Active and Passive Technology Integration in Context-Aware Learning Spaces

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Abstract: Context-aware learning spaces (CALSs) utilise resources of the surrounding context in the learning process. UFractions is a CALS combining a storytelling game and fraction rods for mathematics education, and it was developed for the South African context and later taken to Finland. We divide technology integration into active and passive integration according to the role of technology in the process. In passive integration the technology is integrated into the CALS so that it does not disturb the learner and the context. In active integration the technology integrates resources into the CALS and makes the system adaptive to contextual changes. We analysed, by a mixed method approach, the need for active and passive integration in UFractions in Finland and South Africa. We identified sixteen disturbance factors which had negative effects on the users of UFractions. The results indicate that by improving active and passive integration in UFractions, disturbance factors can be diminished.

Introduction

Technology integration describes how a technology facilitates learning and teaching in a classroom environment (Ertmer, 1999). It refers to the process by which a technology is introduced to a classroom so that the teacher and the students can use it efficiently for pedagogical purposes. Poor technology integration may lead to disruptions in teaching and learning or to wasted technology resources. It is, therefore, important to ensure educational technology's proper integration into the target context. While technology integration is often considered to be a problem of a formal classroom-based education, the same is true for informal learning contexts. If a learning technology were deployed in a museum (for example) while disregarding the influence of the technology on the learner and the context, the technology would fail to meet expectations.

In this paper we focus on technology integration in *context-aware learning spaces* (CALSs) which are mobile-based learning environments emphasising contextuality and utilising surrounding contextual resources (e.g. museum exhibits) in the learning process. Previously, a technology integration model (Laine *et al.*, 2010) has been developed for CALSs. The model was created to assist the CALS developers to ensure that a chosen set of technologies meets various requirements set by the context, established pedagogical guidelines and the design process. As a result, a CALS would offer an appropriate level of contextuality while being unobtrusive to the users. Elements that negatively affect the users in a CALS are referred to as *disturbance factors*.

In 2009 we developed UFractions (Ubiquitous Fractions), a game-based CALS, to help eighth graders in rural areas of South Africa to learn fractions and become motivated towards mathematics (Turtiainen, 2009). The game combines an interactive story on a mobile phone with coloured fraction (Cuisenaire) rods used to perform fractional calculations. The colours and lengths of the rods correlate and this information is in the game (e.g. two yellow rods equal to one orange rod). The game content was originally designed in and for the South African context using the English language, but later translated into Finnish without modifying the content.

In this study we established a division of technology integration for CALSs into active integration and passive integration. Most research on technology integration (e.g. Ertmer (1999), Becker (1994), Levine & Wadmany (2008), Mishra & Koehler (2006)) has concentrated on classroom based education. There has been no research on dividing the technology integration according to the roles of technology in the integration process in order to manage technology's influence on the learner. Based on the concepts of active and passive technology integration we evaluated the UFractions game in South Africa and Finland to answer the questions "To what extent technology integration is needed in UFractions?" and "What are the disturbance factors of technology integration in UFractions?". Through the study we sought not only to propose how technology integration can be improved in the case of UFractions but also derive the principles for proper technology integration in CALS design.

Context-Aware Learning

Mobile learning is a form of technology-enhanced learning where the learner traverses physical contexts while carrying a personal mobile device which provides learning content regardless of place and time (Eschenbrenner & Nah, 2007). Context-aware learning is a subcategory of mobile learning which emphasises context-awareness in the learning environment. Context-aware systems recognise and act upon changes in a collection of *contextual entities* which form a *situation*. We define a situation as a snapshot of a context at a given moment of time. Contextual entities define where the learners are, what they are doing, how they are feeling, who else is with them, what resources are nearby, what time it is, and what kinds of parameters the physical environment has. We define *contextual resources* as a subset of contextual entities which can be detected by a given set of context-aware technologies (e.g. sensors) and utilised in a CALS. We further define *context-free resources* as resources which are not dependent on a given context (e.g. a theory or general knowledge of a topic). By being aware of the various contextual resources a learning system can adapt both contextual and context-free resources to fit the situation in which the learner is embedded. A learning environment which makes use of a context-aware system is referred to as *context-aware learning space* (CALS). Figure 1 illustrates the way a CALS, by using context-aware technologies, detects changes (Δ_1 and Δ_2) in contextual entities between two temporally consecutive situations. $Entity_1$ and $Entity_2$ are contextual resources because they can be detected and utilised by the CALS. By our definition $Entity_3$ is not a contextual resource because it is out of reach of the CALS.

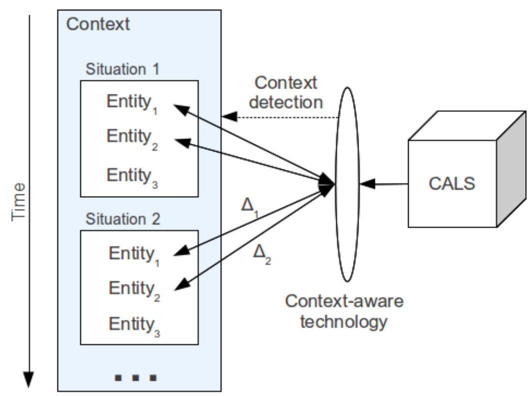

Figure 1. Detection of changes between situations in a CALS

The level of context-awareness is specific to the application – in some cases knowing the user's location within a geographical area is enough (Ballagas *et al.*, 2004) whereas in other applications it may be necessary to detect the parameters of the surrounding environment (Martinez *et al.*, 2004) or changes in the user's body (Aziz *et al.*, 2006). As creating a highly context-aware system requires money and time, trade-offs are necessary. State-of-the-art technology can also become a burden if it is not integrated properly as it may disrupt the user experience (Kaasinen, 2002) or the system simply does not work because of a lack of technical maintenance skills.

Technology Integration in CALSs

The term *integration* refers to a process of combining various distinguishable parts to create a complex whole (Spector, 2002). Technology integration is a concept often used when discussing how a technology is brought to a complex school environment (Ertmer, 1999). It refers to the process by which a technology is introduced to a classroom so that both teacher and students can use it efficiently for pedagogical purposes. In context-aware learning, technology integration is critical because, just as teachers at schools, CALS designers may not have the needed technical and conceptual know-how to choose and integrate correct technologies in a CALS development process, without which technology integration will result in disturbed learning experiences.

We have previously established a technology integration model for CALSs (Laine *et al.*, 2010) which concerns various requirements of context, pedagogy and design which should be met by integrated technology. An analysis of the model identifies two types of technology integration that must be considered in CALSs:

- **Passive integration:** technology *must be integrated* into the CALS so that it becomes subtle and unobtrusive to the learner and to the context. In other words, technology is the object of integration.
- **Active integration:** technology *must integrate* the contextual resources and context-free resources into the CALS and make the system adaptive to the changing situations of the context, including users within. In other words, technology is the subject of integration.

From the perspective of passive integration, technology influences directly the learner for example through poor usability, technical errors or other distractions. From the perspective of active integration technology's influence is indirect – if the contextual resources are not integrated properly by technology, the learner is influenced for example through poorly contextualised learning materials, annoying presentation of content or too difficult learning challenges. Division into passive and active integration helps us to identify and manage the ways in which the technology influences the learner.

Both integration types are driven (or restrained) by available resources (Figure 2). Passive integration aims at achieving unobtrusiveness of the technology from the learners' and the context's perspectives so that the learning process is not disturbed by the technology. The resulting unobtrusive technology provides context-awareness to the active integration process via contextual resource detection. When a situation in the context changes the technology automatically adapts the contextual and context-free resources. The active integration process can utilise various contextual resources such as physical objects, learner’s background and preferences, environmental parameters (e.g. weather), position of objects and learners, and available technology. It is important to note that passive integration must be completed before active integration is feasible.

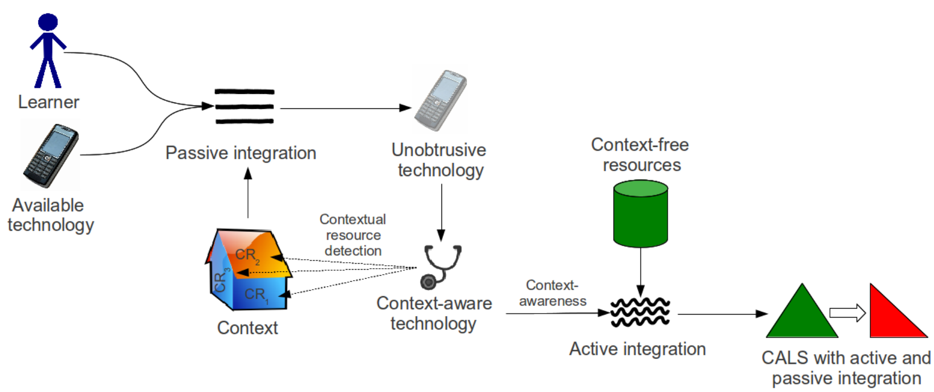

Figure 2. Passive and active integration of technology in CALSs

Research design

UFractions was originally designed for the South African context with local educators and cultural experts (Turtiainen, 2009), and later translated into Finnish. With these two variants we performed a comparative study which measured various aspects of the game in South African and Finnish contexts. The aim was to see how well a game developed in and for a technology-alien context could be transferred to a technology-familiar context without performing a re-contextualisation of the game. The evaluations were conducted in five South African schools and four Finnish schools during March 2009 and March 2010 respectively, using 8th grade middle school pupils (105 in South Africa and 104 in Finland).

A multi method approach comprising qualitative and quantitative strategies was employed in the evaluation. Pre- and post-test questionnaires with closed and open questions were complemented by post-test interviews of a subset of pupils in each test group. Teachers were also asked to fill in a separate questionnaire and were interviewed after the game session. During the game session researchers also observed and took notes on the pupils' interactions with each other and with the game. In this paper only the students’ data are analysed.

The pre-test questionnaire for the pupils queried data on demographics, technology usage, perceptions of mathematics classes and learning mathematics, and five simple fraction problems. The aim of it was to ascertain the pupils' stances towards fractions. The post-test questionnaire used open or Likert scale questions to evaluate the pupils' playing experiences from several viewpoints: motivation, likes and dislikes, game activities, usability, contextual relevance, overall perceptions and suggestions for improvements. Additionally, there were five fraction problems at the end of the post-test questionnaire. The interview questions aimed at collecting deeper insights from pupils on motivation, learning, playing and the usage of fraction rods. In South Africa the data collection instruments were in English and in Finland the instruments were translated to Finnish.

We have previously reported the aspects of pedagogy, culture and technology reception in the reverse transfer process of UFractions (Laine *et al.*, 2011). The results suggested that while there were significant differences in the adaptation of the game to the pedagogical and cultural contexts of the test settings, the technology was well received in both cases.

In the current study we analysed the same data sets from the aspect of technology integration. In particular, we wanted to answer the research questions: “To what extent is technology integration needed in UFractions?” and “What are the disturbance factors of technology integration in UFractions?”. We explored how the pupils experienced the technology and how well the resources were adapted to both contexts in order to identify disturbance factors that have negative effects. The results for research question 1 were derived from quantitative questionnaire data supported by qualitative comments from interviews and open answers of the pupils. For question 2 we first established indicators which were then used to identify the factors from qualitative data, which were then categorised according to the areas of experience.

UFractions

UFractions is a game-based CALS that was developed to help the children at rural South African schools to learn fractions and become motivated towards mathematics. The game combines an interactive story on a mobile phone and fraction rods that can be used to solve fraction problems. The story, presented with text, images and audio, features two leopards, a mother and her cub, with which the player adventures through the first year of the newborn cub's life. The year is divided into three skill levels of varying difficulty. Raising the cub is filled with challenges such as finding food to eat, learning how to hunt, avoiding enemies, and finding sources of fresh water. The player assists the leopards by solving fraction problems with the help of the fraction rods. An example of UFractions tasks with an open answer is presented in Figure 3 (left).

Figure 3. Left: UFractions task with an open answer; Right: Phone is aware of the rods through colour codes. Some students employed also other tools (pen and paper, calculator).

Mobile phones (Nokia N95 and N80, including client software) and coded fraction rods can be directly observed and manipulated by the players of UFractions (Figure 3, right). The hidden part of the technology is formed by the UFractions game server and a wireless network connecting the clients and the server. To the players, the game appears to be running completely on the mobile phone.

The fraction rods currently used represent 10 or 12 different lengths, and each size has its respective colour. The game supports different fraction rod sets and the mapping between colours and lengths is done in a game configuration file. For each challenge the game tells the player the colours and the codes of the fraction rods that are associated with that challenge and the player, in turn, finds an answer based on the rods.

Evaluating Technology Integration in UFractions

Evaluation sessions were conducted for groups with 16 to 32 pupils. In each session, researchers first introduced the story and the basic idea of the game, including instructions for fraction rod usage. The pupils received phones and were given approximately 45 minutes to play the game in groups of two to four pupils. During game play the researchers observed participants' activities and gave guidance if required. Upon finishing the game the pupils completed the second part of the questionnaire. Afterwards, three to five pupils were randomly selected for individual interviews.

Passive Integration

We evaluated the passive integration by measuring how well the technological context (phones, software and rods) suited the pupils. Statements related to entertainment, user interface and ease of use, were answered using a Likert scale (1=Strongly Disagree, 5=Strongly Agree) (Figure 4).

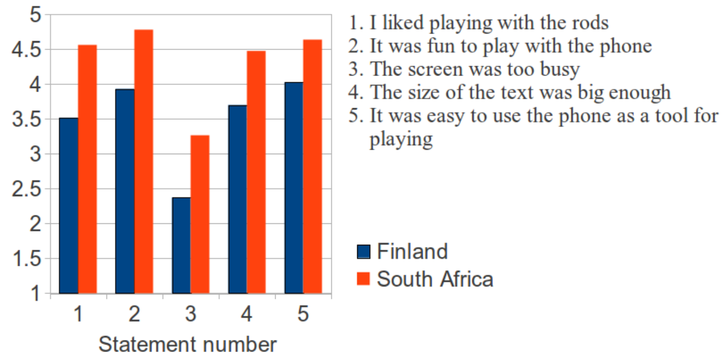

Figure 4. Evaluation of technological context

The South African pupils generally considered the user experience of the technology to be better than the Finnish pupils. An exception was the negative statement of the screen being busy which a higher number of Finns disagreed with (63%) than South Africans (42%). On the other hand, 22% of the Finnish pupils expressed no opinion on this statement compared to 9% of the South Africans (and this was one of the highest "no opinion" answers in the entire South African data set). These patterns could indicate that some pupils did not understand the meaning of the statement.

The phone was considered to be an easy and fun tool for playing by both groups of pupils. All Finns owned a mobile phone while 63% of the South African pupils reported owning one. It is likely that those South African pupils who do not own a mobile phone have been using one with their friends or at home. This boy relates the ability to use the phone to fun factor and learning outcome.

The actual playing it on the phone, actually, that was the fun part. ... 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. (M13, ZA)

Many Finnish pupils did not find rods to be fun to play with as only 64% agreed about the fun factor, which can be partly explained by the lack of interest towards the game story (see below) and partly because some of the Finnish pupils had previously been exposed to manipulatives such as fraction rods in mathematics classes (Laine *et al*., 2011). Many pupils commented on their rod experiences positively, for example:

I enjoyed playing with rods the most. I enjoyed myself very much (F13, ZA)
[I liked] calculating with the fraction rods and playing with them (F14, FI)

Active integration

The success of active integration was determined by analysing how well the resources are adapted to the changing contextual properties. Specifically, we measured how well the game was adapted to the target contexts in both countries in terms of approach to and supporting attitudes towards content matter and comfort zone, using a house metaphor to justify the three perspectives. Approach to content matter shows how well the pupils entered the house. Supporting attitudes towards content matter evaluates how the pupils liked to visit the house. Finally, evaluation of the comfort zone shows if the pupils are comfortable enough to live in the house.

Approach to content matter

Figure 5 shows the results of the statements related to the story-based approach to content matter (the same scale as in Figure 4). As one can observe significant differences in the answers of the two data sets, it is clear that the story was not suitable for Finnish pupils while the South Africans were much immersed in it.

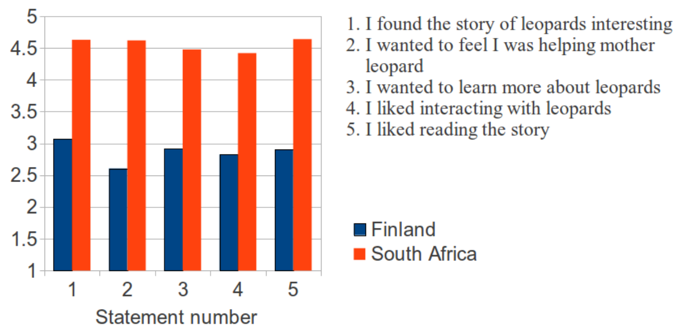

Figure 5. Evaluation of the approach to content matter

Through the interviews and open questions we found out that there were both Finns and South Africans who disliked the story but their reasons were different. Finns considered the story to be childish for their age but South Africans were concerned of leopards' safety:

[It should have] humour and shorter questions. Transform the story for 8th graders. (M14, FI)
I didn't like when I heard that mother leopard is struggling to feed Senatla and keep him from a safe place. (M14, ZA)

Despite of few negative comments, a good majority of South Africans and also some Finns commented positively on the story-based approach. Additionally, a few pupils in both groups suggested improving the presentation by enhancing graphics and adding narration, indicating different preferences on media modalities.

Supporting attitudes towards content matter

Figure 6 shows how UFractions supports the attitudes of the pupils towards mathematics. These results are similar to the results presented in the previous section – the Finnish pupils agreed much less with the statements than their South African counterparts. The number of omitted opinions among the Finnish pupils was also significant. In particular, in the last statement regarding positive attitude towards mathematics, 48% of the Finns chose not to give their opinions, leaving the proportion of positive answers to be only 19%. Overall results of the Finnish data set indicate that the game does not support well attitudes towards content matter.

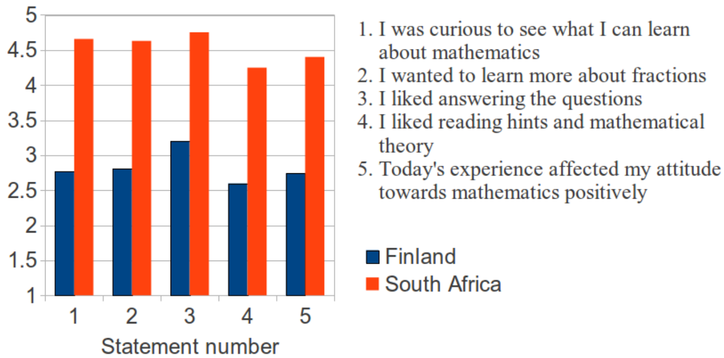

Figure 6. Evaluation of the support for attitudes towards content matter

The South African pupils were much more enthusiastic about the learning experience. In addition to reporting having learned fractions, several South African pupils, like this girl, reported that they learned new things about leopards although it was not the primary target of the game:

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. (F13, ZA)

Comfort zone

By comfort zone we refer to the psychological state of the learners in which they feel comfortable, or "at home", with the CALS. Comfort zone is the goal of technology integration – after successfully approaching the topic and forming a positive attitude towards it, the learner may enter the comfort zone where immersion in the flow can happen (Csikszentmihalyi, 1998). The statements measured the following aspects: comparison to an ordinary class, usefulness of the rods (contextual resource) and team play. The results are illustrated in Figure 7.

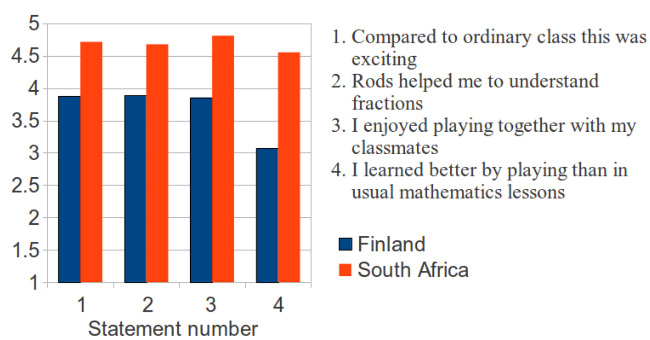

Figure 7. Evaluation of the comfort zone

These examples show how deep the South African pupils were in the comfort zone:

I have learned a lot and had fun. I realized that maths isn't boring or difficult. I won't ever daydream again in class, not even sing during math class. (F15, ZA)
Would want to go on and on and just never stop like when you said that we have to stop I was so angry. (F13, ZA)

Finns were not quite as much immersed but a majority of them also considered the game more exciting than an ordinary class (South Africa: 92%, Finland: 71%). Usefulness of the rods for understanding the fractions (South Africa: 96%, Finland: 74%) and team play (South Africa: 98%, Finland: 78%) were much appreciated by both groups. We observed that the group dynamics in both countries worked well except for a few cases where a pupil joined a group while she/he did not belong to the social circle formed by other members of the group. Possibly because of this, or due to personal preferences, there were pupils who would have liked to play alone.

Finally, the efficiency of the game in regard to learning experience in comparison to an ordinary class was not reported as positive by the Finnish pupils (38%) as it was reported by the South Africans (93%). It must be noted, however, that 29% of the Finnish pupils had no opinion on this statement.

Table **1. Identified disturbance factors.**

Area of experience	Disturbance factor	Indication	I	Evidence
Social experience	Harassment	Group members disturbed game play	A	"It was difficult to concentrate on the tasks when other people in the group were fiddling with the same phone" (Female, 14, Finland)
Learning experience	Below ZPD	References to easiness of challenges	A	"It was easy. A lot of it was very easy. Our group, we just transferred to this school from a school in Rustenberg. We did maths at a high level. It was very easy, I think it was only me that got bored after 10 minutes." (Female, 14, South Africa)
	Beyond ZPD	References to difficulty of challenges	A	"Some [tasks] were a bit difficult" (Male, 14, Finland) "I found that it was bit difficult because I have to calculate a lot." (Female, 14, South Africa)
	Wrong age group	Suggestion to use the game for younger players	A	"The game should be aimed at younger children" (Male, 14, Finland) "Is this really designed for our age group? Seems more like for elementary school." (Female, 14, Finland)
Behavioural experience	Wasting time by pleasing others	Avoidance of answering wrong despite the lack of challenge	A	"It wasn't difficult but I didn't want to get answers wrong" (Male, 13, South Africa)
Emotional experience	Disturbing content	References to shocking or disturbing events in the content	A	"I didn't like when I heard that mother leopard is struggling to feed Senatla and keep him from a safe place." (Male, 14, South Africa)
Immersion experience	Too much story	References to too long story or too much reading	A	"The story could be somewhat shortened" (Male, 14, Finland) "We would like to play more than reading" (Female, 15, South Africa)
	Monotony	References to repetition or monotony of the content	A	"The story could be more versatile" (Male, 14, Finland) "Repeats itself too much" (Female, 14, Finland)
Cognitive experience	Inappropriate graphics	References to poor graphics or suggestions to improve them	P	"The speech bubbles were too large for such small text" (Female, 14, Finland)
	Inappropriate sounds	References to poor sounds or suggestion to improve them	P	"Add more sounds and narration" (Male, 14, South Africa)
	Lack of animation	References of lack of animation or suggestions to add them	P	"Graphics and more animation and sound effects. Someone should read aloud in the game." (Female, 15, Finland)
Contextual experience	Inconvenient interaction with rods	References to negative experience of using the rods	P	"They [the rods] were strange. It was annoying to arrange them" (Male, unknown, Finland)
User experience	Unclear instructions	References to unclear tasks or difficulty of understanding them	A	"Some tasks were very unclear" (Female, 14, Finland) "The other questions were a little not understandable" (Male, 13, South Africa)
	Inconvenient interaction with phone	References to negative experience of physical handling of or properties of the phone	P	"The keys were too small" (Male, 15, Finland)
	Small screen	References to small screen size or difficulty to see the content	p	"I thought that it would be nice if we could do it on computer because computer screen is a bit bigger" (Female, 14, South Africa)
	Technical faults	References to technical problems during playing	P	"The game crashed" (Female, 15, Finland);

Disturbance Factors

By analysing the qualitative data we discovered sixteen disturbance factors which relate either to active (9) or to passive (7) integration of technology. We analysed questions related to dislikes, improvement suggestions and overall experiences of the pupils. Table 1 describes the disturbance factors with indications that map the relevant evidence to the factors. Column I indicates whether the factor relates to active (A) or passive (P) integration. The identified disturbance factors are grouped by the learner's areas of experience which are affected by the disturbance factors. ZPD refers to Vygotsky's Zone of Proximal Development (1978). Contextual experience refers to the experience related to the fraction rods because they form the context of which UFractions game is aware through interaction with the learner.

Our observations supported some of the disturbance factors found from the questionnaires and interviews. Some students accidentally pressed a wrong button and exited the game software (Interaction with phone). In a few cases the game also froze and had to be restarted (Technical faults). Some of the pupils created various constructions from the rods, instead of using them for solving the problems, while other members of their group continued playing and solving challenges. This behaviour may occur for two reasons: (i) the pupils were outsiders in the peer group (team members), and (ii) the pupils considered the game uninteresting (lack of challenge, inappropriate content). Finally, some pupils requested help from their teacher or researchers to get clarification or additional hints for solving a challenging task (unclear instructions, too much challenge).

Discussion

The question "To what extent technology integration is needed in UFractions?" was answered through an evaluation of active and passive technology integration. Particularly, active integration failed in Finland as technology indirectly influenced the pupils by not providing contextualisation of the content. Passive integration was fairly successful as most pupils received the technology well, although some individual pupils who were disturbed either by the rods, the phone or the game software.

To answer the question "What are the disturbance factors of technology integration in UFractions?" we derived sixteen disturbance factors which followed the trend of the results of active and passive integration evaluations. The evidence suggests that some of the factors may be generic to other CALSs and even to other learning environments. For example, we can comfortably assume that the disturbance factors of "Above ZPD" and "Beyond ZPD" could relate to nearly any kind of challenge-based learning environments but without supporting evidence this remains merely a hypothesis. By diminishing the identified disturbance factors, UFractions would become more effective and context-aware as a CALS, and it would provide better experiences to the learner in all nine areas of experience. With improved experiences the learner would more likely enter the flow (Csikszentmihalyi, 1998). While these disturbance factors were derived from the evaluation of UFractions, we hypothesise that they can be used as a check list for designing, evaluating and improving other CALSs.

The process of deriving the disturbance factors and the areas of experience was constrained by the fact that the data were classified by only one researcher, hence leaving a possibility for subjectivity. Additionally, it is possible that with a larger data set more disturbance factors could have been identified. Despite of these limitations, the results achieved with the available data set and with applied methods suggest that various experiences were disturbed by the lack of active and passive technology integration in UFractions.

Regarding active technology integration, the results showed that the technology should integrate the learning content and its presentation format into the target context because mere translation of the content from English to Finnish was not enough to meet the requirements of the Finnish pupils in their context. Active technology integration is necessary in order to serve heterogeneous sets of users in different contexts.

A flexible solution for active integration of content in the case of UFractions could be content adaptation systems (Lemlouma & Lyaida, 2004) which use models, such as a domain or user model, to provide meaningful content based on relevant parameters such as the learner's level of knowledge and learning preferences. A context model could then be used in conjunction with domain and user models to match the content with the target context and users.

Conclusion

We divided technology integration for CALSs into active and passive integration. Both integration types are important to consider, as we found out while evaluating the UFractions mathematics game in two very different contexts. Therefore, one of the main implications of the results reported in this paper is that in order for a CALS to be effective, its technology must be unobtrusive and subtle to the learner while adapting contextual resources to match the learner's profile. This means that the effects of disturbance factors must be minimised. Disturbance factors established in this paper, while being specific to UFractions, may indicate pitfalls in the design and implementation of future CALSs. This information can be useful for the CALS designers to plan the use of technology so that the goals of active and passive technology integration are met. Furthermore, the eight areas of experience are also useful for the CALS designers for ensuring that a variety of different experiences are supported in a CALS. The results yielded by this study can be used as a starting point towards a complete hierarchy of areas of experience and related disturbance factors. Additionally, generalisability of the factors and their experience areas to other learning environments apart from CALSs should be investigated.

A long term goal of UFractions is to become a stable, easy-to-use platform that pupils could access at home or at school with their own handsets. Related to this goal, an implication of evaluating UFractions in controlled environments is that the pupils'/teachers' abilities to launch and troubleshoot the game were not measured. As the pupils' interaction with the technology falls into the domain of passive technology integration, it will be necessary to run another evaluation on independent use of the game in order to verify the success of passive technology integration outside the controlled environment.

Finally, the concepts of passive and active integration are generic but we have only applied them to and analysed them in a CALS. In the future an important research activity is to find out how well the concepts of passive and active integration fit into classrooms or online learning environments.

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