

Savannah: mobile gaming and learning?

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Abstract

This paper reports a study that attempts to explore how using mobile technologies in direct physical interaction with space and with other players can be combined with principles of engagement and self-motivation to create a powerful and engaging learning experience. We developed a mobile gaming experience designed to encourage the development of children's conceptual understanding of animal behaviour. Ten children (five boys and five girls) aged between 11 and 12 years played and explored the game. The findings from this study offer interesting insights into the extent to which mobile gaming might be employed as a tool for supporting learning. It also highlights a number of major challenges that this format raises for the organisation of learning within schools and the design of such resources.

Keywords

animal behaviour, children, experiential, mobile gaming, qualitative

Introduction: experiential learning through mobile gaming

Both mobile technologies and games technologies are increasingly seen as fertile ground for the development of resources to support learning. This interest is driven by a number of considerations: first, there is an increasing awareness that young people's digital cultures outside school are as likely to be shaped by interaction with mobile and games technologies as they are by desktop PC applications and that consequently, the school setting should at least begin to engage with these tools (see, for example, Facer *et al.* 2003; Holloway & Valentine 2003); and second, educational theorists and researchers are beginning to identify these tools as potentially powerful resources in supporting the development of learning communities of offering experiential learning and in encouraging the development of meta-level thinking skills (see, for

example, Roschelle & Pea 2002; Andrews *et al.* 2003; Gee 2003; Wegerif 2003).

Mobile technologies, for example, enable children to interact simultaneously with both the physical world and with digital information. This shift in technical praxis promises new forms of educational experience away from the classroom (Roschelle & Pea 2002). Coupling familiar actions (presence within the physical environment) with the unfamiliar (having a window onto digital resources), it is argued, promotes reflection and new ways of aiding children's learning (Rogers *et al.* 2002; Sharples *et al.* 2002; Price *et al.* 2003; Stanton *et al.* 2003).

Games technologies, by contrast, have for some time struggled to be taken seriously within the educational arena. Games, with their emphasis on fun and pleasure, and their often (to an adult eye) repetitive challenges, have until recently been seen as a distraction from the more serious business of computer-aided learning. Despite Malone's (1980) early research in this field, and Turkle's (1984) identification of the potential role of games in supporting 'learning how to learn', it is only relatively recently

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that sustained educational research has been carried out in this area. What research that does exist, however, is increasingly pointing towards the potential of computer games to offer children powerful opportunities not only to learn through experience, but to develop meta-level reflections on strategies for learning (for example, Gee 2003; Kirriemuir & McFarlane 2003; Squire 2003).

Given recent technological developments, however, it seems to make sense to consider mobile learning and games-based learning not as distinct experiences, but as experiences that could fruitfully be combined. As developers explore ways in which they can become more than communication devices, mobile technology (whether phone or handheld PC) is now becoming seen as a potential games platform. As a result, a number of simple text-based multi-player games are easily available on many mobile phones. At the same time, the new connectivity of handheld games devices is shifting the focus away from the individual player to the connected player able to find fellow gamers on any city street (Flintham *et al.* 2003).

This paper will report an innovative and exploratory project, which attempts to explore how the experience of using mobile technologies in direct physical interaction with space and with other players can be combined with the principles of engagement and self-motivated efforts to overcome challenges (Malone 1980) characteristic of games play, in order to create a powerful and engaging learning experience. We wanted to explore, through this project, whether the combination of these different features of mobile and games technologies could encourage the development of children's conceptual understanding of, in this case, animal behaviour and interaction with the environment.

The Savannah Project

The game consists of two related areas of activity. In the first, children are able to play at 'being a pride of lions' outside in a playing field (100m × 50m), interacting with a virtual Savannah and exploring the opportunities and risks to lions in that space. Children are given global positioning systems (GPSs) linked to personal digital assistants (PDAs) through which they 'see', 'hear' and 'smell' the world of the Savannah as they navigate the real space outdoors. The second domain, the 'Den', is an indoors space where children



Fig. 1 Personal digital assistants (PDAs) and headphones – with image, energy bar and sight, send and smell buttons.

can reflect on how well they have succeeded in the game, can access other resources to support their understanding and can develop strategies for surviving as lions in the virtual Savannah.

In order to 'sense' the Savannah, children use their handheld PDAs (with headphones), moving around the playing field outdoors acting as lions. They hear the sounds of the Savannah relating to the specific zones or wildlife there, they see still images of the environment and animals to be found in the zones and they 'smell' the scents to be found in those zones, through still pictures of animal paw prints. On these PDAs, the children can also 'mark' specific information and send it back to the Den for later analysis; in later levels they can also 'attack' specific features of the Savannah. They also have an energy bar that lets them know their specific energy levels at any time (see Fig. 1). The PDA also receives messages sent by facilitators in the Den – such as 'you are too hot', 'you are hungry' or on occasion 'You are dead – return to the Den'.

In the Den, there is an interactive whiteboard and flip chart. The whiteboard comprises a map of the Savannah, and a series of 'energy bars,' each of which relate to the relative energy of each individual lion. On returning to the Den, children can pull up on the whiteboard the trails that they have made in the Savannah, and recall the sounds and images that they encountered at specific points, 'marked' and sent back to the Den (see Fig. 2).

The virtual Savannah map comprises a number of zones including long grass, short grass, gully, kopje, spring and trees. These areas are also populated by the

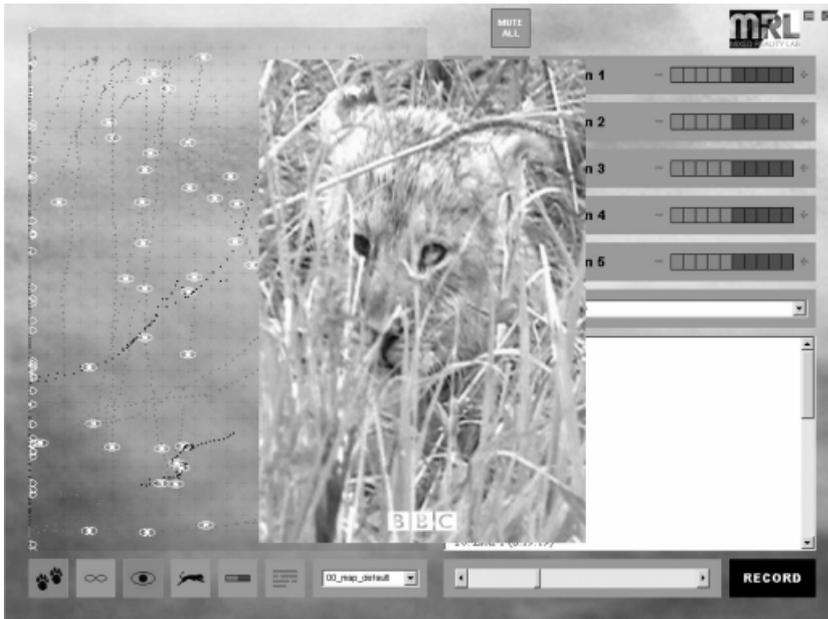


Fig. 2 Interactive whiteboard screen level 1: showing lion tracks, marks and highlighted mark.

wildlife that one would find in those different parts of the Savannah. All these aspects of the gaming environment are based on research carried out as part of the BBC Natural History Unit's work in this area, and a specialist BBC 'lion expert' with over 10 year of experience working in African Savannahs was involved in designing the play space (see Fig. 3).

In the game, children are required to act as a pride of lions living in the Savannah. The main challenge for the children is to understand and survive in this territory. The environment contains a number of threats: for example, an angry elephant, an old water buffalo, bush fire and on the fringes of the territory, the Masai. All of these have to be avoided. Attacking them would lead to certain death. There is also another pride of lions and they have to kill any of this pride's cubs. A number of animals can be found in the Savannah that they could successfully kill and eat – essential for their survival. Some of these require one lion, and others require the whole pack to successfully kill them. There are also sources of water and shade. The children have to balance the costs and benefits of different types of activity – whether attacking, drinking, sleeping or running – in order to maintain their energy levels. They also have to negotiate with each other, in order to decide whether or how to collaborate in achieving the games objectives.

Technological support

Savannah is a client/server system in which the handheld computers (iPAQ 5450) carried by the children/lions act as mobile clients to a PC-based game server. The mobile clients have integrated 802.11 b wireless networking capabilities, a full colour screen, a sound system, 256 Mb of file storage containing all the images and sounds used in the game and an attached GPS unit. These capabilities allow the mobile clients to:

- determine their locations in the outdoor game area;
- accept inputs from the users in the form of button events ('mark', 'attack');
- transmit location information and user interface events to the remote game server over the wireless network;
- accept responses from the game server that required individual clients to display a picture or a message, play a sound file or change the energy level shown on the client's screen.

The game server uses the information received from the mobile clients to determine what happens in the game and thus what the children/lions experience. For example, the server interprets incoming location information from the clients with respect to maps that relate the virtual Savannah to the physical game space. As a result, the server may instruct a client to render a

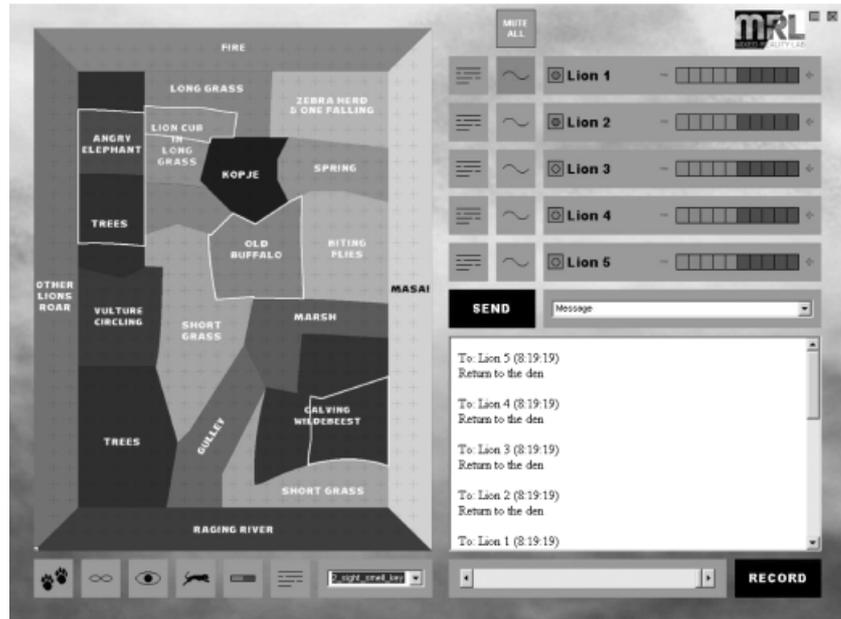


Fig. 3 Level 2 Savannah 'sound map' on Den Interface.

sound, image or scent that represents something that a child/lion would encounter at that location in the virtual Savannah, such as an angry elephant.

The server also provides the data for the Den application and acts as a mediator between the Den and the client. During the game play, the Den application monitors and logs the movements, actions and consequences of the children/lions as reported to the server. At this point, the games server supporting the game was not fully automated; as a result, two members of the research team located in the Den were responsible for awarding and removing energy points from the children in the light of the children's actions in the field.

Study

We conducted an exploratory study to investigate children's use of Savannah and what they learnt about animal behaviour, research activities and collaboration after playing Savannah. It took place in a secondary school in Bristol (a city in the south-west of England). The children involved in the project were all from year 7 and were aged between 11 and 12 years. There were two groups: one group of five boys (day 1) and one group of five girls (day 2). The purpose of these first trials was both to test whether it was possible to overcome the technical challenges of building such a

complex system combining games activities, media content and GPS, and to explore the underlying concepts concerning mobile game-based learning.

The days were organised into two challenges. In the first challenge, the children were told that they were a lion pride who had recently been displaced and had just arrived in a new area of the Savannah. The children had to get to know this area, understand what was in it and identify various threats and opportunities. The teacher introduced this challenge with a discussion about the types of habitat that might be found in a Savannah, and encouraged the children to consider what lions might need to survive there. During this phase, the children could NOT kill or be killed and so could freely explore the virtual Savannah. On each day, the group of children took two searches to fully explore the virtual Savannah outside. After each search the children went back to the Den and discussed with the teacher what they had found. The children used the flip chart paper to create a map of what they found and they used the interactive whiteboard to revisit their movements within the environment, examine where they had not searched and discuss how they could improve their search techniques.

In the second challenge, the children were told by the teacher that they had to learn to survive in the Savannah. In this challenge, the children could both

die (if for example they attacked the wrong animal alone) and hunt, and their energy points would increase or decrease depending upon their actions. The group of boys had three games and the group of girls had four games and the games lasted approximately 15 min. After each phase the children went back in the Den and discussed with the teacher what had happened and what they could do differently in the next game. At the end of the day, the children had a discussion with the teacher about what they had learnt.

Observers of the trials were located both within the Den and outside in the play field. Within the Den two video cameras were set up to capture interactions and visual displays on the whiteboard, and two observers took field notes. Outside in the playing field, two observers watched each game and took field notes. A video camera with a radio microphone was trained on one child for each challenge – a different child for each challenge. At the end of each day, the children were interviewed in groups concerning their experience with Savannah. These interviews were videotaped. All the videotapes were transcribed.

Findings

As discussed in the introduction, the key challenges in designing the Savannah project have been to create an experience that encourages children's engagement and identification with their identity within the game, to encourage self-motivated attempts to overcome the obstacles in the game and thereby to achieve an understanding of the rule system on which it is based, namely, the rules of animal behaviour and interaction with the environment. We carried out an episodic analysis, where observers identified episodes in the game play and while the children were interviewed, which were concerned with either learning the rules of the game or engagement and identification. An independent observer classified these episodes and inter-observer reliability was adequate (80%).

Engagement and identification with games identity

Analysis of the video data provided some evidence to suggest that the students felt they were actually experiencing the Savannah, were identifying with their new roles 'as lions' and found it highly engaging. The students often talked in the game as if they were directly

experiencing the simulation. During play, they exclaimed that 'I'm nearly dead', 'we're hot', 'we're attacking' and 'I'm dead'. Example 1 illustrates this point.

Example 1 (Game play)

- G2 We need to get some water lets go
Where's the water ?
G3 We're too hot
We're too hot are you ?

Analysis of the post-interview also revealed evidence that students felt they were experiencing being on the savannah and found it engaging (see Examples 2–5).

Examples 2–5 (Interview)

- 2 B5 I actually thought that what was on the screen was actually what was real. ...
3 G3 It felt like Africa
4 G4 The bit when it said it was getting too hot made it feel like Africa
5 B2 When there were flies I was like [turning head, to check where the flies were]'

This example also shows the importance of sound for making the children feel they were actually in the savannah. In the post-interview, two girls compared Savannah with horse-riding, saying that in both activities '*you could get killed*' – suggesting that the perception of risk and identification with the role as lion was high.

The two most stimulating areas of the savannah were the fire and the Masai tribe; these zones triggered the most animation and physical response like dancing, singing, shouting or quickening of pace, some of which, such as the dancing, were repeated in the Den setting on hearing the sound again. Emotional responses to the play were also in evidence as the children responded visibly and audibly to the responses from the system. When they received a message that their attack was successful they cheered and punched the air; when they received a message that they were in danger they ran.

An interesting aspect of the game is its physical nature, which arguably contributes to the directness of the experience. When the children are running away from the elephant they are actually running and not moving an avatar in a desktop computer game and we would suggest that this aspect of Savannah supports children's learning. Furthermore, the physical nature

of Savannah could contribute to children's enjoyment of the activity out in the field, because the physical exercise of running around a field and dancing can be an enjoyable experience in itself. These are characteristics of mobile gaming that are not shared with desktop gaming and we suggest that this could make mobile gaming more engaging and more direct than desktop gaming or simulations.

The engagement with the system was also evident when the children attributed significantly more intelligence to the system than it actually possessed, often assigning meaning to what was, in fact, little more than a vagary in the GPS. For example when the boys were all trying to group together to attack the elephant, one boy says 'Wait till I get it – damn the thing ran away man!' or when the GPS stopped transmitting and the image on their iPAQ froze, one boy shouted 'This lion is still chasing me!' On another occasion one boy said 'I've killed a bird and it's flown away' – when all that had happened was that he had seen a picture of a bird and then he moved into a new zone where a different image appeared.

At times, however, 'identification' with the role of lions broke down for a variety of technical reasons and because the design of the interaction within the game was not sufficiently sophisticated. On several early occasions, for example, the children had to come 'out of role' to allow difficulties with handsets or systems to be fixed. On others, the children expected a greater degree of sophistication in the system than was available. Example 6 shows that when the children were told they were too hot, the children moved into a watery area and began 'attacking' the water as they assumed that this would enable them to drink.

Example 6 (Game play)

- G1 Do you attack it
 G2 Attack the water
 G1 you can't
 Do you attack
 It won't work
 G2 I'm attacking the water
 You can't do it
 G1 How do you get water [to observer]

All they needed to do was to stand in the water zone, but this was not clear and led to the only instance of a child directly addressing one of the observers during game play. At this point, the children were pulled out

of the game experience to the reality of standing in a playing field working with very new and untested technology.

Post-interviews, particularly with the boys, also pointed out the extent to which this age group has grown up expecting rich and immersive media experiences when playing games. While observation of their game play suggested identification and immersion in the experience, these later reflections suggested that the children expected a much richer and interactive environment that, to date, this technology is unable to support (see Examples 7 and 8).

Example 7 (Interview)

- B5 You couldn't like move around on the screen
 It was just like pictures

Example 8 (Interview)

- B1 Also – the way that it worked
 That would actually do like a projection of where you are
 So you could see what is in front of you

What was also in evidence in post-interviews was the extent to which the children compared the experience with other perceived 'realities' of being in the Savannah. Most of the children, for example, were familiar with images of lion behaviours from television programmes, and explained how the games experience compared poorly with their perception of what they felt might happen in the 'real world' (see Example 9).

Example 9 (Interview)

- G4 You couldn't like see all around the way around
 G3 In reality you would like be able to move around and be able to see things a head of you
 So you could got away quicker
 If you were in danger
 You'd be able to see your other lions as well, not just other animals

This disjuncture between the reality of the games world and the reality of the actual Savannah is a problematic feature of the current game not only for the children in the study but also for the designers. There are a number of important technical challenges, for example, in achieving the responsiveness of the environment that the children would expect. More importantly, however, is the notion of different time

scales in the 'real' Savannah as compared with the virtual Savannah. In the virtual Savannah, played out on a 100m × 50m playing field with no physical obstacles, for example, it is possible for children to traverse the area within 5 min. In a real Savannah, the same space would take lions several hours and would offer up numerous physical challenges – such as heat, other creatures and natural obstacles such as gullies, trees and marshes. The challenge of creating a 'real' experience of lions' day-to-day lives in a virtual environment mapped onto empty physical space remains on-going in terms of the prototype development.

Despite these caveats, however, identification with roles in games-play is not wholly reliant on 'realism', but on the perceived reality of the challenges within the game world. As one girl said during her post-interview 'when I watch the lion king, I'm kind of like watching, but now I know what it feels like to be a lion'. Children's identification with roles in the games illustrates the degree to which the children are directly experiencing the game in a way that can be qualitatively different from desktop gaming. However, the breakdowns in identification discussed above show that children's experience with the game was not always as direct as it could have been.

What have also emerged as of interest in the analysis of the video data are the numerous identities that children have to juggle in the games experience, which would lead us to look beyond simple 'identification with the role' as a feature of the learning experience. The children were required to act as 'lions acting as lions', as 'children acting as lions' and as 'children reflecting on their actions and the rules of the game' in order to play better. As Gee has noted, this is often a key feature of games play:

Learning involves taking on and playing with identities in such a way that the learner has real choices (in developing the virtual identity) and ample opportunity to meditate on the relationship between new identities and old ones. There is a tripartite play of identities as learners relate, and reflect on, their multiple real-world identities, a virtual identity and a projective identity (Gee 2003, p. 208).

During the Savannah experience then, while children say '*I'm too hot*' (as a lion), they are also saying 'Hey, look a lion cub – I'm going to kill it! Look I got points for that' when observing their energy points (child as

lion), and also saying, on dying after deciding to attack the Masai, 'next time we wont do that!' (child as reflective games player).

The design of the day's experience, combining introduction to the game and reflection on play within the Den, with periods of play 'as lions', was intended to facilitate this interplay of identities as players and reflective learners. Children were encouraged, in the Den, to reflect on their success in mapping the Savannah play space and in achieving energy points. They were facilitated in this by being able to interrogate their actions, and 'relive' them by following the trials and actions they had made sequentially on the board. This process was facilitated by a teacher who had been asked to provide the children with the opportunity to reflect and to introduce them to relevant further information when it seemed useful. What was clearly observable from this process, however, was that another important aspect of children's identity as players of this game in a school setting was their identity as 'pupils' – when they were leading the reflection in the Den, interacting with the whiteboard and discussing their actions and strategies, they were highly engaged and motivated; when the locus of control in the Den rested with the teacher; however, they adopted a passive pupil identity that was resistant to engagement with the task. We will go on to explore this observation in more detail in the discussion.

Learning the 'rules of the game'

In principle, the interplay of different identities in a game should be an interplay between immersion and reflection, between the specifics of a particular challenge and coming to understand the rules of the game (Turkle 1984). If Savannah was designed successfully, then the children, through the games play, would begin to understand the rules that governed the game and, consequently, the rules that shape lion's behaviour in the wild.

In certain instances, we did see evidence that this was occurring. For example, a key feature of lion behaviour is quantification of risk – lions encountering lions from another pride will 'count' the numbers of their opponents before deciding whether to fight; they will calculate whether they have sufficient numbers to take on prey of different sizes. These features were all built into the game rules, with energy points awarded

or deducted for children making the correct calculations. This sort of behaviour was encouraged by the game and in evidence in the children's play after their initial attempts (see Example 10).

Example 10 (Game play)

G3 What's this
 G5 Wildebeest
 attack
 G3 Attack a wildebeest
 G5 Your not going to attack that all on your own
 G5 Everyone attack it

Both groups became gradually aware that working in groups rather than isolation was likely to lead to greater success and also encouraged collaborative activities among the children. Example 11 shows the children coordinating their movements through the virtual space and worked together to perform attacks on prey.

Example 11 (Game play)

G4 A baby lion
 Do we attack it
 G3 Yeah
 G4 1, 2, 3 attack

These behaviours were reinforced by the facilitators' awarding of energy points, and were largely seen to be spontaneously developed behaviours. Indeed, it was one of the features that the boys in particular mentioned after playing (see Example 12).

Example 12 (Interview)

B1 Because we learnt to trust each other and know that if you attacked something, the others wouldn't leave you on your own to get killed

The game allowed the children to make and test hypotheses about the relative merits of working in groups to overcome prey of various sizes – for example, regardless of the number of children/lions attacking it, an angry elephant would always cause severe loss of energy points, and often death (as it would in the wild).

Similarly, the children were encouraged to become aware of the other threats that faced lions in the Savannah, such as human habitation, and to balance these with the opportunities these offered for energy in the form of food. Example 13 illustrates the children discussing these opportunities.

Example 13 (Game play)

G1 We have prey
 G5 We have prey
 We have
 G3 Yeah we have Goat
 G5 River
 G1 Grass
 G3 Yeah but we have humans
 G5 Okay
 Yeah but humans
 G1 Prey
 G3 They might make trouble

Other rules of the game environment were built into the geography of the Savannah itself, namely that there are features of the environment and threats in the environment that limit lion movements (fire, humans, other prides, features such as major rivers). Moreover, the game geography also served to highlight the richness and diversity of the Savannah; in other words, what kinds of animals there might be found sharing a lion's habitat, for example, other lions, zebra, wildebeest, elephants, vultures, biting flies and termites.

The children were, however, also coming to learn certain rules about the games environment that in fact conflicted with the generalised understanding of the Savannah that had been intended. For example, children had little understanding of the complexities of actual lion hunting strategies, which could be taught very effectively in this experiential manner. As can be seen from Example 14, they were happy to coordinate attacks and actively pursued this strategy but clearly there is far more to a lion hunt than collaborative timing of attack. No consideration was given to formation or strategy.

Example 13 (Game play)

G3 We got a lion
 Don't attack it
 G1 Attack
 G4 1, 2, 3 attack

Similarly, the children were not encouraged to develop an understanding of how lions actually use the territorial space of the Savannah. Due to the game design, they were being reinforced to think that lions spend equal amounts of time in all areas of the Savannah; this was because of a lack of accurate understanding about the structure of lion behaviour over a typical day, too much emphasis was placed on

repeatedly killing prey (as the children found this to be the most rewarding aspect of the game), and the prey could be found all over the savannah. Thus the children were motivated to repeatedly search around the savannah, killing prey indiscriminately.

Part of this problem stems from a reinforced lack of differentiation in the game rules between the relative energy costs of going after some types of prey; the children began to think that it was beneficial to go after all types of prey and attack all types of threat without discrimination. The fact that the only digitally mediated interaction that the game afforded was of 'attacking' further privileged the strategy of coming together to attack, rather than reflecting on other actions a lion might use.

What was clear from this pilot study was that the children were very quickly coming to identify the rules and problems within the game, and as such, the main challenge to designers is to develop sufficiently sophisticated game rules, and sufficiently focused challenges in order to encourage the children to attempt different strategies to overcome these problems. For example, when specific challenges were presented to the children, such as the message 'you are too hot', then they were able to identify the need for water to cool themselves down (Example 3). Similarly, when they were low on energy, they understood that they needed to search for food. However, these types of challenges led only to fairly low-level strategic solutions (albeit solutions that were successful within the game as currently designed), namely, that certain animals required more than one lion to attack and that certain animals should not be attacked such as the Elephant and the Masai.

Discussion

The savannah prototype offers a number of interesting insights into the extent to which mobile gaming could be used as a tool for supporting learning, and a number of major challenges that this format raises for the organisation of learning within schools and the design of such resources.

One key aspect to emerge from the study was the importance of paying detailed attention to the question of how learners might 'manage' their identities as games players, as characters (lions) within a game, as strategic reflective thinkers about the game world and

as pupils within a school setting. One of the least successful aspects of the trial was the attempt to combine a more formal 'schooled' experience with the games play. As many commentators are increasingly arguing in relation to computer games, in particular in relation to massively multiplayer online games, players are fully able to develop strategic and critical thinking in relation to computer games as part of a gaming community in which the dominant pedagogic approaches consist of just-in-time learning, trial and error and participation in activities with more knowledgeable others. Explicit teaching and injunctions to reflect on actions tend to occur only in response to specific requests rather than as a framing activity for the games play. From our observations, the greatest failure of the study to date was the failure to maximise the opportunity for the children to act as self-motivated learners in the Den setting, reflecting on and developing strategies for improved games play. Instead, perhaps out of our own concern about the limitations of the game structure, we offered children the opportunity to act as players outside, and then in the Den requested that they act 'as pupils' and listen to useful information. This failed to encourage children either to look for, or to use, the more complex theoretical information on lion behaviour that was available to them for use in the game.

What has become clear is that the use of games formats are unlikely to sit easily alongside traditional classroom power relations. Gamers are expert when they control their own learning alongside more knowledgeable peers. If these sorts of experiences are likely to be successful, we may need to build in the expectation that children as gamers are more likely to learn effectively by subsequently acting as mentors to novice learners (see Gee 2003; Williamson 2003). This will require some degree of courage, and, to be honest, some reorganisation of the school setting.

In order for this sort of model to be effective, it is clear that the challenges presented in the game require significant modification. In the Savannah game to date, we have two overarching challenges: 'map your new territory' and 'survive'. What emerged from the study was that children expect and respond effectively to significantly more focused challenges (for example, when told that they were hot and needed to do something about it). At the same time, the challenges were simply insufficiently 'challenging' – we had

underestimated our players. For games to encourage the sorts of problem solving, hypothesis generation and testing that are in evidence in effective mainstream games and in the best learning environments, the challenges need to be real and complex and difficult to solve. They need to be, as Kirschner *et al.* (2002) call it, 'wicked-problems' that have no simple closed solution. In itself, this is a benefit to the game, as the complexity of lion survival in the wild is, after all, a complex, difficult and problematic challenge. The technical challenges involved in achieving this, however, clearly remain problematic when working with such new and potentially unreliable technologies as GPS in interaction with games servers.

Which brings us to another observation, namely that in creating games for education that operate in real physical space but attempt to reproduce another physical space, we are seeing a potential clash of 'realities'. Whereas games designers creating the games children are used to playing outside school only have to create a compelling and exciting experience, designers of games for learning are required to create a compelling and exciting experience that is underpinned by the nature of the realities you are trying to enable children to understand. It simply is not appropriate, in an educational setting, to 'overlook' the unfortunate limitations of the real world and create a more engaging virtual world. The games rules need to be usable as a basis for discussion and interrogation of reality as we currently understand it. This is, moreover, rendered significantly more complicated by the fact that in creating mobile games, such as Savannah, which offer no interaction with the real physical space in which children are playing, there are the competing realities of the virtual map and the physical environment. As we pointed out earlier, there is a need to create 'virtual' obstacles to compensate for the lack of the physical obstacles one would encounter in the real world being replicated.

In Savannah, we combined the potential of mobile and games technology in a novel and innovative way, to support children's learning. The only study that is remotely similar was a disease simulation game reported by Colella (2000, 2002), which was implemented using a variation of 'Thinking Tag' technology developed at the Media Lab, MIT, USA (Borovoy *et al.* 1996). The Tags used in this simulation were small computers with input and output de-

vices and displays for the users. During the simulation the tags were constantly exchanging information. Each student had a Tag that displayed the number of people the student had interacted with and whether the tag was sick. A student's tag would become sick when it exchanged information with another tag that was already sick. This game is similar to Savannah in that the children experience and influence the simulation directly, in comparison with other technology controlled role-playing games that mediate interaction through avatars or with components of a microworld. Colella (2000, 2002) argues this type of experience is qualitatively different from other technologically mediated role-playing games and raises the interesting proposal that the more direct the experience the better the learning experience. Our study does not address this proposal directly, but we have reported observations that we suggest that the children were experiencing the simulation directly and were learning from this experience. Of course, these observations have been made concerning other technologically mediated simulations, but we, like Colella, feel that the experience of playing these games is more direct than playing the equivalent game on a desktop computer. Further research is required to investigate this interesting proposal by directly comparing games like Savannah with equivalent desktop computer versions.

In conclusion, it is clear that this format could support learning – we simply have to learn how to do so effectively. If the fact that children are using these resources outside school as powerful learning environments is not sufficient to encourage us in this direction, then the engagement and enthusiasm for the experience reported by the children in this study should act as a spur to further exploration. As one boy said:

It was a bit like school but better, you didn't have to rely on a book – because we took more part cause we [...] got more involved

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