different functions of the game, the use of the mobile phones and one problem example. Then the students played the UFractions game for 30-45 minutes (Figure 6). During the game play the researchers observed the players' reactions to the game. The researchers as well as the teacher helped students if they had problems in the mathematical content or the use of UFractions.

Figure 6: Pupils engaged in game play in South Africa (March 2009) and Finland (March 2010)

After playing the game, students and teachers completed questionnaires, and in each class three to five students and the teacher were interviewed to collect data on the unique experiences and attitudes of the teachers and learners, as well as the technical aspects and usability of the game.

In the following sections we present the evaluation results on cultural and pedagogical context adaptation, followed by the results of technology integration.

### 3.4.2 Cultural Context Adaptation

To evaluate the adaptation of UFractions to cultural context we considered the elements of the language used (statement 1) as well as the story and the player's immersion (concentration on the story) in it (statements 2-5). Immersion can lead to the *flow*, which in turn can be interpreted as deep, intrinsically motivated, and therefore effective, learning experiences (Csikszentmihaly*i et al*., 1995). Figure 7 illustrates the evaluation results on cultural context adaptation, and reveals several differences between the Finnish and the South African data sets. The South African pupils were very positive about all evaluated aspects as only few pupils gave negative answers. Finnish pupils, on the other hand, were rather negative about most aspects, particularly in those that concerned the story and the players' immersion in it.

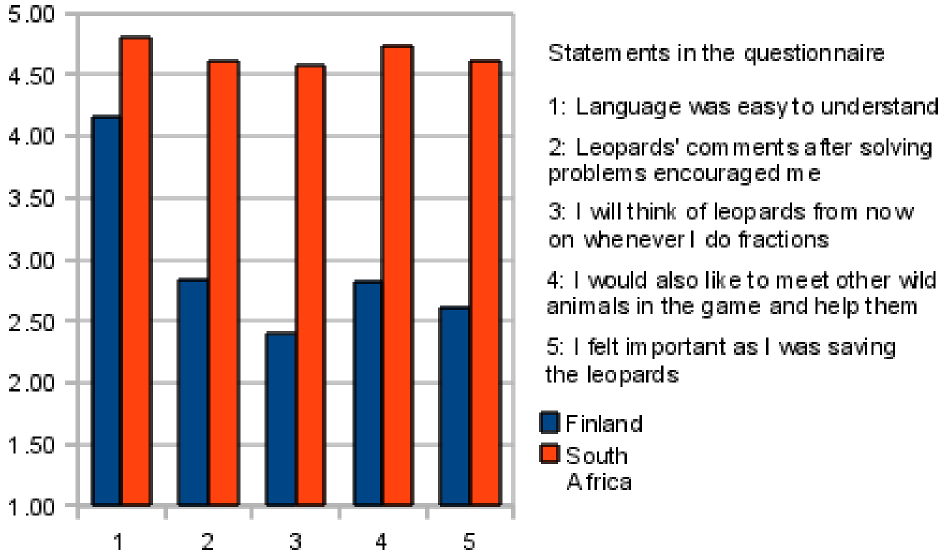


Figure 7. Evaluation of cultural context adaptation (1=Strongly Disagree; 2=Disagree; 3=No opinion; 4=Agree; 5=Strongly Agree)

Language was considered to be easy to understand, resulting in the highest positive ranking of all results in the cultural context category in both data sets (Finland: 88%, South Africa: 97%). What makes this very interesting is that in South Africa the game was played in English while the majority of the pupils (77%) reported their native language to be other than English. On the other hand, the South African pupils were taught in English in most cases so they most likely had the necessary language skills to understand the story and the challenges in the game. In Finland there were only two pupils who reported their native language to be something other than Finnish, and they disagreed with the “easy language” statement.

The second statement measured the motivational value of immediate comments after solving a challenge. South African pupils highly appreciated the comments (91% of positive answers), consistent with the other story-related statements, suggesting that the South African pupils were able to immerse themselves in the story. Finnish pupils reported more negative (42%) than positive (28%) answers for this statement, and 30% did not give their opinion. These results, together with the subsequent story-related results, may indicate that story was not appropriately adapted for Finnish pupils.

The third statement measured the players' immersion in the story as well as how well the story was able to have relevance in the players' minds and whether the story would have a chance to be remembered in the future in the context of fractions. Finnish pupils were negative about this as 57% reported that they will not be thinking of leopards in their future fraction-related endeavors, and a further 24% offered no opinion. Most of the South African pupils (93%), on the other hand, reported that they would remember leopards in the future. This great difference between the two data sets confirms our previous observation that the story was not as immersive for the Finnish pupils as it was for the South Africans.

The fourth statement measured the pupils' willingness to use similar games to meet other animals and help them. The idea behind this statement is to see whether the pupils would be interested in using other perspectives and apply the experiences of UFractions to similar games relating to different areas (e.g. geometry). Additionally, this statement measures the immersion in the story. The South African data set gives high support (94%) for the idea of using other animals and their respective challenges. Finnish pupils, on the other hand, were not so eager (41% disagreed and 27% had no opinion). We consider these results as yet another indication that a learning tool cannot simply be (reverse-) transferred without proper context adaptation or re-contextualization.

The last statement on cultural context adaptation further measured the level of immersion in the story. In the South African data set 94% of the pupils agreed, thus we can again confirm that the story suited very well for the South African pupils, but 46% of the Finnish pupils disagreed and 30% did not have an opinion. We can conclude that many Finnish students, due to lack of contextualization, may have not entered the flow at all.

One of the key findings regarding cultural context adaptation was that there was a significant difference in the level of immersion between the two groups. Deep immersion of the South African pupils can also be seen in their comments during interviews:

*[I] would want to go on and on… and just never stop…like when you said that we have to stop I was so angry.* (Female, 13)

*It was like real but I was using just imagination.* (Male, 14)

*Mother said that she needs help to raise the child, so I wanted to help to raise the child*. (Male, 13)

*It's perfect, I loved it. There are always some wrong things, but this one… I loved it.* (Female, 14)

*Are you still going to come again?* (Female, 14)

Possible reasons for the Finnish pupils' lack of immersion included questions being too easy, the story being uninteresting/too long and the game being too childish, and these were mentioned several times:

*The story could be shortened* (Male, 14)

*I would remove the leopard* (Male, 14)

*Better images, more action, more interesting story and characters* (Female, 14)

*That the game would not be so childish* (Female, 14)

*Not a game for 8th grade, the questions were too easy* (Female, 15)

These qualitative data support the findings from the quantitative statements related to cultural context adaptation, hence we can conclude that the game, culturally designed for South African pupils, does not work equally well for Finnish pupils of the same age.

### 3.4.3 Pedagogical Context Adaptation

The role of pedagogical context adaptation was evaluated by three statements which measured the comprehension of problems, the use of concrete manipulatives (Cuisenaire rods) in learning fractions, and the general effectiveness of UFractions as a learning tool (Figure 8). These results relate to cultural context, and this relevance is analysed below with the results.

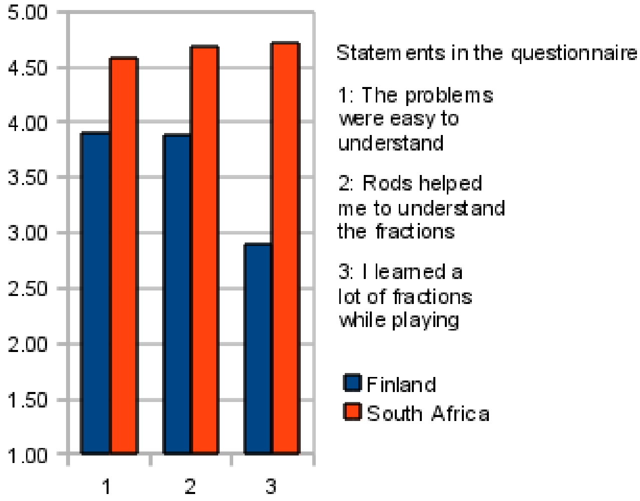


Figure 8. Evaluation of pedagogical context adaptation (1=Strongly Disagree; 2=Disagree; 3=No opinion; 4=Agree; 5=Strongly Agree)

From the pedagogical context perspective, the presented problems were considered easy to understand by both sets of students (Finland: 78%, South Africa: 94%). However, the data suggests that there is room for improvement especially in the Finnish version of the game (11% negatives, 12% no opinions). One explanation for this is that in the Finnish data set there were two pupils who reported their native language to be something else than Finnish; this relates to the cultural context adaptation where the game language was evaluated. Additionally, when translating the content from English to Finnish, the color codes were kept intact. This could also have caused confusion to some players although we explained to the pupils in the beginning to follow the color codes.

The second statement measured the importance of using concrete manipulatives to connect fractions theory to physical objects. Again, this aspect of the game was highly valued by South African pupils as 96% of them considered the rods useful in learning fractions. The use of rods might have had novelty value for South African pupils as several South African teachers reported that they had not used concrete manipulatives or games previously in the class. Most Finnish teachers, on the other hand, reported that they had been using either manipulatives or games or both in their mathematics classes. 74% of the Finnish pupils reported the rods helping them in understanding fractions, and 13% did not give an opinion. These results support the view that physical manipulatives may help the pupils to understand theoretical concepts better (Raphael *et al.*, 1989; Sowell, 1989).

With the last statement, we investigated the educational value of the game by measuring how much the players felt that they learned fractions during the game session. This metric is far from comprehensive but it may give an indication of educational effectiveness as well as pedagogical suitability of UFractions to the target groups. South African data set revealed that 95% of the pupils reported that they learned while playing and 80% thought that they learned a lot (strongly agreed). On the other hand, only 33% of the Finns reported that they learned fractions while playing, 40% did not report any learning at all, and 28% had no opinion. These results indicate that the game and its challenges were useful in the South African context and they were also useful for some of the Finnish pupils. As the cultural context adaptation results above suggest, the Finnish pupils were not immersed in the story as much as the South African pupils, hence rendering their learning processes ineffective. Additionally, 51% of the Finnish teams played through at least two levels of the game whereas in the case of South African teams this figure was 19%, suggesting that the challenges were easy for at least some of the Finnish pupils, resulting in challenges being solved routinely.

The game was created for South African 8th graders to learn fractions. Positive learning experiences of South Africans can also be seen in qualitative data when we asked the pupils what they enjoyed about playing with the leopards. In these results we observed several pupils reporting that they learned not only about fractions but also about leopards, and team play was appreciated too:

*I enjoyed learning how leopards survive in the wild and what they eat.(Male, 14)*

*I enjoyed playing with the cuisenaire rods and solving the problems. It was also interesting to see how the leopards grow and how they take care of themselves. (Female, 13)*

*I liked everything because we were working together as a team (Female, 13)*

*It exercise your brain (Male, 13)*

Several Finnish pupils suggested that the game was not suitable for their skill levels and some pupils suggested that parts of the problems were difficult to understand:

*I would give it for second graders* (Female, 14)

*[The tasks] were a bit boring, too easy* (Male, 15)

*Some questions were difficult to understand and there were too many intermediate explanations* (Female, 14)

*Some tasks were very unclear* (Female, 14)

### 3.4.4 Technology Integration

UFractions is not based on complex technologies. The only technologies that the players experience are the mobile device and the fraction rods, hence in this section of the evaluation we measured the motivation and easiness of using these technologies (Figure 9). The aim was to see how natural the use of integrated technology was to the pupils.

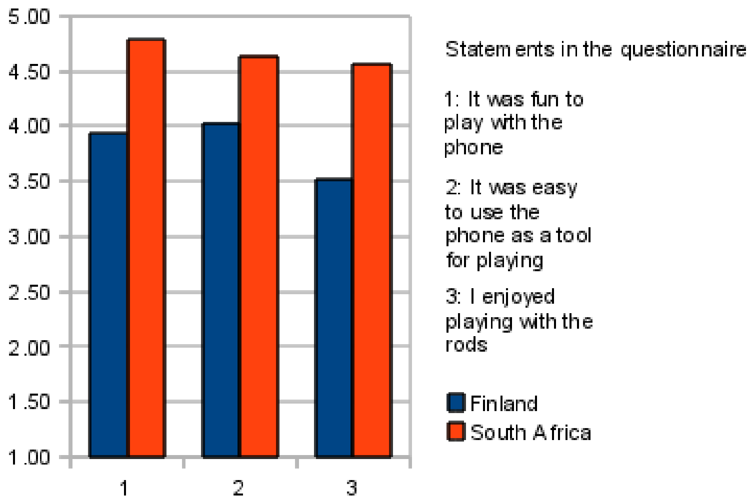


Figure 9. Evaluation of technology integration (1=Strongly Disagree; 2=Disagree; 3=No opinion; 4=Agree; 5=Strongly Agree)

The first statement measures the motivation (fun factor) of using the mobile technology. The high positive ratings in both groups (Finnish: 78%, South African: 95%) suggest that the phone was received well as a platform for UFractions. In the Finnish data set 13% chose the "no opinion" option whereas in South African data set the value was only 3%. For some pupils there might have been a degree of novelty value in using the phone for playing – to understand this factor better we would need a longer term investigation on phone usage as a learning tool.

The phone was considered to be an easy tool for playing in both data sets (Finland: 83%, South Africa: 93%). In the Finnish data set 10% of the pupils chose not to give an opinion. These figures indicate that the phone (hardware) and the game that was running on the phone (software) were functioning well enough so as not to disturb the pupils. In the Finnish data set the mobile phone ownership was 100%, whereas this number in the South African data set was 63%. It is possible and even likely that those South African pupils who do not own a mobile phone have been using one with their friends or at home.

In the third statement we measured how much the pupils enjoyed using the rods during game play. In the Finnish data set, rods were not appreciated as much as mobile phones were, as only 64% answered positively and 25% disagreed. On the other hand, South African pupils gave once again very high positive feedback (96%), but the number of strongly agrees was lower than in the two previous statements, hence the lower overall score. These results indicate that in addition to mobile devices, fraction rods as a learning technology were enjoyed by most of the pupils.

The technology integration results suggest that the technology worked well in both contexts. This follows the logic of reverse transfer: when a technology designed in a technology-alien context is brought to a technology-familiar context, it is likely that the users in the technology-familiar context do not experience problems with operating the transferred technology. In both South Africa and Finland, mobile devices are widely distributed, and especially in South Africa the mobile device can be seen as the main computing device (see Section 2). The use of mobile technology and fraction rods was also reflected in pupils' comments in qualitative data in both countries.

*The game is very exciting and keeps your mind busy. It keeps your concentration on it. I think it is very good focus if we can have it on our mobile phones to keep us away from bad things.* (Female, 14, South Africa)

*It was nice to play around on a phone and getting educated at the same time.* (Female, 13, South Africa)

*The actual playing it on the phone, actually, that was the fun part. Because usually it's only a piece of paper and start writing. […] For some children it's difficult to learn while they've been telling you or reading it. But it is on the phone now, something you're good at so you can just learn quickly instead of always being stressed after.* (Male, 13, South Africa)

*I enjoyed playing with rods the most. I enjoyed myself very much.* (Female, 13, South Africa)

*We never ever worked with the rods and this was my first experience with the rods and its really fun* (Female, 14, South Africa)

*[I liked] that there were rods and fancy phones* (Female, 14, Finland)

*Touch screen version would probably be better* (Male, 14, Finland)

*[I liked] finding the sticks (Female, 15, Finland)*

*It was nice to play with sticks* (Female, 15, Finland)

*[I liked] calculating with the fraction rods and playing with them* (Female, 14, Finland)

### *3.5 Discussion*

From the evaluation results it is interesting to see that whereas South Africans were eager to choose “Strongly agree”, Finns preferred to choose “Agree”. Additionally, considerably many Finnish pupils chose “No opinion” (up to 30% in some statements), suggesting that the Finnish pupils may be more comfortable with withholding their opinions. These patterns partly explain why the Finnish pupils have lower mean values than South African pupils.

In several statements standard deviation values differed substantially between the two data sets. The standard deviations for the Finnish data set were generally higher than those for the South African data set (the means being 1.07 and 0.69, respectively). We can think of two possible reasons for this: (1) given the high positive answers across the data, South African pupils may have tried to impress the authority (i.e. researchers) rather than disappoint them; and (2) English literacy level of South African pupils is not as high as the Finnish language literacy of Finnish. This may lead to a situation where the pupils having the strongest English literacy skill help other team members to fill in the questionnaire. Without a focused study on this aspect we cannot confirm these reasons.

One of the most significant results of the data is that when the UFractions game is contextualized properly to the cultural and pedagogical contexts, it is valued higher by the learners. In other words, when a ULS such as UFractions is badly contextualized (or not contextualized at all), its pedagogical and motivational values decrease. At the same time, the results support our view that the role of technology in reverse transfer is not significant as when a technology developed in a technology-alien context is brought to a technology-familiar context, the users in the target context are able to use the technology because it is familiar to them. In case of UFractions, the mobile devices used (Nokia N95, N80) were already three to four years old when the tests took place so the pupils in both contexts were used to them. Should the transfer occur in the other direction, technology in context adaptation would be more important.

According to our definitions in Section 2.3, UFractions, as a ULS, should in an optimal situation be able to adapt automatically to any context. Our evaluation results proved that this is not the case for reasons of culture and pedagogy. A future solution would be to concentrate on increasing the context adaptivity of the story and the challenges, and introducing smart fraction sticks which can be used to detect the game's context and the players' actions more precisely.

## 4 Future Trends

Since Weiser's prediction in 1991, ubiquitous technologies have developed significantly and today we can find affordable sensors, tags and wireless communication devices all around us; familiar environments such as work, home, public transportation, cinemas and hospitals are becoming increasingly intelligent and are thereby able to provide us with more context-sensitive services. We expect this trend to continue as nano technologies are coupled with sensors, enabling new materials to build new services on. Body sensors will be increasingly available and gathered data can be used to adapt services to users' body status. Needless to say, ethical concerns regarding the use of ubiquitous technologies increase as the technologies pervade our comfort zones.

In the future of ubiquitous learning, powerful mobile technologies with sensing capabilities will grant us new pedagogical possibilities to take learning from classrooms to the pockets of the learners while maintaining close links to the surrounding contexts. Mobile learning, as we know it today, will become more ubiquitous and pervasive, although we suspect that the term m-learning will remain in use. We envisage that mobile learners will become ubiquitous learners who use a general purpose ubiquitous learning tool to access various context-sensitive learning resources and activities, as they traverse contexts in their everyday lives. The learning tool will be able to seamlessly adapt to new contexts and provide the learner with meaningful material and activities in a way that is the most comfortable for the learner. The adaptation is done based on various aspects of the surrounding context (e.g. physical, cultural, political, technological, social) and the learner's personal context (e.g. previous experiences, preferences). Following this idea, UFractions could develop into a tool which can be used for learning everyday mathematics by automatically adapting story and challenges to the surrounding context. Fraction sticks, for example, could then be replaced by real world objects that are specific for a particular context (e.g. sticks in a forest, a cake in a bakery).

We see reverse transfer as a future trend of learning technology development where the core concept and technology are developed in a technology-alien context, and then re-contextualized to suit the needs of a technology-familiar context. The advantage of this model is that the designers and developers must take into account serious challenges (e.g. pedagogical, technical) that they face in the technology-alien context. By meeting these challenges, the end product is likely to be more robust than in the case of an ordinary technology transfer. To investigate more on the effectiveness and the benefits of reverse transfer, we will continue developing technologies in places like South Africa and Tanzania, and then reverse-transferring or re-contextualizing them to technology-familiar contexts such as Finland.

## 5 Conclusions

We have analyzed how pupils from grade 8 use a ubiquitous mobile game UFractions in two different contexts, South Africa and Finland. The game was created in South Africa, and it was intended for learning fractions by solving problems encountered on a storyline. The game makes use of manipulatives, called Cuisenaire rods, for concretizing the concept of fractions. The game was reverse transferred to Finland as such, only translated into Finnish.

The reverse transfer process, taking a technology from a context where the use of technology is on the average relatively low (South Africa) to a context with a high use of technology (Finland), helped us to focus our analysis on the role of the contextual factors for making functional use of technology for learning. In the conventional setting of transferring technology from the North to the South, it is hard to assess how much of possible obstacles in using technology are due to being not familiar to it rather than the cultural or pedagogical biases inherent in using a technology originated in a different context. Contrary to that, the reverse transfer process resulted in a scenario where pupils with a solid expertise in technology were given a technology with only cultural or pedagogical bias, not technical.

We were interested in two aspects of the context: the cultural and pedagogical ones. The results, obtained by questionnaires and interviews, indicated that the pupils in the Finnish context had significantly more problems or complaints in using the UFractions game than their South African counterparts. We interpret the results so that plain reverse transfer is not enough for a functional learning environment. Instead, a full re-contextualization process is required which covers at least the cultural and pedagogical aspects of the context of the users. With emerging ubiquitous technologies, part of this re-contextualization process can be automated by the context-aware features of these technologies, assuming appropriate knowledge architecture, for example ontologies,

Although not investigated in the current study, the results also question the meaning of localization, especially if it is limited to translation or transformation of the contents. Our results indicate that whereas a story works in one context as a platform for learning contents, a completely different type of platform might be needed for another context. This exceeds the limits of localization. Instead, re-contextualization is needed.

**Definitions**

*Contextualization* refers to a design principle which takes seriously the expectations, needs and especially the strengths of the context that the proposed technology should serve.

*Reverse transfer* refers to a process where a technology, designed for and within a technology-alien context, is transferred as such to a technology-familiar environment.

*Context adaptation* is the ability of a system to adapt automatically to diverse aspects of context (e.g. physical, cultural, political, technological, social) when the system is being transfered to a new context.

*Ubiquitous learning space* is a context-aware learning environment in which mobile and context-aware technologies are used to automatically adapt the learning experience to the learner's current context (context adaptation). In other words, ubiquitous learning space can seamlessly transfer across different contexts.

*Pervasive learning space* is a context-aware learning environment in which mobile and context-aware technologies are used to adapt learning experience to a specific context. In other words, pervasive learning space is designed for a specific context (e.g. a museum).

**References**

**Biographies**

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