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**MOBILE LEARNING USING MIXED REALITY GAMES
AND A CONVERSATIONAL, INSTRUCTIONAL AND
MOTIVATIONAL PARADIGM**

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PhD

UNIVERSITY OF BRADFORD

2011

Mobile Learning using Mixed Reality Games and a Conversational, Instructional and Motivational Paradigm

Design and implementation of technical language learning mobile games for the developing world with special attention to mixed reality games for the realization of a conversational, instructional and motivational paradigm.

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Submitted for the Degree of
Doctor of Philosophy

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Abstract

Mobile Learning using Mixed Reality Games and a Conversational, Instructional and Motivational Paradigm

Faranak Fotouhi-Ghazvini

Mobile learning has significant potential to be very influential in further and higher education. In this research a new definition for Mobile Educational Mixed Reality Games (MEMRG) is proposed based on a mobile learning environment. A questionnaire and a quantifying scale are utilised to assist the game developers in designing a MEMRG. A 'Conversational Framework' is proposed as an appropriate psycho-pedagogical approach to teaching and learning for MEMRG. This methodology is based on the theme of a 'conversation' between different actors of the learning community with the objective of building the architectural framework for MEMRG. Various elements responsible for instructing and motivating learners in educational games are utilised in an instructional-motivational model. User interface design for the games incorporates an efficient navigation system that uses contextual information, and allows the players to move seamlessly between real and virtual worlds. The implementation of MEMRG using the Java 2 Micro Edition (J2ME) platform

is presented. The hardware and software specification for the MEMRG implementation and deployment are also discussed. MEMRG has produced improvements in the different cognitive processes of the learner, and also produced a deeper level of learning through enculturation, externalising ideas, and socialising. Learners' enjoyment, involvement, motivation, autonomy and metacognition skills have improved. This research will assist developers and teachers to gain an insight into learning paradigms which utilise mobile game environments that are formed by mixing real and virtual spaces, and provide them with a vision for effectively incorporating these games into formal and informal classroom sessions.

Keywords:

Mobile Games, Conversational Framework, Instructional Design, Motivational Design, User Experiences.

Acknowledgments

First and foremost, I would like to express my deepest gratitude to my supervisor, Professor Rae Earnshaw. I have been extremely lucky to have a supervisor with excellent academic and professional background who cared so much about my work and constantly inspired me with his progressive vision. He responded to my questions and queries so promptly and offered me detailed constructive comments. He patiently supervised me during a particularly difficult period in my life. This thesis would not have been possible without his valuable guidance, kind support and encouragement.

I would like to thank my second supervisor Mr David Robison for his suggestions, ideas and assistance throughout the project development. I am also especially grateful for the administrative help of Miss Rona Wilson.

I also wish to express my sincere thanks to my external supervisor, Dr Ali Moeini from the University of Tehran. His kind support and guidance have been of great value in this study.

I would also like to express my gratitude to Professor Peter Excell for supervising the early stages of my PhD and introducing me to the world of mobile learning.

Furthermore, I would like to thank University of Qom especially Dr Gandomkaar, Dr Khazai, Mr Hani and Miss Mirafzal for their kind support and understanding during this research.

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Fotouhi-Ghazvini, F., Excell, P. S., Robison, D. (2007) Potential Scenarios for Mobile Learning in a Developing-World Context. *Eighth Informatics Research Workshop*, University of Bradford, 28th June 2007, UK, pp. 142-145, ISBN 978-1-85143-2462, 2007.

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Chapter 1

Introduction

Mobile learning is a new paradigm of learning that takes place in a meaningful context, involves exploration and investigation, and includes opportunities for social dialogue and interaction where learners have access to appropriate resources. The learning process can be supported by the use of mobile phone in a responsive manner by means of context aware hardware and technologies that facilitate interaction and conversation. This mode of learning can enhance and improve learning, teaching and assessment.

1.1 Literature Review

This literature review is primarily a survey of the field prior to the research reported in this thesis which started in 2005-06. Further significant developments in the field since then are noted in the respective chapters in this thesis which deal with the various aspects of the research completed by the author.

Many educational establishments have considered utilising modern technology to disseminate their learning materials to a wider community of learners than those who can physically attend on campus. The low barrier to entry has made e-learning into a global business with many providers. For some Universities, the number of learners on their virtual campus exceeds those on the home physical campus. This may become increasingly important to the survival of the University if local, home costs increase substantially and markets fluctuate without warning. Many Universities have chosen a more conservative approach to their markets and have set up "blended learning" programmes which are a mixture of classroom-based teaching and also e-learning. The objective here has been to get the best of both worlds - attract students to the physical campus, and also enable them to use the latest software tools and technologies to supplement the learning they receive in the traditional lecture room environment.

There is one key aspect that most educational providers agree on and it is the initial high cost of putting together a high quality e-learning or blended learning programme. It can be an intensive process as it also needs to consider the requirements of the student who is learning at a distance without the more traditional support mechanisms in place on the physical campus.

Gordon Moore (1965), founder of Intel Corporation, the semiconductor company has proposed in his 'Moore's Law' that the power and speed of processing and telecommunications doubles every 1.5 to 2 years for the same price. The implication of this law is that hardware has almost become free of charge. Many laptops are now offered free of charge if bundled in with the

purchase of a service from a telecommunications provider for a fixed period. Nicholas Negroponte (<http://web.media.mit.edu/~nicholas/>), former Director of MIT's Media Laboratory, has initiated the low cost "*one laptop per child*" (<http://one.laptop.org/>).

Over the last decade a less formal kind of e-learning has been introduced where the power of wireless technology is utilised in educational settings. It is more personal and yet more connected than traditional e-learning and uses mobile devices such as mobile phones that are portable, low cost, and widely available and accepted devices (Kukulska-Hulme 2005). The learners are mobile (O'Malley et al. 2003) and the learning is spontaneous, ubiquitous and pervasive (Kukulska-Hulme 2005).

Mobile learning has been assisting many facets of learning. In the literature the following elements have been suggested:

- Increased motivation (Perry 2003)
- Increased learners' autonomy (Vahey and Crawford 2003)
- Increased collaboration, engagement and self-confidence (Attewell 2005) and (Cortlett and Sharples 2004)
- Advancing the social skills of the students (Berger et al. 2003)
- Flexibility of access to learning materials and interacting with the real world (Barker et al. 2005)
- Improved language learning (Song and Fox 2005), (Uther et al. 2005) and (Bull et al. 2005).

- Helping the disadvantaged in developing countries (Traxler and Leach 2006), (Barker et al. 2005), (Brown 2004) and (Taylor 2005).

Mobile learning faces many challenges due to the variety of mobile devices, differing input techniques, variability in types of connectivity, limitations of small screens, short battery life, limited processing power and memory capacity (Kukulska-Hulme 2005 and Holzinger et al. 2005). Therefore pedagogical and technical usability must be taken into consideration when designing mobile learning applications for improved learning and more usable learning environments (Kukulska-Hulme and Shield 2004 and Syvänen and Nokelainen 2004). Mobile learning is often advertised by slogans such as “*anywhere, anytime learning*” (mLearn 2004). However, educators and designers must avoid the “*mechanistic approach*” (McKenzie 2003) in using mobile technology which “*is limited, simplistic and likely to damage millions of students since children are not hamburgers or widgets. Schools do not achieve impressive results by acting like factories or fast food restaurants*” (McKenzie 2003). Mobile learning should not be about turning e-learning materials into smaller, incremental packages. Rather, different methods of learning that are more appropriate for these devices must be designed and implemented. For learning to be effective and motivating it must involve seeing, hearing and doing (Confucius 551 BC – 479). Computer games with their rich multimedia capabilities and high interactivity provide immersive environments that engage and draw players into learning and motivate them to discover further (de Freitas 2006, Halverson 2005, Maney 2005, De Castell and Benson 2004, Carlson 2003, Klopfer 2004, Squire 2005, and Mitchell and Savill-Smith 2004). These games are considered by the players as intrinsically rewarding activities which

engage them in a flow state where they can experience total involvement with the task (Funk et al. 2004). These tasks are often in the form of puzzles that generate an experience of “*hard fun*” (Klopfer 2005) whilst being caught up incidentally in learning goals without realizing it (Gee 2005).

There are novel types of games emerging that combine both real and virtual worlds which are called mobile mixed reality games. These games often require wearable computers, head mounted displays, a GPS receiver, digital compass and possibly a fiducial tracking system to immerse the player in the game play. Examples are ARQuake (Piekarski and Thomas 2002), Human Pacman (Cheok et al. 2004), Treasure (Barkhuus et al. 2005) and CitiTag (Vogiazou et al. 2005).

In parallel with these mixed reality games, alternate reality games (ARG) have been growing. In contrast to mixed reality games, they are large scale multiplayer games that are formed via a rich interactive narrative using many different platforms and technologies. *“These games are an intensely complicated series of puzzles involving coded Web sites, real-world clues like the newspaper advertisements, phone calls in the middle of the night from game characters and more. That blend of real-world activities and a dramatic storyline has proven irresistible to many”* (Borland 2005). These cross media games combine web technologies with real life objects and locations while solving puzzles and finding clues, for example Perplex City (Mind Candy 2005) and I Love Bees (I love bees 2004) which blur the distinction between the game and real life (Borland 2005).

In mobile learning, portable versions of mixed reality games have been designed. These games have often been implemented on PDAs with GPS

receivers while connecting to a wireless LAN, for example in participatory games (Klopfer and Yoon 2005), Environmental Detective (Klopfer et al. 2002), and Savannah Facer (2004). A detailed analysis of these games will be presented in chapter 5. The very rapid developments in mobile technology have helped the game designers to use the latest technology and produce mixed reality games with improved portability. However, these games face many pedagogically issues and challenges despite the extensive technology that has been invested in their production. They need to facilitate deep learning where students are active and committed to learning. There are different learning theorists that propose how to achieve such a pedagogical approach which includes Piaget (1980), Bruner (1966), Papert (1980) and Vygotsky (1978), and Laurillard (1993). In chapter 3 these pedagogical approaches are discussed in detail.

The British Educational Communications Technology Agency (2004) states that the educational goals for portable devices must be as clear as for the traditional classroom. According to Laurillard (2002) the design of educational content must be *“driven by the learning objectives and aspirations of the course rather than by the capabilities of various technologies”* (Laurillard 2002, p.30). Sharples (2005) and Taylor et al. (2006) have proposed Laurillard’s (2002) Conversational Framework as a suitable pedagogical structure in the mobile age. Mobile learning in this approach is considered contextual in relation to physical space and the community in which the learning takes place. Mobile technology provides a method of communication to promote conversation. When learners share and discuss their description of a solution, a shared understanding of the problem can be reached (Sharples 2005) and (Taylor et al.

2006). The Conversation Framework “*forms an iterative dialogue between teacher and students*” (Laurillard 2002, p. 29). which focuses on both theoretical and practical aspects of learning (Laurillard 2002). It also includes Socratic elements of learning (http://en.wikipedia.org/wiki/Socratic_method) where teacher and students constantly use question and answer techniques which are very likely to result in critical thinking where “*interpretation, analysis, evaluation, and inference*” (Facione 1990) are fundamental elements of learning.

1.2 Safety of Wireless Networks and Mobile

Phones

There have been frequent statements in the media over the years about the dangers associated with the use of wireless networks and mobile phones, particularly for young people, because of the associated electromagnetic radiation. The Health Protection Agency (2011) has issued the following statement –

“There are many different manufacturers producing WLAN equipment and there are several different technical standards to which equipment can be designed. The systems the Health Protection Agency (HPA) has seen operate in the 2.4-2.5GHz frequency band. The output powers from the base stations and computer terminals were a few tens of milliwatts during data transmission and very much lower while on standby. There are also systems operating in bands between 5 and 6 GHz.”

The HPA has made measurements of the power density of radio waves generally in and about the offices where WLANs are deployed and these have always been found to be very much below the guideline levels referred to above. The situation is rather more complicated for exposure within the first few centimetres of the transmitters, for example, for the situation where a laptop computer is placed on someone's lap with its transmitting antenna projecting on one side, or mounted inside the case. This is the situation where exposure would be highest and there is no practical assessment that can be rapidly performed to check levels with an installed system. Nevertheless, given the low powers, a problem with guideline compliance would not be expected.

When a radio terminal is used close to the body, some of the radio energy penetrates into the body and it is absorbed in the tissues. The pattern of this absorption and the total amount of energy absorbed depend on parameters such as the frequency, output power, position of use, antenna type, etc and it is not easy to predict without a detailed investigation. The exposure is characterised by the Specific Absorption Rate of energy (SAR) in the tissues and this will generally have a spatial peak value near the surface of the body and close to the radiating antenna.

Guidelines expect SAR to be averaged over various different tissue-masses and time-periods before comparison with the basic restrictions. The most stringent basic restrictions for the situation where low power radio transmitters are used near to the body are those on localised SAR in the head, which involve an averaging mass of 10g and an averaging time of six minutes. For this situation, the ICNIRP guidelines for workers advise that SAR should not exceed 10W/kg. The ICNIRP guidelines and Council Recommendation basic

restriction for the general public is that SAR averaged in this way should not exceed 2W/kg.

On the basis of current evidence, the HPA does not consider there to be a problem with the safety of a WLAN. If an explicit statement that exposures are within the ICNIRP guidelines is required, this would have to be obtained from the manufacturers; however, it could be argued that this is implicit in the CE marking.” There is further information available in the EMF guidelines (1998).

1.3 Research Demographics of Users

In 2006 a study of opportunities for m-learning in a developing country was undertaken, using surveys of focus groups, based on psycho-pedagogical principles (Fotouhi-Ghazvini et al. 2007, Fotouhi-Ghazvini et al. 2008 a). Examination of international comparative data (Fotouhi-Ghazvini et al. 2008 a) demonstrated that environments where network connectivity is limited but where mobile 2G services are available are not untypical of ‘developing world’ countries in the contemporary context and hence conclusions drawn can be argued to have wider significance. The penetration of cabled access in developing countries is almost axiomatically low, reaching only a modest proportion of the population. Ownership of appropriate personal computers is also very limited, economic factors being compounded by problems of unreliable electricity supplies. On the other hand, access through the mobile phone system has the potential to be far more propitious, since the terminal hardware is far cheaper than a PC, has a more reliable power supply, avoids

cabled connections, is already very widely deployed and has the great advantage of familiarity to a substantial proportion of the target audience.

The standard mobile phone is, and will continue for some time to be, the dominant platform. This platform must therefore be the focus of content design, whatever its limitations. Early adopters such as students will increasingly have more advanced mobile phones, which they could use to facilitate their learning progress through constructivist conversation theory. Sampled students expressed a preference for using m-learning as an extension to their traditional classroom (Fotouhi-Ghazvini et al. 2008a). There was already a significant use of mobile phones in the educational domain using the phone's camera, Bluetooth and SMS (Fotouhi-Ghazvini et al. 2008a). Due to the fast diffusion of mobile phones, gaming has become increasingly popular. In a separate study in 2008 it was discovered that mobile games are played more by female computer engineering students when compared to their use of desktop games (Fotouhi-Ghazvini 2008). The development of mobile games is more suitable for a developing world context due to their low cost of production, and introducing mobile educational games could have a bright future. In this research different mobile games are designed for learning that follow these criteria:

- (1) The device and the overall technology used are cheap and easily available to students in developing countries.
- (2) A bottom up approach is followed for the game's deployment where there is no need for involvement at institutional level.

- (3) The logistical barriers such as the need to purchase certain hardware or provide special space arrangements are kept minimal and involve no radical change to the status quo.
- (4) The game learning approach is practical and easily understood and demonstrated by the teachers.
- (5) Students are able to use their everyday skills to play the game.
- (6) Games are installed, run and played with no need for specialised technical staff knowledge.
- (7) The games' coding steps, and their corresponding learning model, are in a generic format and are reusable for other learning scenarios.

1.4 Current Limitations

The objectives of educational games are to create competence in a certain field of knowledge often via exploration, solving puzzles and working with others. By careful design these games have more potential to engage and immerse students in learning than any other kind of learning (De Feritas et al 2006 and Malone 1981).

Currently there are four main weaknesses in educational games:

- (1) It is difficult to keep the learners' simultaneously engaged in the game play and in learning (Prensky 2001).
- (2) The educational game content is not appropriately designed for the curriculum. The amount of irrelevant content is high and wastes the class time (Kirriemuir et al. 2006).

(3) It is challenging to find ways that game learning results in critical learning (Prensky 2001).

(4) The teacher's role in the classroom during the game based learning is not clear (Kirriemuir et al. 2006).

Beside the general weaknesses, the existing mobile games lack the following features (Fotouhi-Ghazvini et al. 2009 b):

(1) Hierarchy of learning.

(2) Higher level thought development.

(3) Game rules that assess a wide range of skills and knowledge.

(4) Systematic face to face dialogues.

(5) Specific game challenges according to each learning objective.

(6) Ease of access to different resources.

(7) Efficient user interfaces.

(8) A self-assessment system.

(9) Real-time assessments by the teacher

1.5 Aims

This thesis provides strategies for solving existing problems in educational games in the mobile environment, and also assists the developers and educators to successfully incorporate these games into specific curricula. It focuses on four issues as follows:

(1) *Conversational framework* which provides appropriate support strategies to learners during knowledge construction. It involves the instructor actively in

the learning process and promotes peer-to-peer collaborative learning that is highly likely to result into critical learning.

- (2) *Instructional design* which follows hierarchical conceptual growth and assessment to benefit learners in acquiring diverse knowledge and skills, and possibly produce higher level cognitive development.
- (3) *Motivational design* that utilises the engaging power of games to help the learners achieve an optimal experience during the learning process.
- (4) *Mobile interface design* that is suitable for the unpredictable nature of the mobile environment with devices that have many limitations compared to their desktop counterparts.

1.6 Contributions

- (1) In chapter 2 the new game based learning paradigm of the Mobile Mixed Reality Game (MEMRG) is introduced which takes advantage of distinct features of mobile learning (Fotouhi-Ghazvini et al. 2011 b).
- (2) In chapter 3 a review of constructivists' theories are carried out to identify the main constructive features necessary for mobile games. A conversational framework is introduced as an architectural structure for MEMRG interactions (Fotouhi-Ghazvini et al. 2011 d).
- (3) In chapter 4 an instructional/motivational model of learning is proposed. This model is built by extracting the main elements suggested by the most influential instructional and motivational researchers in these fields. The model could be used to convert the instructional content into a game structure, as it has been incorporated in the Detective Alavi game described in chapter 6.

- (4) In chapter 5 the main features and weaknesses of innovative augmented reality games are assessed in order to propose improvements (Fotouhi-Ghazvini et al. 2009 b).
- (5) In chapter 6, the design procedure for different language learning games is presented. This chapter details the important steps necessary to design a mobile game user interface. These games incorporate the different cognitive processes that have been set out in (Anderson and Krathwohl, 2001). The mobile Adventure Quiz games have been published in Fotouhi-Ghazvini et al 2009 d which targets the 'remembering' cognitive process. The MOBO city package that has been published in Fotouhi-Ghazvini et al. 2009a targets 'remembering' and 'understanding' cognitive processes. The Butterfly game that will be published in Fotouhi-Ghazvini et al. 2009 d incorporates the 'remembering' cognitive process. The Detective Alavi game as a MEMRG has been published in Fotouhi-Ghazvini et al. 2011 a, c and d, and it implements all the cognitive processes necessary to develop higher order thinking.
- (6) In chapter 7 the necessary technologies, hardware, costs, programming language and coding step requirements for developing MEMRG are detailed (Fotouhi-Ghazvini et al. 2011 a).
- (7) In chapter 8 the implemented games have been assessed and evaluated according to their instructional, motivational and conversational features (Fotouhi-Ghazvini et al. 2009 a and d and Fotouhi-Ghazvini et al. 2011 a and d).

1.7 Thesis Outline

This section presents the outline of each chapter in this thesis.

In *chapter 2* the following concepts will be discussed:

- Different definitions of mobile learning are categorised and discussed. These groups are (1) technology oriented (2) electronic learning oriented (3) location oriented (4) and communication oriented.
- Distinctive features of mobile learning are stated :
 - It is mobile according to physical space, technology, conceptual space, social space and time.
 - It is contextual having:
 - Spatio-temporal context using sensors such as GPS, compass, Bluetooth, camera, accelerometer, and gyroscope,
 - Device context in term of its hardware and software
 - Virtual world context by monitoring progress of teaching, learning and playing
 - Personal context by considering the learners physiological, mental and biographical features
 - Role context as peers, teachers and virtual characters.
 - Mobile learning is considered communicative because it uses connection technologies and facilitates conversations, students' discussions and teacher's feedback.

- Mobile educational mixed reality games (MEMRG) are introduced and their construction is explained in terms of forming larger super-spaces. These spaces use semantic information in the form of text, graphics, audio, score, location and orientation - integrating real, virtual, mobile and cyber spaces.
- Subsequently a questionnaire and a scale are proposed to evaluate the mobile mixed reality games for their degree of mobility, context and communication

In *chapter 3* a review of constructivist theorists with their main points of view will be introduced as follows:

- Piaget (1980): constructing knowledge through assimilation and accommodation.
- Bruner (1966): use of images and symbols and hierarchical progression in knowledge.
- Papert (1980): constructing knowledge through microworlds.
- Brown (1989): situated learning in an authentic environment.
- Vygotsky (1978): social learning using feedback from a more competent person.
- Engestrom (1978): importance of role distribution and significance of rules and norms in any community.
- Laullilard (2009): iterative feedback from teacher, customization of learning material, and collaborative learning

In *Chapter 4* the following instructional and motivational theorists with their main points of views will be presented to draw a model as follows:

- Bloom's revised taxonomy (Anderson and Krathwohl, 2001) introducing the six levels of cognitive progress: remembering, understanding, applying, analysis, evaluating, creating,
- Gagne et al. (1992): gaining attention, informing about learning objectives, presenting the content, providing guidance, providing practice, providing feedback, assessing performance, enhancing retention and generalization
- Keller (1987) elements of attention, relevance, confidence/challenge, satisfaction/success
- Malone and Lepper (1987): elements of challenge, curiosity, control, fantasy, cooperation, competition, recognition.
- Quinn (2005): elements of story, goal, challenge, relevance, control, exploration, feedback, and attention
- Gunter et al. (2008) elements of relevance, embedding, transfer, adaptation, immersion, and naturalization
- Csikzentmihalyi (1990) optimal experience and state of flow
- A model for converting the instructional content into an educational game
- A model for Incorporating the motivational factors in the game structure

In *chapter 5* different features of existing innovative augmented reality games will be discussed to highlight the main challenges in the structure of these games. First, the following elements in the game structure will be investigated: learning objective, learners' preferences, genre, story, rules,

characters, different levels, puzzles, communication capabilities, knowledge chunks, and menus. Then the motivational elements such as the learner's attention, goals, appropriate challenges, feedback, real experiences and control will be explored.

In *chapter 6* the design processes for different mobile games used in this research will be explained. These games are:

- Mobile Adventure Quiz games (Fotouhi-Ghazvini et al. 2009 d) will introduce elements of an engaging game such as exploration, attractive virtual characters, scoring, chance of winning and losing with regard to a series of multiple questions concerning technical English vocabulary.
- MOBO city (Fotouhi-Ghazvini et al. 2009 a) will teach a non-language related subject and implicitly expose learners to technical English vocabulary. It is an adventure game that takes place in a fantasy world of a computer's motherboard. There are buildings which are represented by electronic components and the main character is a data bus that must transport data in the right order from a starting point to a specific destination. Computing knowledge is structured according to concept maps and related images to increase the learner's '*understanding*' cognitive process.
- Butterfly game (Fotouhi-Ghazvini et al. 2009 d) explicitly practices vocabulary spelling to correct learners' common errors and increase their '*remembering*' cognitive process. The game uses attractive game characters like an animated duck and butterfly.

- Detective Alavi game (Fotouhi-Ghazvini et al. 2011 a) is a mixed reality game that moves between real, virtual, cyber and mobile space. It uses Quick response (QR) codes to extract information from real space, send an SMS, initiate a phone call or launch a URL. Bluetooth is used to add the competitive element by broadcasting the group scores to other devices. The game narrates a detective story that requires language and technical knowledge to solve a cryptogram. The game has hierarchical levels according to different cognitive processes of 'remembering', 'understanding', 'applying', 'analysis', 'evaluating' and 'creating' based upon a conversational framework. It is designed according to instructional, motivational and user interface design recommendations. Moreover it considers the diversity of students such as different cognitive levels, disabilities and gender.

Chapter 7 discusses the J2ME's advantages such as its portability, availability, low cost and high security. Then the J2ME disadvantages such as primitive database and user interface capabilities are stated. The steps taken to optimise the coding are presented for decreasing the size of the java file and increasing the speed of the game at run time. Then the necessary mobile technologies and essential hardware such as Bluetooth, camera, processor, RAM and audio codec to deploy the game are elaborated. In the implementation the following steps will be detailed:

- Setting the view window of the display to accommodate the main game screen, scoring and the dialogue text.
- Incorporating appropriate graphics to avoid high memory consumption.

- Preserving the game status when the player moves between different screens.
- Presenting the game feedback and dialogue in an appropriate order.
- Criteria for incrementing appropriate variables, cognitive progress and language progress.
- Criteria for winning and losing the game.
- Saving, updating and pausing the game.
- Controlling the mobile phone camera and capturing the QR code.
- QR identification and discovering the encoded data using filtering, positioning, sampling and decoding.
- Initiating a voice call.
- Opening a URL in a browser.
- Sending an SMS Message.
- Acting as a Bluetooth client to discover nearby devices and receiving scores.
- Acting as a Bluetooth server to set the local device as discoverable and sending scores to other devices.

In *chapter 8* the Adventure Quize games, MOBO city package and Detective Alavi game will be assessed to evaluate their pedagogical effectiveness compared to the traditional classroom environment. In this study the Detective game represents a MEMRG game. Further information will be collected during and after the game as follows:

- Students' learning processes during the game play.
- Teacher's observation during the game.

- Students' opinions on changes in their thinking after playing the game.
- The usage of feedback, interactions and conversations during the game play.
- Students' experiences concerning game usability inside and outside classroom.
- Students' opinions about the game's characters, its story and puzzles.
- Students' degree of engagement while playing the game.

Finally, in *Chapter 9* the conclusions of this thesis are presented and further work is outlined.

Chapter 2

From Mobile Learning to Mobile Educational Mixed Reality Game

2.1 Introduction

Mobile learning is a new educational paradigm which is more flexible than learning which uses desktop computers (Fotouhi-Ghazvini et al. 2011b). Often technology acts as a supplement when PCs are used, whereas with mobile devices the technology can be more integrated into the learning process. It is also portable from one environment to another, such as classroom to outdoors and from outdoors to home. It thus allows the potential of seamless learning to be realised, where the technology mediated learning is flexible and adaptable so that teacher and student are not bound to a particular learning space. Mobile learning also utilises real-world or situational data to make the learning experience more meaningful and memorable. Klopfer (2008) provides a number of reasons why using computer rooms in educational institutions could present challenges to the learner, if not difficulties. It is noted that:

1. *“Computer rooms are located in another place”* (Klopfer 2008, p. 62) and not in the classroom; students have to change their location and work in unfamiliar surroundings.
2. *“Access is irregular”* (Klopfer 2008, p. 63) due to the limited number of computers, scheduled time to use the computer room might not happen at the same time as the learning material is being taught in the class.
3. *“Computer labs are not maintained”* (Klopfer 2008, p. 63) due to the limited number of technical staff.
4. *“Computer labs are not conducive to teaching”* (Klopfer 2008, p. 63) and it is difficult for teachers to walk around in a crowded computer room and check students’ work.
5. *“Computer labs are not conducive to learning.”* (Klopfer 2008, p. 63) It is hard to walk and talk, and face-to-face collaborative work is very unlikely.

It is also noted with regard to computer-based learning that *“activities involve spending the majority of time interacting with the computer. Opportunities for real world interactions with partners and classmates are rare”* (Klopfer 2008, p 64). It can be inferred that computer-based learning in most schools and universities could impose a barrier to learning and sometimes slow down the process rather than facilitate it. Learning in nature is intrinsically mobile. Vavoula and Sharples (2002) noted *“learning is mobile in terms of space, i.e. it happens at the workplace, at home, and at places of leisure; it is mobile between different areas of life, i.e. it may relate to work demands, self-improvement, or leisure; and it is mobile with respect to time, i.e. it happens at different times during the day, on working days or on weekends”*.

Mobile learning is not bound by time and space and can appropriately enhance the process of learning, especially in an academic environment. It can take place in a classroom, be used frequently, and with no requirement for maintenance. Students can collect data with their camera, share information using Bluetooth, and collaborate face-to-face in an educational mobile game. Mobile learning forms a flexible and adaptable learning environment that can be used for education independent of time and physical location. M-learning environments fall into two categories:

- I. Field-work - where the learner is experiencing real world situations, continuously communicating through the mobile device and using mobile resources as a reference, or as an assessment tool – in this case materials are designed to be simple and effective.
- II. Classroom-based - which often utilizes virtual worlds to inform and engage the learners via multimedia content.

A rich mobile learning system would include both of these environments and combine them into one framework. For example, mobile mixed reality games could be played in a classroom and at the same time use real world data. This system would take into account the mobility of the learners, would help to strengthen the interaction among learners located in the same place, and would assist in creating a virtual mobile arena to learners that are geographically distributed using web, SMS and telephone calls. This approach develops a situated learning experience through physical encounters and social interactions, forming a ubiquitous, learner-centred, individualized learning

experience which uses mobile technology to network learners into collaborative teams of explorers (see Detective Alavi game in chapter 6, section 6.4.3).

2.2 Mobile Learning Definitions

A range of definitions for mobile learning has been proposed in the literature. In this section they have been divided into four main categories: '*technology oriented*', '*elearning oriented*' '*location oriented*' and '*communication interaction-oriented*'. These definitions may overlap and be similar on some points and differ on others.

2.2.1 Technology-oriented definitions

These definitions describe mobile learning in terms of mobile devices and related technology, such as mobile phones, PDA, Nintendo DS, PlayStation Portable, iPod, etc, and mobile communication and networking. Quinn (2000) defined mobile learning as learning that takes place with the aid of mobile devices. Colazzo et. al. (2003) considered the mobile learning educational process "*as any learning and teaching activity that is possible through mobile tools or in settings where mobile equipment is available*". Nyíri (2002) states "*in the course of person to person mobile communication, whose site of production, circulation, and consumption is the network*" Polsani (2003). Brugnoli and Lorusso (2005) broaden these definitions into a mobile access "*to use learning service at any time, from any place, quickly and simply, through a simple mobile device, a PDA, a tablet PC, a pocket PC, a "converged device"... with the ability to connect to a broad range of wireless network*". In this approach the

pedagogical aspects of m-learning are completely ignored. It assumes no guidelines for teachers and content designers and falls short of a suitable definition of m-learning.

2.2.2 Electronic (e) learning-oriented definitions

This viewpoint characterizes mobile learning as an extension of e-learning. Pinkwart et. al. (2003) defines mobile learning as “*e-learning that uses mobile devices and wireless transmission*”. Ally (2004) defined m-learning as “*the delivery of electronic learning (e-learning) materials on mobile devices such as personal digital assistants (PDAs), mobile phones, Tablet PCs, Pocket PCs, palmtop computers, etc*”. There have been attempts to create mobile versions of Learning Management Systems (LMS) such as Joomla, Drupal and Moodle for access through mobile phones (E-learning 2010). Other specialised LMSs such as Mobilim have also been developed to help students to access educational content through mobile devices (Istanbullu 2008).

This mode of classification often fails to recognise the major differences between m-learning and e-learning. E-learning is often used in formal distance learning while m-learning is semi-formal and used to bridge the gap between formal learning and informal learning. In the fieldwork category of m-learning, the communication facilities of the device allow the learner to utilise the teacher’s or the expert’s guidance, which adds a formal element to the informal setting of the field. In classroom-based m-learning, the virtual spaces of mobile games add the informal ingredient to the formal setting of the classroom. Table 2.1 shows how m-learning utilises the variable, mobile and spontaneous nature

of informal learning while allowing the learner to assimilate a curriculum and benefit from just in time instructions.

On the other hand, m-learning is more suitable for situated learning, where learning happens in the same physical or stimulated context that the knowledge applies.

Table 2.1 A comparison between traditional formal learning, traditional informal learning and semi-formal mobile learning.

	Formal E-Learning	Traditional Informal Learning	Semi-Formal Mobile Learning
Learning Content (LC)	Set by the teacher according to the curriculum	Students derive their own (LC) according to their learning needs	Set by the teacher according to the curriculum, more content accessible for further research
Learning Modules	Large and fixed	Variable in size according to the context	Short and context driven
Learning Route	Activities set by the teacher	Planned by the students	Could be planned by both teacher and students. Students often negotiate with other peers
Learning schedules	Fixed	Variable	Fixed/Variable
Learning Space	Fixed	Mobile	Mobile, could use a mixture of virtual spaces with real spaces
Context Awareness	None	Happens in context	Happens in context and is aware of the context
Connectivity of Technology	Limited to certain areas with accessibility to a PC	Accidental	On demand
Group Formation	Planned	Ad hoc	Ad hoc

Learners can dialog with virtual or real gurus (i.e. apprentice) in a real life manner through discovery processes, as illustrated by Detective Alavi (chapter 6, section 6.4.3). However, in e-learning heavy emphasis is placed on learning

repositories where the construction of content and the nature of interaction is fixed and predetermined by the LMS. E-learning can use significant bandwidth where there is no limitation on textual or multimedia content, but m-learning uses slower mobile transmission techniques such as GPRS with considerable limitation on media access and storage. In addition, m-learning is mobile, spontaneous and always connected which helps students to learn in a constructive realistic environment which is dynamic.

“Conventional e-learning nearly always takes place in situations where the learners’ time and space have been dedicated and committed to e-learning, facing their computer, sat with their back to the world, with e-learning taking centre-stage. Mobile learning in the sense that we have been talking about it takes place woven into a host of daily tasks, places and situations” (Traxler 2009, p 5).

2.2.3 Location oriented definitions

There are definitions of m-learning that are more centred around the learner, his/her mobility and the locational context. Malley et. al. (2003) defines m-learning as: *“any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies.”* (Malley et. al. 2003, p.6). Chan et. al. (2004) differentiates mobile learning *“by rapid and continual changes of context, as the learner moves between locations and encounters localized resources, services and co-learners”*.

This approach has been accommodated in m-learning research and methodology and it does reveal a distinguishable feature of m-learning through location-centric learning.

However, it still overlooks the pedagogical aspects of learning. Most locational m-learning systems are not much more effective than traditional teaching and in reality mobile maps and locational resources which are not built around a constructive framework of learning could be replaced by pen and paper.

2.2.4 Communication interaction-oriented definitions

This definition emphasises communication and conversation in context. It considers the mobility of the learner during formal or lifelong learning. It regards learning as a constructive and social process. It analyses learning as a personal and situated activity facilitated by technology. Sharples et. al. (2007) defines communication interaction oriented mobile learning as *“the processes of coming to know through conversation across multiple contexts amongst people and personal interactive technologies”*. This definition of m-learning uniquely encompasses the exceptional spirit of m-learning which is to become informed from other people’s *‘informings’* by changing the context which is created as a result of negotiation and dialogue between people facilitated by technology.

2.2.5 Discussion of definitions

Approaches that begin with technology alone have generally felt to be inadequate simply because they are primarily technology driven and, initially at least, leave the user out of account. Theories of human learning have emphasised that pedagogical requirements should come first and then an

appropriate learning environment is mediated to the learner by an appropriate selection of the technology that best furthers the pedagogic aims and objectives and meets the pedagogic requirements. To put technology first undermines this educational process and runs the risk of providing the learners with the latest gadgets without any underpinning educational foundation or purpose. In chapter 6, section 6.4.1 an adventure quiz game is designed for mobile phones but the quizzes are not related to the game story. Students do not pay attention to the quizzes and they are considered as distractions to the gameplay, so no meaningful pedagogical benefits resulted from these games. Approaches that see m-learning as e-learning with mobile devices may underestimate the significant contribution that context and participative interaction play in the experience of the learner. If a mobile device is only delivering e-learning materials at a distance, it is little different from traditional e-learning (E-learning 2010 and Istanbullu 2008). Similarly, location-centred learning without a pedagogical framework may not advance real learning or use the location to best advantage (e.g. by incorporating it directly into the learner environment and the learner experience).

Klopper (2008, page 120) identifies students that were involved in a locational game play but could not understand the concept of the outdoor portion. During the game students were running around collecting different types of information at different locations, but they could not understand why this information had not been given to them in the first place. The learning activity was considered inefficient by students. If the location becomes a place where paradigms are tested and experiments conducted then it is likely to live in

the memory of the learner as a reference point – rather like a real chemistry laboratory does for a chemistry student. Theory and practice can then be understood by the learner as different aspects of the same fundamental principle, and also that you cannot have one without the other. Learning is facilitated by seeing a theory or concept demonstrated in real-world examples and demonstrations.

Understanding m-learning as communication and interaction processes highlights the importance of understanding the relationship between the learners and the educational environment, and also between the learners in a group context (in that they can learn from each other to some degree as they are involved together in the learning process). However, without an underlying pedagogical framework such communication and interaction can be ad hoc and lack a well-defined goal. Learning on this basis can be accidental and serendipitous rather than structured and defined. The learners in the group then receive a social experience but not necessarily an educational one (Laurillard 2009).

A balanced definition seeks to give primary weight to the pedagogical needs and requirements and the framework within which the educational objectives will be advanced. Technology will be utilised that effectively and efficiently implements these pedagogical goals. Communication and interaction will be facilitated, and the locations of the learners will be utilised as an integral part of the learning process in order to harness the learner's contextual and real-world experiences to further the learning process.

2.3 Distinctive Feature of Mobile Learning

Mobile devices such as mobile phones often cost less than desktop computers and are owned by many people, even the underprivileged in developing countries. Users are able to carry these devices all the time because they are small in size, portable and wearable - often in the pocket or handbag. They have a long battery life and they do not need a mains connection as much as laptops. Mobile phones can be switched on and operated immediately. They are easy to use and have useful functionalities, especially for instant communication. They are not obtrusive and can be used to collect, record, capture and store data.

2.3.1 Mobility

Mobile phones can be carried by users all the time and therefore can support mobile learning. Sharples et. al. (2009) defines the different aspects of mobility in mobile learning as follows –

1. *“Mobility in physical space”* (Sharples et. al. 2009) which helps the learner to carry the mobile device comfortably all day long, every day and learn in spare moments. They are not bound to a certain location like a classroom. For example in chapter 6, section 6.4.2 the MOBO city game helps the university students to acquire technical vocabularies on the move while travelling, at home or in restaurant with no requirement to be present in a particular physical environment.

2. *“Mobility of technology”* (Sharples et. al. 2009) makes it possible for technologies such as Bluetooth, Mobile Web, WiFi, GPS and a camera to come together in a lightweight device ready for utilization whenever required. In chapter 6 a detective game is presented which uses a mobile phone’s camera, Bluetooth and mobile web to help a virtual character ‘Detective Alavi’ to solve a mystery using an information acquisition process.
3. *“Mobility in conceptual space”* (Sharples et. al. 2009). The learner can move from topic to topic, concept to concept and learn in small chunks whenever necessary through the mobile web. Teachers can use the mobile web to study different language learning comprehensions in their spare time (Fotouhi-Ghazvini et al. 2009 c).
4. *“Mobility in social space”* (Sharples et. al. 2009). The mobility of the learner in physical space facilitates the forming of different groups during the day for collaborative learning. In chapter 6, section 6.4.2, MOBO city is not a multiplayer game. However as the learner plays the mobile game at different locations, different groups of students are attracted to the game and therefore help the learner by forming a social space. In chapter 6, Detective Alavi players are able to play against any other group of learners using an ad hoc Bluetooth connection.
5. *“Learning dispersed in time”* (Sharples et. al. 2009). The learning can be distributed across different points in time and increasingly built up. In chapter 6, section 6.4.3, the Detective game builds knowledge in a hierarchical fashion. The players are able to save their scores and cognitive progress and come back to the game when appropriate.

Different dimensions of mobility result from the contextual and communicative features of mobile learning.

2.3.2 Contextual

Mobile learning occurs across different contexts. A system is regarded as context-aware *“if the system uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task”* (Dey 2001). The learner has a situated role while being able to use the contextualized information in a mobile device readable form (Hu and Moore 2005). A mobile learning context definition has been given as *“any information that can be used to characterize the situation of learning entities that are considered relevant to the interactions between a learner and an application”* (Wang 2004). Cole (1996) presents a significant difference between context as *“that which surrounds us”* and context as *“that which weaves together”*. In a mobile learning context is not just a shell to surround mobile learners, but it increases interaction and engagement between learners and the learning environment.

Factors that contribute to creating context in mobile learning are the learners’ interaction with system, the mobile device, wireless infrastructure, environment and other learners. Different context types exist in mobile learning environments and these are discussed below.

2.3.2.1 Spatio-temporal context

This context type depicts the characteristic of a learner’s context regarding time and spatial aspects. Sensors such as GPS, compass, Bluetooth, camera,

accelerometer and gyroscope are part of today's mobile device and collect ambient information in the form of:

(A) Temporal contexts, in this case the mobile device is aware of time-dependent data and provides temporal information to the learner concerning the period during which some event happened or will occur (Wang 2004).

(B) Spatial contexts are:

- (1) Absolute position of the mobile device provided by a combination of a GPS (Global Positioning System) receiver and compass (Pederson et al. 2008).
- (2) Relative position of the mobile device provided by Bluetooth (Fotouhi-Ghazvini et al. 2011 a).
- (3) Relative position and orientation of a physical object to the mobile devices' camera using QR codes, or augmented reality markers to discover the embedded text, activate a web browser, make a phone call (Fotouhi-Ghazvini et al. 2011 a) or overlay the physical object with virtual text, graphics or audio (Liu 2010).
- (4) Orientation of the mobile device measured by a combination of accelerometer and gyroscope (Mehigan 2009).

2.3.2.2 Device context

Device context provides a basis for exploiting the potential of hardware and software and the capabilities of the device. Access to different services is provided according to the device context. Information such as location, camera, communication tools, screen size, browser types, bandwidth, connectivity, battery, operating systems, amount of available memory and processing power

are essential for detecting the kind of services that could be installed or accessed through the device (Benlamri and Zhang 2008).

2.3.2.3 Virtual world context

This provides computational data concerning events occurring within the virtual environment of the mobile learning system. It assigns goals, modules, calculates the current state of the learner in learning activity, monitors the learner's progress, the learner's grades or scores, and the current state of the teaching procedure such as specifying the next step of instruction or what learning resources must be utilised (Hu and Moore 2007).

2.3.2.4 Personal context

This could be divided into three parts: physiological, mental and biographical. The first part includes information such as name, nationality, gender, address, physical feature, disabilities etc. The second part contains information such as learning habit, mood, interest, and hobbies etc. The third part includes information such as qualifications achieved, job experiences and training, skills gained, affiliations, modules registered etc. (Hu and Moore 2007).

2.3.2.5 Role context

The learner uses this information to assist with the social role in collaborative learning. Role context provides information about the learning system's virtual characters and information from other users such as the learners, friends, colleagues, teacher, supervisor or advisor in a peer-to-peer networked mobile learning environment (Hu and Moore 2007).

2.3.3 Level of interactivity

Mobile context-aware applications include two levels of interactivity: (1) active context aware applications, and (2) passive context aware.

2.3.3.1 Active context-aware application

In this mode, sensors obtain contextual data and the application automatically updates a service for the learner. For example in (Mitchell and Race 2005) visual codes are distributed in different locations in a museum, and the application uses these codes to instantly connect the learners to specific web-based information. In this mode, learners are less in control and are passive. On the other hand the application does the entire work and is proactive (Hu and Moore 2007). This process could consume a considerable amount of time and resources, but user input is minimised and learners are less distracted.

2.3.3.2 Passive context-awareness

In this approach the application is passive and only shows the changes in the context. However, the learner actively participates and analyses contextual information via the interactive interface of the application, and makes decisions if it is appropriate to apply changes such as location or time (Mitchell and Race 2005).

2.3.4 Communicative

Mobile learning systems are able to use wireless or mobile phone connectivity such as Bluetooth, Infrared, WiFi, phone calls, SMS, MMS or mobile web to

connect people across contexts. This mode of connectivity allows students to build learning communities that facilitate conversations between learners in real and virtual worlds. In mobile social interactivity, learners converse, share and interrogate their perspectives on subject matter, negotiate, send and receive feedback to and from others, share data, aggregate and distribute them with other learners, experts or teachers forming a collaborative learning environment. This could considerably increase the engagement (Attewell 2010) among learners and provide a significant boost to the learner's confidence (Trinder 2007).

2.4 Mobile Games

2.4.1 Mobile games and learning

Learning can be facilitated by the effective combination of different kinds of resources and different modes of developing knowledge and skills. Mobile learning helps the learners to take advantage of the learning opportunities offered by mobile technologies through the use of mobile devices such as mobile phones and Personal Digital Assistants (PDAs) in contextualised authentic settings. This mode of learning enables learners to interact simultaneously with both the physical world and with the virtual world of digital information. Combining familiar actions in the physical environment with new information in the virtual world promotes a new experience with more engagement and higher social learning among learners. Information in digital space can be translated into game content characteristics: concepts, topics, and tasks. Game based learning is greatly satisfying and fast-paced compared

to repetitive and boring tasks in schools (Papert 1993). Educational games have demonstrated by careful design that they are able to offer a flow experience that immerses the learners in active learning and are able to boost the intrinsic motivation level of a learner by means of highly engaging challenges and feedback (Quinn 2005, Gunter et al. 2008). Given recent progress in mobile and wireless technologies, it is appropriate to consider combining mobile learning with game-based learning. Mobile games are often played in mutual awareness of players' other daily activities such as walking in a park or a street. The game system depends to some degree on external input such as the players' proximity from each other, or the player's location. Players receive different questions and hints as their physical position varies and they can switch attention between activities to play the game. These games take place in the real world and contain non-players; consequently, each game session can produce different experiences. In order to obtain the players' context, each player's mobile device is augmented with an array of software or hardware features, such as Global Positioning System (GPS) device, Radio Frequency Identification (RFID) reader, Bluetooth, Infrared or decoding software, and a camera for tapping into QR codes and other visual code information.

These games can be very innovative and can belong to different game genres. Mixed reality games are one of the most exciting genres that are often very difficult and impractical to implement on other platforms especially for educational purposes. Mobile games can use the mobile platform's distinctive features to implement this genre for classroom activities and field work. This

leads to new types of game which are termed in this research a 'Mobile Educational Mixed Reality Game' (MEMRG).

2.4.2 Mixed reality games

To define the concept of mixed reality games, Milgram and Kishino (1994) introduced the concept of '*Virtuality Continuum*'. Benford (1998) defines this as a '*mixture of classes of objects presented in any particular display situation*'. At one end of his scale is a 'virtual environment' which consists of only virtual objects and graphical simulation. At the other end is a 'real environment' with real objects that can be sensed directly. Mixed reality environments are defined by Milgram and Kishino (1994) as applications where "*real world and virtual world objects are presented together within a single display, that is, anywhere between the extrema of the virtuality continuum*". From Milgram and Kishino (1994) it can be inferred that the emphasis from the mixed reality definition is on the superimposition of real world and virtual world objects.

Benford (1998) studied mixed reality environments formed by mixing real and virtual spaces together in different ways; and display is only one of these. These spaces are not superimposed but are placed adjacent to each other and a window is created between them. According to this research a mixed reality system could have multiple boundaries to many distributed spaces. These separate spaces form a larger super-space where they can complement each other, share information and increase social interactions.

2.4.3 MEMRG and the semantic concept

In an educational setting the most important element that is transmitted, received, shared and discussed is information. Here we describe 'Semantic' as meaningful information that is necessary for the game to operate, or for a learning objective to be achieved. It is extracted from a mobile device's sensors or different virtual game space processes. Ideally, semantic information leads to 'assessing', 'instructing' or 'motivating' the learners in the process of 'knowledge acquisition' or 'knowledge construction'. Semantics are often in the form of:

- (1) Text, graphic, audio, other player's scoring data extracted from the virtual game space or cyber world space,
- (2) Location and orientation data from the real world
- (3) Audio or text from the mobile space or any other type of information that could be picked up with our five senses.

For example, in chapter 5, the Live Long and Prosper game (Klopper 2008) the semantics are in the form of location data and the game's virtual space data (the gene's compatibility). In chapter 5 the Environmental Detective and Outbreak@MIT games (Klopper 2008) the semantics are in the form of location data, audios, texts, videos. In the Savannah game (Facer 2004) semantics were in the form of smells, sounds, texts, graphics, and location data. In these games' user interfaces we cannot observe that at any moment in the game play, real objects visually superimpose virtual objects. This trend is evident in most MEMRG projects. The important limitation in this kind of mixed reality games is to maintain the 'flow' of the game when shifting from real space to virtual space and vice versa.

MEMRG must be able to combine mixed physical/virtual space with the mobile space for conversation and information exchange, and also be connected to cyberspace for accessing multimedia information, collaborative tools and conversational possibilities which are all encapsulated in a semantic learning space. Figure 2.1 represents a MEMRG learning space where mobile, cyber, virtual and real spaces are placed next to each other. There are close boundaries between the spaces but they do not superimpose. The virtual space has a pivotal role for different processes such as image processing, decoding, extracting locational data, educational assessment and instruction. The windows to real, mobile and cyber spaces are provided by different interfaces that increase the accessibility of the game for the players. Data flow in MEMRG is carried out by different semantics. The type 'mobile', 'cyber', 'real' and 'virtual' depend on where they have been originally generated. Different sensors such as GPS, Bluetooth, camera and accelerometer generate location and orientation semantics. However when decoding a QR code captured by a camera, alphanumeric semantics such as a phone number, a URL address, an SMS template or just pure text could result. Learners also extract and use semantic information from the mobile space and cyberspace without relying on any software during phone calls, SMS conversations and mobile web searches. They use their own perceptions through collaborative work with peers to extract the necessary semantics.

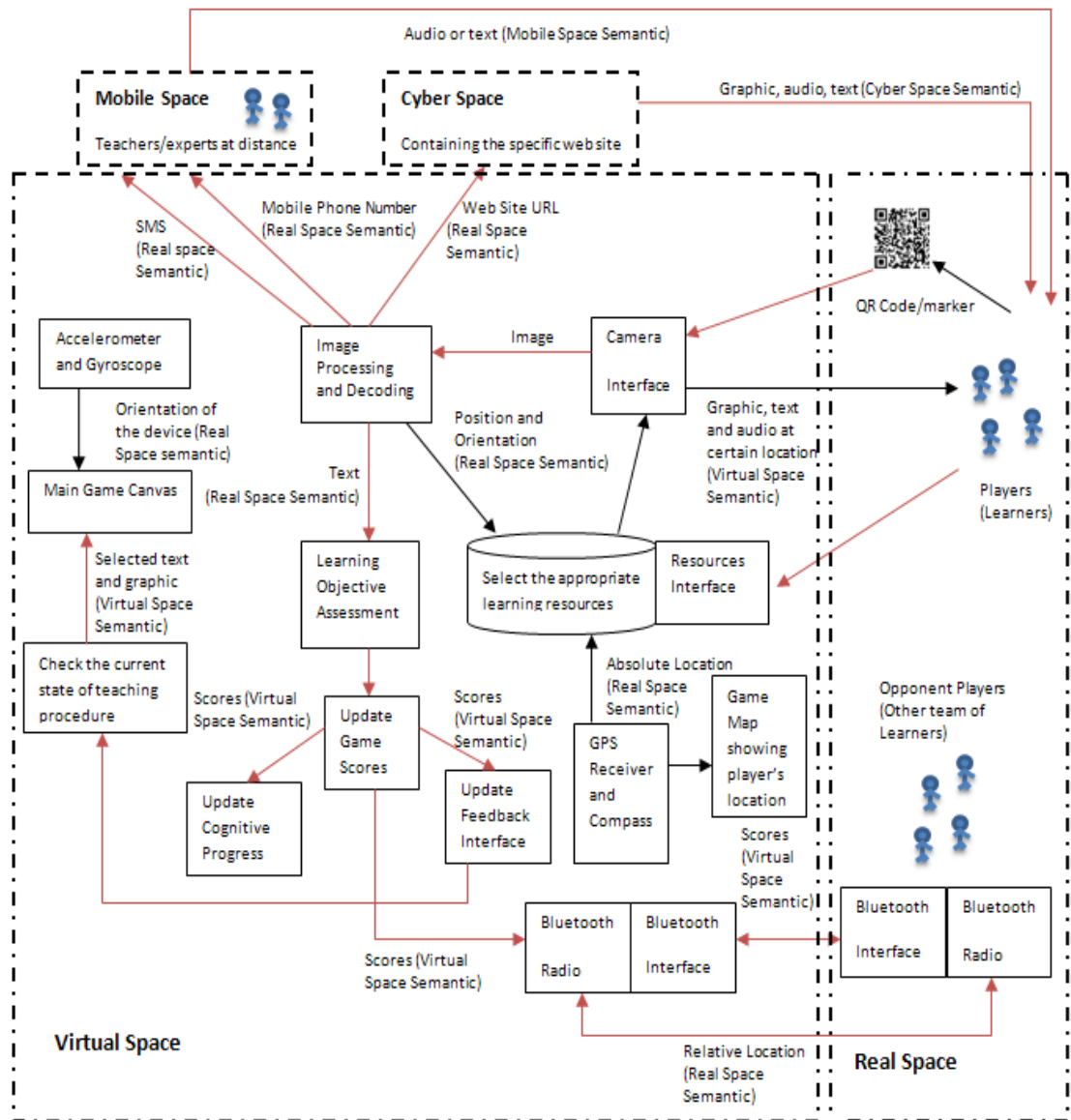


Figure 2.1 Semantic Learning Space Model for the MEMRG realisation

Not all of the sensors in Figure 2.1 are necessary for a mixed reality game. Object recognition using markers and augmenting the real world with graphic and audio is more suitable for natural sciences like physics, biology and chemistry where observation, experience and experiment are important. In the case of geography and history GPS could be valuable for encompassing large areas. In Engineering, and social sciences like linguistic, law and philosophy that are more analytical and critical, communication facilities like phone calls, mobile web and Bluetooth connections are helpful.

2.4.5 MEMRG and mobility, context and communication features

To support MEMRG mobility, contextual and communication features must be included and these introduce new opportunities for learning. Instructional content designers need to exploit the true nature of this novel approach. It is essential to consider the important aspects of mobility, context and communication in mobile learning. To facilitate this process the following table provides a questionnaire for MEMRG designers to measure the degree of mobility, context and communication in their game by acquiring positive answers to the questions.

Table 2.2 A questionnaire to measure the degree of mobility, context and communication in MEMRG

Degree of mobility in a MEMRG (DM)	
	1- Is the learner able to take your game and play it in the gaps between work?
	2- Is your game free of bounding to certain location?
	3- Does your game utilise Bluetooth or Infrared?
	4- Does your game utilise WiFi, GPRS or 3G?
	5- Does your game utilise GPS?
	6- Does your game utilise mobile camera?
	7- Does your game utilise SMS or MMS?
	8- Does your game utilise phone calls?
	9- Does you game allow the learner to move from topic to topic?
	10- Does your game allow forming different groups?
	11- Does your game allow learning that is accumulated at different points in time?
Degree of context in a MEMRG (DC)	

Spatio-Temporal Context (ST)	1- Is your game aware of time?
	2- Does your game provide temporal information to the learner?
	3- Does your game utilise absolute position of the mobile device?
	4- Does your game utilise relative position of the mobile device?
	5- Does your game utilise relative position and orientation of a physical object?
	6- Does your game utilise orientation of the mobile device?
Device Context (DC)	1- Is your game designed considering information about device screen size and resolution?
	2- Is your game designed considering information about available device memory?
	3- Is your game designed considering information about device processing power?
	4- Is your game designed considering information about mobile internet bandwidth?
	5- Is your game designed considering information about device's operating system and software capabilities?
Virtual- World Context (VW)	1- Does your game assign learning goals?
	2- Does your game assign the learning modules or topics?
	3- Does your game calculate current state of learner interactivity?
	4- Does your game calculate learner's progress?
	5- Does your game calculate learner's score?
	6- Does your game calculate current state of teaching?
	7- Does your game calculate other team's progress?
Personal Context (PC)	1- Is your game designed considering physiological aspects of learner?
	2- Is your game designed considering mental conditions of learner?
	3- Is your game designed considering biographical information of the learner?
Role Context (RC)	1- Does your game help the learner to have a social role according to other learners?
	2- Does your game help the learner to have a social role according to virtual characters?
	3- Does your game help the learner to be acknowledged about social roles of other learners?
	4- Does your game help the learner to be acknowledged about social roles of virtual characters?

	5- Does your game help the teacher to have a social role according to learners?
Degree of communication in a MEMRG (DCom)	
	1- Does your game encourage learners to converse and collaborate with other learners?
	2- Does your game encourage learners to share information?
	3- Does your game encourage learners to offer their own ideas and understanding?
	4- Does your game encourage the learners to participate in discussion and debate?
	5- Does your game encourage learners to compete with other learners?
	6- Does your game encourage learners to ask questions from the teacher?
	7- Does your game encourage learners to present ideas to the teacher?
	8- Does your game provide a method for teachers to send feedback to learners?

There are two choices of 'yes' and 'no' available to each question. Table 2.3 below explains how we quantified the results from the questionnaire. We have scored the various categories and responses and we devised a scale from 'Very Good' down to 'Very Poor', to show how we measure the degree of mobility, context and communication. We regard 'very poor' and 'poor' as unacceptable levels of responses and 'moderate', 'good' and 'very good' as acceptable levels of responses.

Table 2.3 A devised scale to quantify MEMRG questionnaire responses from table 2.2.

	Number of positive answers	Level of acceptance
Degree of mobility	1, 2	Very poor
	3,4	Poor
	5,6	Moderate

	7,8	Good
	9-11	very good
Degree of context	1-4	very poor
	5-9	Poor
	10-14	Moderate
	15-19	Good
	20-26	very good
Degree of communication	1	very poor
	2	Poor
	3,4	Moderate
	5,6	Good
	7,8	very good

2.4.6 MEMRG limitations

GPS technology is used for outdoor positioning in mobile games. However its accuracy could be diminished by:

- (1) The level of noise introduced by the signals close to the GPS receiver
- (2) Bad weather conditions
- (3) Multipath reflection and occlusion of the satellite that are due to the barriers around the GPS receiver such as nearby trees, buildings and mountains.

Mobile phones transmit and receive radio waves from a service provider's base station while being in the Universal Mobile Telecommunication Service (UMTS) coverage during phone calls, sending SMS and browsing the web. This coverage could be affected by the local conditions such as:

- (1) Multipath fading where the signal might reflect off an object such as a building which leads to signal distortion
- (2) Interference from signals with same frequencies

- (3) Attenuation as the signal passes through a building wall
- (4) Proximity of the phone to the base station
- (5) Weather conditions
- (6) Capacity of the network to handle a specific number of callers
- (7) Signal hand off when travelling from one mobile phone cell to another.

Camera phones often do not have the advanced features of digital cameras to take a sharp and accurate image. Consequently the device might fail to process and decode the QR coders/markers images taken while the camera is being shaken or there are poor light conditions. In the case of markers, if the position and orientation of the physical object is not accurately tracked, the synthetic image is not able to superimpose the object accurately. This prevents the real and virtual space from correctly aligning together.

2.4.7 Detective Alavi- An example of MEMRG

Detective Alavi is a MEMRG whose design and implementation is described in chapter 6 and 7 respectively and in Figure 2.1 the red arrows show the flow of semantics and different processes and components of this game. The degree of mobility, context and communication in this game is very good (see Appendix A, Tables A.1 and A.2). The game's main canvas depicts a fantasy world of a computer Central Processor Unit (CPU). A mysterious problem has occurred that stopped the CPU from functioning. The mystery requires the 'Detective Alavi' to use his language skills and knowledge of electronics to solve it. Clues to the game's puzzles are distributed in the real space's learning resources, the virtual character's conversations, the teacher's feedback and different web sites. The puzzles are located in the real space built by QR codes in the form of

puzzles, word games and board games. The QR codes help to connect to the mobile space where there are teachers, experts and more competent peers that are at different physical locations. During the game they can be contacted by phone calls or SMS. They can offer their explanations and feedback to the students or ask them to present their ideas in the context of the normal game play and the game story line. Mobile learners can also access the web and search for information that is provided for them as further learning resources, or additional clues to solve the game's challenges. The players interact face to face with each other, ask questions and share ideas. This less restricted style of interaction could help towards enhanced communication skills, better analysis and improved thought processes.

2.5 Conclusion

MEMRG can be easily implemented in classroom and field-work using mobile devices. This is due to the following three factors:

- (1) Mobile devices such as mobile phones have reasonably low costs and are available to the players
- (2) Its form factor is suitable for novice players and most game play could take place unsupervised
- (3) The device is self-contained and fully packaged with necessary sensors and consequently is independent of the institution's infrastructure.

MEMRG uses mobile technology and is mobile in physical, conceptual and social spaces. It makes use of contextual data such as spatio-temporal, device, virtual world, personal, role, and context. It is able to communicate face to face or at a distance using SMS, MMS, phone calls and mobile web with

peers, teachers and experts. Contextual and communication information are extracted by software or via the learner's conceptual abilities into a meaningful form that is defined as semantic. Different forms of semantics are present at various stages in the game play which can be visible or invisible to the learners. These semantics build a learning space that weaves together real, virtual, mobile and cyberspace into a uniquely engaging learning environment which facilitates communication between different members of the learning community (Fotouhi-Ghazvini et al. 2011 a).

Chapter 3

The Pedagogical Perspectives of Mobile Educational Mixed Reality Games

3.1 Introduction

Ebbinghaus proposed that learning can be achieved by establishing a relationship between a stimulus and a response: a phenomenon entitled 'associationism' (Wozniak 1999). The law of effect was later introduced by Thorndike who believed that learning comprises the formation of a connection - between a stimulus and a response – together with the response's after-effects (Thorndike 1913). Pavlov discovered that when an unconditioned stimulus (e.g. food) is combined with a conditioned stimulus (ringing a bell), over a period of time, to produce a response (salivation), this conditioned stimulus gradually produces the same response on its own (Pavlov 1927). Operant Conditioning was the result of Skinner's work (Skinner 1974) which was a continuation of

Thorndike's Law of Effect and Watson's law of frequency (Watson 1912); here, the learner actively operates on an environment, produces a stimulus, and receives a response. The response can be satisfying and may reinforce behaviour; the latter will be more likely to occur in the future; whereas for non-satisfying behaviour, the opposite will occur. Behaviourism theory can be employed when a specific target behaviour has to be achieved. Chunks of information, based on the learner's ability, are presented to the learner; the reinforcements are then introduced as appropriate. Cognitivists accept behaviourist concepts, but they consider learning as a cause of acquisition and a re-organisation of the acquired (Good and Brophy, 1990). They explain learning as a process carried out by different parts of the learner's brain. They propose different methods to increase the processing at each stage. It starts as the learner is sensitised towards learning objects during the first few seconds of encounter whilst being registered by the sensory organs. Next, short-term memory stores chunks of information, 7 ± 2 at a time (Miller 1956). If the information is rehearsed, it stays in short-term memory for a few seconds. On the other hand, if it is over-rehearsed, encoded and recalled, it will more likely be passed on to long-term memory. At the final stage, information resides in the long-term memory which means the learner has established a deeper level of understanding in relation to the learning object. During the 1960s and 70s, Constructivist Theory was introduced. In Constructivism, the emphasis is on the student rather than the teacher. The learner interacts with the environment and through the exploration and investigation builds his/her own concepts and finds answers to the problems. In Constructivism, the learner possesses maximum autonomy and independence and constructs knowledge individually.

Piaget and Bruner contributed to this theory. Piaget developed different stages of children's cognition capabilities; he believed that knowledge is built on a step by step basis through actively participating in the learning process. He demonstrated that the mind is not an empty vessel to be filled with information and he claimed that there are two processes for assimilation and accommodation for actively processing material (Piaget 1980). Bruner has developed the concept of 'discovery learning'. Bruner holds that learning instructions must be built according to the learner's prior knowledge, as well being motivating. The learning material, he believes, must be organized into understandable components with the right sequence and appropriate pace. It is in this environment, according to Bruner, that the learner is able to learn even the most difficult of concepts (Bruner 1960). Papert has introduced Constructionism, a different version of Constructivism. It involves some external activity that entails the learner in actually building something concrete during the process of learning. He used computers as tutees and engaged students in instructing the machine in order to solve problems and perform certain tasks, and allowed them to make mistakes and state false theories and subsequently learn from them (Papert 1980). In mobile learning, participatory games have been used to emulate a constructive environment, in real space, using mobile devices. In Environmental Detective, students take the active role of a detective to investigate the source of water contamination. They use virtual sampling and analyse interviews of different people to derive their own hypotheses. These resources were made available at certain physical locations via GPS-enabled PDAs. Teachers' interventions and scaffolding were very modest; the students themselves were encouraged to discover the solutions to

the problem (Klopfer 2008). In Savannah, children acted as lions in Savannah's jungles. At certain locations they could see, hear and smell the virtual Savannah and the appropriate content was displayed on their PDAs. Such virtual activity based on models and simulation has a close analogue with flight simulators, where a pilot is able to undertake training and emergency procedures in a ground-based machine solely by interaction through the cockpit controls and appropriate g-forces produced by the manoeuvres are fed back to the pilot via hydraulic pistons (Vince 1995). This corresponds exactly to the real-time flight characteristics. Thus pilots gain their certifications to fly particular aircraft by passing the tests set by the instructor in the aircraft simulator. They are also regularly re-tested to ensure their skills are maintained at the required levels of competence. Thus instruction and certification in an artificial environment that is indistinguishable from the real one in its essential elements plays a key role in education and training. Following with the constructivist theories Brown et al. (1989) proposed 'Situated Cognition' by arguing that many classroom practices merely concentrate on abstract knowledge and ask students to use tools for a specific academic discipline without actually exposing students to that culture. They place a great emphasis on learning through enculturation in the academic discipline's community and apprentice-like practices in concrete situations, and involvement in the complex social environment of that community. Mobile learning devices are portable and thus may be taken into authentic environments for data collection and assistance. Ambient Wood was one of the contextual and authentic mobile learning projects that promoted scientific enquiry of invisible ecological processes in the situated environment of woodland. Digital

information (i.e. image, sound and video) together with embedded electronic objects had acted as a 'teacher' to guide and inform learners, providing them with interactions that were more intuitive and natural (Rogers et al. 2004). According to Vygotsky (1978), learning is realised via socialising with other people whilst using mediating tools when the learner is within his/her zone of proximal development. Engestrom (1987) built on Vygotsky's mediating tools and models activity theory which could be used for the analysis of interactions in collaborative learning. In his theory it is stated that in addition to tools, rules of community and each member's role is also important and contribute strongly to the learning process. Mobile communication and wireless technologies such as GPRS, WiFi and Bluetooth support a new mode of communication and connectivity that is synchronous using mobile web, text messaging, voice and beaming. In chapter 6, Detective Alavi is designed for collaborative mobile learning. Here the interaction extends from user and device to other users such as teacher and students. This mode of collaborative learning creates loose groups with shared goals whenever and whenever they are required, and blurs the boundaries between teacher and students who are at different locations. The face to face collaboration in a classroom is enhanced by connecting the student's mobile devices using Bluetooth and WiFi and supplementing the everyday interactions with a new dimension of social learning by means of wireless interactions.

In this chapter we review the most important psycho-pedagogical theorists of the last century and their proposed psychological learning models, starting from constructivism and constructionism moving towards situated learning, social learning and collaborative learning. These models tell us how

learning has been initiated and how it proceeds and what is expected at the end. As is evident, each theoretical model or sub-model of learning is limited to particular, rather than universal, scenarios. Naturally, no single theory is adequate to account for all aspects of learning. At the end, we shall offer a 'conversational framework' that incorporates different learning theories, and which is based on the theme of 'conversation' amongst different actors of the learning community with the objective of building the architectural framework for MEMRG.

3.2. Piaget - Constructivist

Piaget (1980) is known as one of the first constructivists. The central component to his theory on learning is that knowledge must be constructed and reconstructed in order to be acquired, and that the learner must act on his/her environment and learn by gaining experience. He arrived at these deductions by studying the different stages of children's cognitive capabilities and their developmental processes. Piaget explained the process of thinking by reference to the concept of assimilation and accommodation. Assimilation is when an individual changes environment to meet his/her need. Assimilation involves the inclusion of new ideas into earlier cognitive structures. When an individual changes his/her mental models and world views to meet the requirements of the environment this is accommodation. The existing cognitive structure changes to make room for new ideas. These two processes enable schema formation. During the learning process the equilibration is used to create a balance between accommodation and assimilation.

3.3 Bruner - Constructivist

Bruner (1966) has been one of the key figures in the 'cognitive revolution'. Instructing someone is *"to teach them to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for themselves, to consider matters as an historian does, to take part in the process of knowledge-getting. Knowing is a 'process not a product'"* (Bruner 1966, p. 72).

Bruner (1966) suggests that a theory of instruction must concentrate on learner motivation, readily understandable structuring of the knowledge, effective progression on material presentation, and the right level of feedback. Bruner (1964) proposed that when an individual encounters new material, they follow three modes of representation, starting from enactive (action based- manipulation of real world objects and using motor responses) to iconic (image based-,one to one representing real world objects with internal representations) and progressing ultimately to the symbolic mode (language based – having internal abstract representation of the real world). Bruner believed that any material with any level of difficulty could be taught to the learner as long as it is categorised appropriately in a hierarchical fashion with an appropriate format. As the learner moves to the higher level of the hierarchy, each category becomes more advanced with more detail, and intellectual abilities develop. He suggested that the learner must revisit the learning topic at intervals, each time in more refined manner. He proposed a spiral curriculum: *"A curriculum as it develops should revisit the basic ideas repeatedly, building upon them until the*

student has grasped the full formal apparatus that goes with them” (Bruner 1960, p.13).

3.4 Papert - Constructivist

Papert is one of the first leaders and pioneers of learning through a digital world (such as microworlds) and one of the initiators to bring ICT to classrooms. He has proposed ‘constructionist learning’ which extends the constructivist theory to the idea of learning through making something concrete such as touchable objects and meaningful products through creative experimentation. In his view, externalising ideas are as important as internalising them. Giving expression to ideas and making their reasoning explicit helps ideas to become tangible, sharable and negotiable. This guides the learner to further improvement, actualisation and abstraction of principles. Therefore, similar to Piaget, he believes that the learners must reconstruct the knowledge, but he added that the learners need to employ or produce cultural mediation such as tools, toys or language. Papert compares his approach to Piaget by stating *“ give more weight than he does to the influence of the material a particular culture provides in determining child developmental order”* (Papert 1980 a, P. 20).

In Papert’s vision, an exceptional tool for education could be provided by computers. He believed in computers as a unique educational medium with *“the ability to facilitate and extend children’s awesome natural ability and drive to construct, hypothesize, explore, experiment, evaluate, draw conclusions -- in short to learn -- all by themselves”* (Papert 1999). Papert and his team invented the LOGO language to teach geometry in a microworld setting, which

programed a virtual turtle or a robot to draw. He explained LOGO as an environment where *“powerful ideas from physics or mathematics or linguistics are embedded in a way that permits the player to learn them in a natural fashion, analogous to how a child learns to speak”* (Papert 1980 a, P. 27).

In Papert’s view, computational environments are *“more powerful, more accessible and more intuitive than the non-computational”* (Papert 1976) environments. He uses an analogy to make this more clear, *“learning Math by talking to Turtles (a computational object in LOGO environment), is like learning dancing by dancing with people while learning math by doing pencil and paper ‘sums’ is like learning dancing by rote memory the pencil and paper diagrams of dancing ‘steps’”* (Papert 1976). He believed that very difficult mathematical ideas could be learned the same way as someone learns to speak his/her own native language, if he could have lived in a “Mathland” or was engaged in a computational model of “Mathland” (Papert 1980).

He believed that the learners do not have *“opportunities to bring their thinking about thinking into the open”* (Papert 1980 a, p.28) in schools. According to Papert *“learning is essentially hard; it happens best when one is deeply engaged in hard and challenging activities”* (Papert 1998). He extends this to his LOGO program where the learner teaches a graphic turtle to move *“teaching the Turtle to act or to ‘think’ can lead one to reflect on one’s own actions and thinking. And as children move on, they program the computer to make more complex decisions and find themselves engaged in reflecting on more complex aspects of their own thinking”* (Papert 1980 a, p.28).

He saw computers as unique tools for overcoming obstacles in the progress from child to adult thinking. Using computers provides an opportunity for the *“knowledge that was accessible only through formal processes to be approached concretely. And the real magic comes from the fact that this knowledge includes those elements one needs to become a formal thinker”* (Papert 1980 a, p. 21).

3.5 Brown (et al) - Situated Cognition

Many instructional methods that are used in schools make a distinction between knowledge and its context of use. Knowledge is learned individually, de-contextualised and is in its abstract form. Related activities and context are considered only as an auxiliary to learning. Brown et al. (1989) has introduced the concept of situated cognition based on the work of Lave (1988). They explain activities and situations that produce these activities as essential, and an inseparable part of learning and cognition. They describe situated knowledge by presenting an example of the vocabulary learning process. When vocabularies are learned in their real environment, learning is fast and successful. In ordinary communication, different ways of handling conflicts that exist in using language skills are automatically taught by the context of utterance. Dictionaries only provide abstract concepts and they do not include the authentic context of complex negotiations and situations of everyday communication. Brown et al. (1989) have extended this notion to other forms of knowledge and argued that all knowledge is a product of situations and activities. Concept is always under construction and will evolve as new situations occur. They then continue considering conceptual knowledge as a

“*set of tools*” (Brown et al. 1989) and reject the idea that they are abstract units. As tools they are only understandable when they are used in a certain culture with a unique “*belief system*” (Brown et al. 1989). It is possible to learn theoretically how to use a tool, but not be capable of using it. On the other hand, people that use the tool in its actual context and interact with it, will gradually acquire an implicit knowledge of its world. Tools themselves could belong to different categories of communities. Communities each have their own distinct way of using the tool, which is known to its members and is a result of “*cumulative wisdom*” (Brown et al. 1989) which is formed through negotiation. Academic disciplines have tools and belief systems and they belong to a certain culture. Students must act as an apprentice and adopt their culture and see the world through their eyes - this is called the process of “*enculturation*” Brown et al (1989). As a result of “*practice in situ*” (Brown et al. 1989) the student will learn the necessary norms of “*ambient culture*” (Brown et al. 1989). This ‘*pervasive culture*’ (Brown et al. 1989) is different from school culture that students are familiar with. For example, they know how to use a mathematical formula in the classroom but are unable to transfer their knowledge in the same way as a practitioner employs them in authentic practice. Authentic activities which are defined as “*ordinary practices of a member of the culture*” (Brown et al. 1998) when used in school are replaced by school tasks and their actual use by practitioners is dismissed or considered peripheral.

3.6 Vygotsky – Social Learning

Vygotsky believed that technical tools (such as eyeglasses, binoculars, or a telescope, and in our time computers, mobile phones, internet) and

psychological tools (such as culture, signs, symbols, language) helped people to escape from relying on their basic functions (such as the five senses) and needing to adapt to the environment like other animals. People use these tools to expand their senses and communicate meaning, which in turn makes them able to overcome nature, to cope with the external world, and reach higher psychological functions. We do not have to act immediately and directly on the environment. Using these tools helps the mind to be indirectly involved with environment in more sophisticated manner. *“The central characteristic of elementary functions is that they are totally and directly determined by stimulation from the environment. For higher functions, the central feature is self-generated stimulation, that is, the creation and use of artificial stimuli which become the immediate causes of behaviour”* (Vygotsky 1978, p. 39).

Human activity in Vygotsky’s view needs to be mediated by artifact. The subject cannot act directly on an object; it has rather to use a mediator to develop his/her cognitive functions. It acts as a filter to limit or afford cognition. These tools help us to transform our *“elementary psychological functions”* (Vygotsky, 1978) to higher psychological functions. Vygotsky conceived 'elementary psychological functions' as our natural abilities in total isolation from society when there is no assistance from cultural tools, such as to be able to eat and walk, when no real thinking occurs. Higher psychological functions are the acts that are augmented using cultural tools such as language and signs. Development happens in the two stages of *“intermental”* (i.e. between people) or *“intramental”* (i.e. within people) (Vygotsky, 1978). In the former stage, the learner tries to use tools to communicate with others. Socialising with others gradually helps the learner to internalise concepts and transform them into

superior content and form a new psychological system which is intermental. *“Every function in the child's cultural development appears twice: first, on the social level, and later on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relations between human individuals”*(Vygotsky 1978, p. 57).

In this stage, control is transferred from the environment and from other people to the learner and he/she appears to be in control of his/her actions with a conscious understanding of his/her mental processes. This is a higher mental function which Vygotsky believed to be the goal of development. Vygotsky explained that this cognitive development occurs through social interaction within the learner's *“zone of proximal development”* (Vygotsky 1978). Vygotsky described it as *“the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers”* (Vygotsky 1978 p. 86).

Vygotsky believed a learner cannot gain much out of doing tasks that he/she can already perform independently. To be able to achieve the maximum cognitive growth, the learner must attempt tasks that are higher than his/her normal ability, but which are achievable through collaboration with more competent peers or a teacher. The teacher can help the learner through scaffolding, which includes introducing simpler version of problems, giving hints, asking leading questions or performing demonstrations. As the learner becomes

more competent and confident, the teacher can slowly remove the scaffolding and lead the learners to perform independently.

3.7 Engestrom - Collaborative Learning

Human actions cannot be analysed in isolation in a laboratory; they must be studied in context within a situated environment. Activity theory provides the requirement for contextualised actions. Engeström (1987) has expanded Vygotsky's idea of social learning and his notion of mediation. Vygotsky has proposed that for a subject to be able to interact with its environment and achieve an objective it must use mediating tools and signs. There is no direct relationship between subject and object. Vygotsky's structure was too simple to map the complexities in the collaborative nature of human activities when they are members of a community with a set of rules and roles. Engeström (1987) in his expansive activity model added elements of community, rule and division of labour. *Rules* (Engeström 1987) are the laws, norms and limitations that exist in a certain community with a shared goal. For example, a community in a classroom consists of a teacher and the learners, where the teacher desires to teach certain learning objectives and the students wish to acquire these learning objectives. *Division of labor* (Engeström 1987) is the distribution of responsibility amongst the community.

3.8 Lessons Learned from Modern Pedagogical Theories

We have extracted and adapted the following procedures from important psycho-pedagogical theorists for designing the educational games presented. Games that have been selected in chapter 5 for evaluation and games that have been designed in chapter 6 (i.e. MOBO city package and Detective Alavi) follow these constructivist and collaborative guidelines. These features help to protect the pedagogical integrity of the game. The lessons learned are summarised in Table 3.1.

Table 3.1 General lessons learned from pedagogical theories for designing educational games.

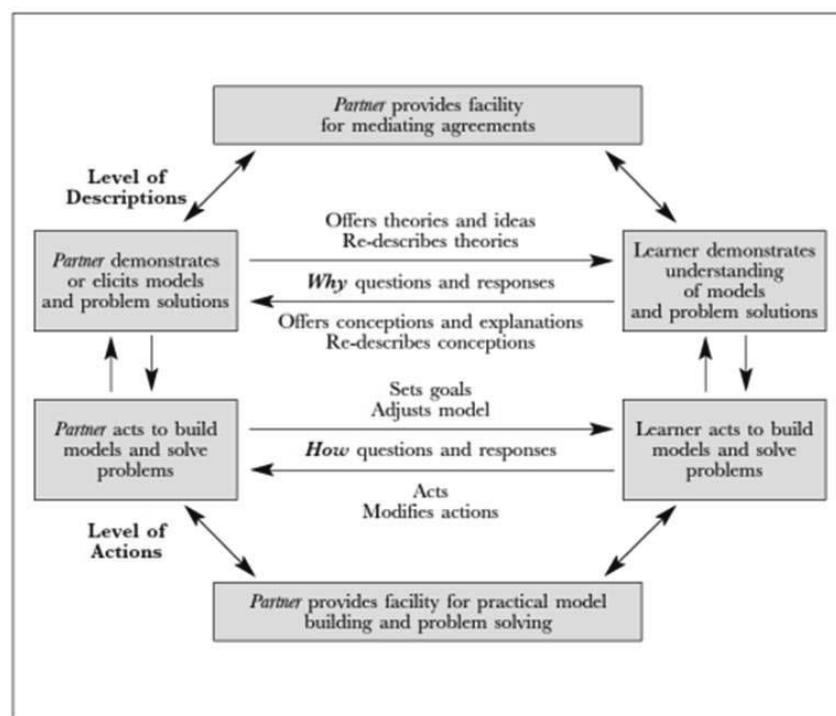
Guidelines	Corresponding Psycho-pedagogical theorist
The game must promote exploration and discovery.	Piaget (1980), Bruner (1964), Papert (1980 a) and Brown (1989)
The game play must take place in appropriate contexts, having natural setting with real and simulated peoples and objects.	Piaget (1980) and Papert (1980 a)
The virtual characters must be designed as practitioners and experts. The learner' character must be designed to act as an apprentice seeing the world through the eyes of an apprentice.	Brown (1989)
The learner should be allowed to make errors and false theories and he/she must be encouraged to learn from them.	Piaget (1980), Papert (1980 a)
The learner should reflect on his/her own actions.	Papert (1980 a)
Game environment should be designed at a level higher than the learner's current developmental level (zone of proximal development was considered).	Vygotsky (1978)

The learner should not be forced to correction and opportunities for scaffolding should be provided to guide the learner indirectly towards the correct answer and deliver help at the crucial moments.	Papert (1980 a), Brown (1989), Vygotsky (1978)
Opportunities for authentic problem solving must be provided.	Bruner (1964), Brown (1989)
Tools and platforms that enhanced collaborative learning and interaction between the learners themselves and the learners with teacher where used. These tools should be used to mediate learning even when the learners and teacher were not at the same location.	Vygotsky (1978), Engestrom (1987) and Brown (1989)

3.9 Laurillard - A Conversational Framework for Higher Education

Laurillard has proposed a psycho-pedagogical framework for higher education that clearly defines the role and responsibilities of the teacher, the learners and the peers. In the first version of her model she uses Pask (1976) conversation theory to represent her model. Pask believed that learning is basically a conversation between different knowledge systems (i.e. students, teacher and computers), where the system converses with itself and reflects on its actions and converses with other systems to share a description of the world. Pask believed learning is “*not ‘transmit knowledge’, rather, they provoke participants into becoming informed of each other’s ‘informings’*” (Scott 2001). Pask made a distinction between knowledge of “*‘knowing why’ (cognitive, conceptual knowledge) and ‘knowing how’ (procedural, performance knowledge)*” (Scott 2001). Laurillard (1993) constructed her first version of a conversational framework based on learning as a conversation (Figure 3.1). The framework had two levels of action and description. In action, learners converse with each

other while they are experimenting or doing practical work. They ask questions such as “*what’s happening here?*”, “*what do we do next?*” (Laullilard 1993). They set goals, experiment and converse until they reach a shared understanding. In the description level, they discuss what happened in the action level, they ask questions such as “*why did that happen?*”, “*what does this mean?*” (Laullilard 1993), and they offer re-explanation of theories by means of justification and rationalization. The horizontal connections are verbal exchanges while vertical connections are where the learners are conversing with themselves and reflecting on their own knowledge.



First 3.1 First version of Laullilard’s conversational framework for learning (from Sharples 2005, p.115)

Then she proposes a second version of the conversational framework (Laullilard 2009) where she combines her representation of learning as conversation with other important pedagogical theories. She extracts all the

important features of instructionism, social learning, constructionism, and collaborative learning, where each is emphasizing a particular aspect of learning. Her complete framework is shown in Figure 3.2. She classified learning into two levels of *“the discursive, articulating and discussing theory, ideas, concepts, and forms of representation; and the experiential, acting on the world, experimenting and practicing on goal-oriented tasks”* (Laullilard 2009). We see that the teacher is added to the framework as an important element in formal learning. Teachers and learners converse with each other with *“repeated iterative interaction on both levels”* (Laullilard 2009). The two levels connect with each other when the learners reflect on feedback received from teachers and other peers at a conceptual level or at a practical level; teachers also reflect on the learner’s actions and adapt the practice environment accordingly.

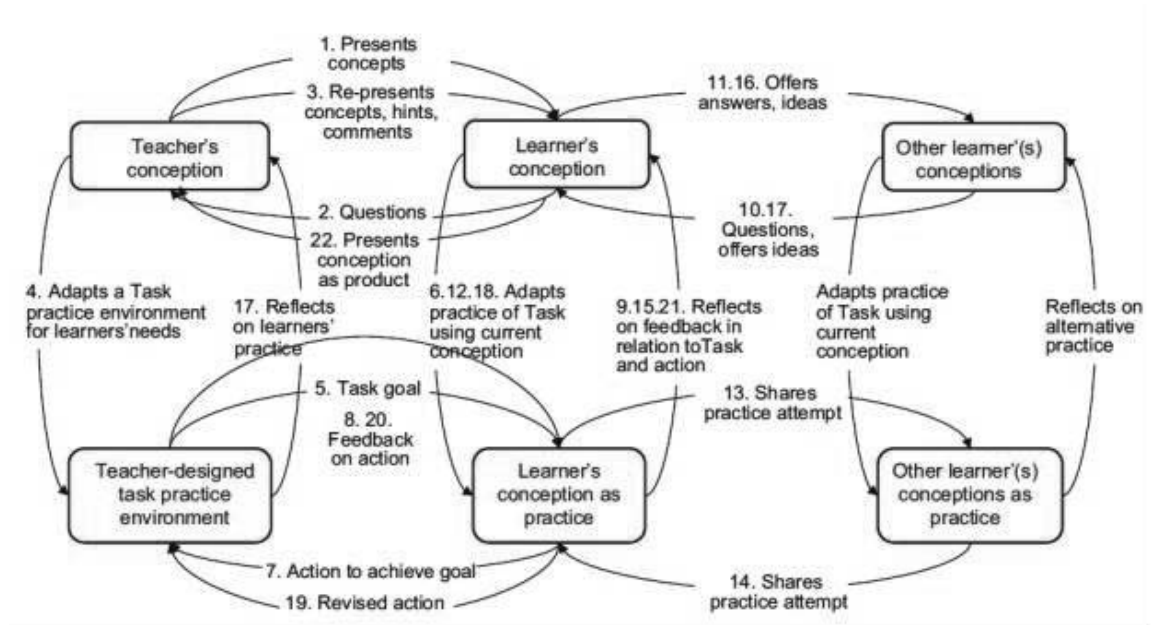


Figure 3.2 Laullilard's Conversational Framework (2nd version): 'Numbers show a possible ordering of the successive activities of the learner, teacher, and peers' (from Laullilard 2009, p.11).

Laullilard suggests that her model can challenge any pedagogical design in any digital form in its pedagogical mission. She regards her model as showing “*what it takes to learn*” (Laullilard 2009). She has provided a check list for educational environments to see if their learning systems possess all the necessary elements. Laullilard (2009) states this as follows: “*Do they motivate students to:*

1. *Access explanations and presentations of the theory, ideas or concepts (1, 6)?*
2. *Ask questions about their understanding of the theory, etc, by providing the opportunity for answers from the teacher (2, 3), or their peers (10, 11)?*
3. *Offer their own ideas and conceptual understanding, by providing comment on them from the teacher, or their peers?*
4. *Use their theoretical understanding to achieve a clear task goal by adapting their actions in the light of their understanding (5, 6, 7), or in response to comments (10, 11) or feedback (8)?*
5. *Repeat practice, by providing feedback on actions that enables them to improve performance (5, 6, 7, 8)?*
6. *Repeat practice, by enabling them to share their trial actions with peers, for comparison and comment (13, 14, 15, 16, 17)?*
7. *Reflect on the experience of the goal-action-feedback cycle, by offering repeated practice at achieving the task goal (5, 6, 7, 8, 9, 12, 19, 20, 21)?*
8. *Discuss and debate their ideas with other learners (10, 11)?*

9. *Reflect on their experience, by having to articulate or produce their ideas, reports, designs, performances, etc. for presentation to their peers (13, 14, 15, 16)?*
10. *Reflect on their experience, by having to articulate or produce their ideas, reports, designs, performances, etc. for presentation to their teachers (21, 22)?” (Laullilard 2009, p.19).*

3.10 Psycho-Pedagogical Conversational Framework for MEMRG Structural Design

In MEMRG we propose a new approach to developing a conversational framework. Mobile learning provides teachers, experts and students with a unique opportunity to have a degree of presence in a number of different physical locations. Mobile devices have made it possible for students to connect with the physical world and collect and analyse data and even display the results immediately. This facilitates the management of different kinds of data as well as offering flexibility of learning by new modes of interaction that were difficult or impossible to achieve in traditional classrooms, or in other modes of digital learning. In this model, we show how the virtual world provides a basis for giving the learner a window into different environments. Whenever the learner raises questions which cannot immediately be answered by the model or the virtual world, then teachers and experts provide supplementary information to assist the learners, and allow teachers and learners to attain a shared understanding.

Figure 3.3 shows an architectural view of the game which uses a conversational framework. Table 3.2 shows its corresponding interactions. Game virtual space, mobile space and cyberspace are all accessed through the mobile device, but here we illustrate them as separate entities to show the different interactions that exist between these spaces. The game virtual space is shown as a black box, because it will use the instructional/motivational design proposed in chapters 4 to build its structure. Consequently our game has one external design which incorporates the conversational framework and one internal design which uses instructional/motivational design. In Figure 3.3, the virtual space adopts a practical test for the learners, sets goals and provides feedback. In mobile space we have teachers, experts and more competent peers that are located at different physical locations. During the game they will be contacted by phone calls or SMS. They will offer their explanations and feedback to students or ask them to present their ideas; all happening through the normal game play with the game story's theme. By connecting to cyberspace the learners can access the mobile web and search information that is provided for them as further learning resources, or additional clues to solve game's challenges.

The task practice environments designed by the teacher in real space provide puzzles and mini games using Quick Response (QR) tags printed on pieces of paper (see Appendix 3). These visual tags contain information that could be accessed via a mobile phone camera. QR codes are two dimensional bar codes that are read on camera phones using QR reader software. Once they are accessed, they allow players to complete an action. QR codes launch

and redirect a phone's browser to an embedded URL, or initiate a phone call, or send an SMS or simply present some text. This technique helps the learners to collect data from puzzles and transfer them to their own game's virtual space for further analysis. These tags can also activate access to mobile space and cyberspace, and act as a dynamic hub for accessing further help and learning resources. In Figure 3.3, only the interactions concerning one learner are shown. However, the same interactions will take place for all members of the team. The learners interact face to face with each other and become involved in an enjoyable, deep exploration of a game environment. Using this method, teachers can arrange for the learners to access different experts during the game via a phone call or SMS, each of them acting as a game character which specialises in a certain topic. This less restricted style of interaction helps towards enhanced communication, better thinking and improved thought processes (see chapter 8). The practice environment is flexible, and the teacher can easily change the puzzles and produce new QR tags. There is both flexibility in content and connections, and challenges are provided by both virtual and real space information. Teachers have a game framework that they can easily customise without needing technical knowledge. Game puzzles could be distributed across different rooms in the building. This extends the game semantic learning space to the size of a building and overcomes real space barriers, objects and people. This framework is also ubiquitous and it is not restricted to a certain physical location.

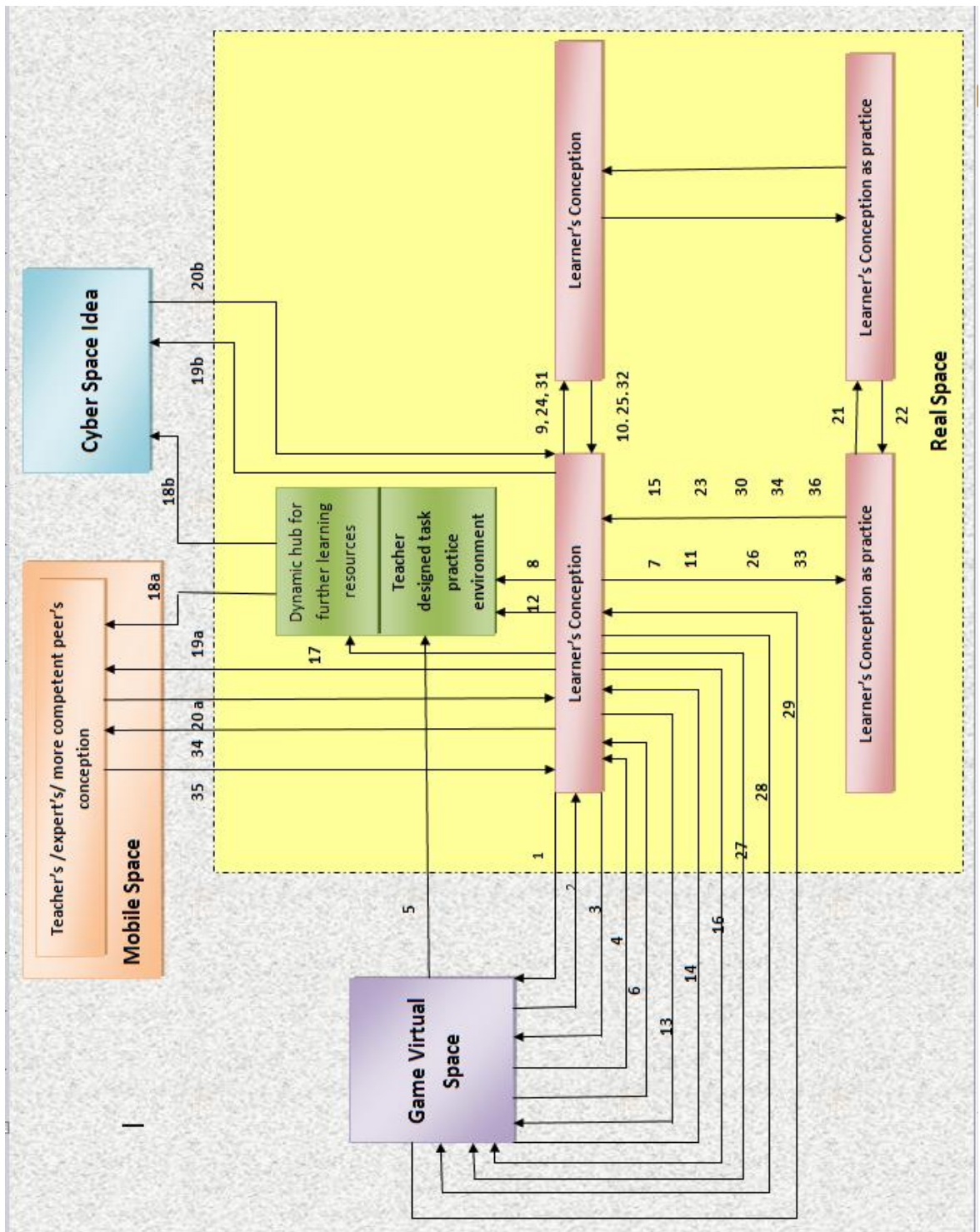


Figure 3.3 Conversational Framework for MEMRG Structural Design

Table 3.2 shows the different interactions in MEMRG architectural view with their corresponding numbers.

Interactions in MEMRG architectural view	Corresponding numbers
Learner explores the virtual space to obtain concepts	1
Virtual space presents concepts	2
Learner searches the task goal	3
Virtual space presents task goal	4
Virtual space adapts a task practice	5
Virtual space guides the learner to an specific task	6
Learner explores the task	8
Learner adapts the practice of task using his/her current conception	7, 11, 26, 33
Learner acts on the task practice to achieve the goal	12
Virtual space provides feedback on action	14, 29
Mobile space provides feedback on action	35
Learner reflects on the action	15, 23, 30, 34, 36
Learner activates the device to access further resources	16, 13, 27
Learner acts on the learning resources	17
Learner contacts a knowledgeable person via SMS or phone call	18.a
Learner connects to a web site with learning resources	18.b
Learner asks question from a mobile expert	19.a
Learner searches for answers from a mobile web	19.b
Mobile expert discusses concepts and gives hints	20.a

and comments	
Mobile web presents the answers	20.b
Learners share the phone conversations and searches of the web	21, 22
Learners ask questions and share ideas	9, 10, 24, 25, 31, 32
Learner revises his/her action on the virtual space	28
Learner presents a product or an idea vi teach back to the mobile expert	34

The key advances in Table 3.2 may be summarised as follow:

(1) The game space presents the concept to the learner, sets task goals, adapts a task practice and provides feedbacks by updating the learner's cognitive progress.

(2) The learner could ask questions or share ideas face to face or using mobile communication.

(3) The concepts could be re-represented and appropriate feedback could be provided by the on-site teacher, the real space using QR codes, experts at distance or searching the Cyberspace.

The extensions to the Laurillard model in this research are concerned primarily with the greater variety of pathways created for instructional and motivational design including engagement, flow, motivation, assessment and cognitive growth. The pathways included the mobile space, game space, cyberspace and real space, so there is a sense in which these virtual spaces complement and add value to the learning experience.

3.11 Conclusion

In this chapter, different learning theories have been reviewed. Each has special features which contribute to particular aspects of the learning process. In constructive learning, the learner constructs knowledge by discovery and enquiry. Direct instruction is not acceptable; however students need some instruction at the beginning. They have to slowly build up knowledge and be able to experiment with their ideas in the real world. On the other hand, if the learner has difficulties with a problem, it is more effective to provide some direct instruction rather than allow the learner to waste valuable time by trial and error. This mode of learning often results in covering only a small amount of content, which makes it difficult to address the extensive curriculum of formal education. Constructivists pay less attention to standard evaluations and their belief is that students themselves must judge if they have learned. Only careful analysis of the student's work will determine how much they have actually learned and what the next step in their education should be. In Situated Learning it is emphasized that learning happens in authentic situations with concrete instruction. However, the concrete instructions are not always clear to students and they may end up with misconceptions and incorrect conclusions. Including abstract instruction in situated learning could accelerate the actual authentic activity and increase skills transferability to new situations. In collaborative learning, where the role of teacher is negligible, students learn through interactions and sharing ideas. Again the role of instruction becomes a concern. At critical stages students need to receive feedback or present concepts and theories. The Conversational Framework combines all these

modes of learning into one overall learning approach. Considering the unique nature of mobile learning, we have designed the MEMRG's architecture using the conversational framework. In the next chapter we will detail the design of MEMRG's internal structure which defines its virtual world space. This space in MEMRG plays the role of an instructor and at the same time is responsible for motivating the learner. Instructional design and motivational design are the two primary aspects we focus on.

Chapter 4

An Instructional-Motivational Paradigm to Design Educational Games

4.1. Introduction

Depending on the material to be taught, the content and learning objectives determine the structure and story of the game. Bloom's revised taxonomy (Anderson and Krathwohl 2001) helps to extract learning objectives from the educational content. Firstly, it determines what kind of knowledge is going to be learned and divides the knowledge dimension into the four categories of factual, conceptual, procedural, and meta-cognitive. Secondly, the taxonomy provides a way to organize the process of learning into six levels of remembering, understanding, applying, analysing, evaluating and creating from the most basic cognitive process to the higher order levels of thinking (Anderson and Krathwohl 2001). Gagne's nine events of instruction (Gagne et al. 1992) show how to integrate these objectives into an instructional design, and how to sequence instruction to provide an effective hierarchy of learning. Czikszenmihayi discovered that when the task has clear goals, an appropriate level of

challenge, clear and immediate feedback, stable rules and uncertain outcome, the learner will be able to concentrate, complete and control the learning by intrinsic motivation, and be fully absorbed by the task (Czikszenmihalyi 1990). Keller's ARCS model identifies attention, relevance, confidence and satisfaction for motivating instruction (Keller 1987). Malone and Lepper proposed individual motivational factors as having appropriate challenge, a clear goal, presenting cognitive and sensory curiosity, promoting a feeling of control, creating an emotional fantasy environment, cooperating with others, and taking part in competitions (Malone and Lepper 1987). These instructional and motivational factors must be integrated into the game design elements to produce an engaging educational game which ensures the required academic skills are acquired after the game play. This chapter will provide a new design paradigm which is based on sound instructional/motivational design factors. It is believed that this model also has predictive capabilities in determining the eventual success of a game intended for educational settings.

4.2. Instructional Design

Simply presenting educational content is not sufficient for learning. They must be an integral part of the storyline and help learners to apply and reflect upon specific knowledge and skills during the game play. The main goal of instruction provides a clear overall picture of the target academic subject domain. However it must also be defined as smaller, discrete and measurable learning objectives that are attainable by the learners in small incremental steps resulting in specific outcomes. Incorporating learning objectives in hierarchical order in a game will also assist teachers to evaluate learners more easily and

precisely, and be in a better position to provide more timely feedback to the learner. Moreover students can benefit from constant self-assessment and build metacognition. In this section, Bloom's revised taxonomy is introduced to help the designers drive the learning objectives according to each learning process. Next Gagne's nine events of instruction are put forward to represent the overall steps required in an effective instruction.

Bloom and Krathwohl (1956) have developed a classification for learning objectives which has organized the thinking skills into the six levels of *knowledge, comprehension, application, analysis, synthesis, and evaluation*. Later on Anderson and Krathwohl (2001) updated the taxonomy into six levels of *remembering, understanding, applying, analysis, evaluating, and creating*, starting from basic skills and gradually constructing a strong foundation for higher order thinking at more advanced levels:

- (1) In the '*remembering*' level, learners must be able to recall, recognize, list, retrieve, name and find information.
- (2) In the '*understanding*' level, learners must be able to explain ideas or concepts, interpret, summarize or classify information.
- (3) In the '*applying*' level, the learner must use the acquired knowledge in a different situation.
- (4) In the '*analysing*' level, students must be able to deconstruct a problem into smaller ones and compare different sources of information to solve problems and draw conclusions.
- (5) In the '*evaluating*' level learners make choices according to in-depth reflection and are involved in critical thinking.

- (6) In the '*creating*' level, learners make new products and generate new ideas, however this level could be distributed in lower learning processes and in each separate level build part of a product or an idea.

Bloom's revised taxonomy has provided six levels of the learning process, and Gagne et al. (1992) has introduced a series of instructional events which are required at each level. According to this approach, learning events possess a hierarchical nature in the following sequence:

- (1) The attention of the learners must be captured by stimulating the sensory receptors.
- (2) The learners must be informed of learning objectives and expect certain outcomes.
- (3) The prior learning objective must be recalled to activate short-term memory.
- (4) The new content must be presented.
- (5) The content must be encoded to ease long-term memory storage.
- (6) The content must be practiced by means of questions to boost encoding.
- (7) Appropriate feedback must be provided by the teacher or the environment to correct the performance of the learner.
- (8) The performance of the learner must be assessed as the final evaluation step.
- (9) The acquired knowledge must be applied to real life situations.

Barendregt and Bekker (2004) describe each interaction cycle of the user with a computer game in the following stages:

- (1) The planning stage where the learner must be informed of the goals and the rules of the game.
- (2) The learning content must be translated and conveyed to the learner.
- (3) The learner needs to participate in a physical action to accomplish a task.
- (4) The game must provide appropriate feedback.
- (5) The learner must evaluate his/her success.

The learner then decides either to repeat the same cycle or start the next cycle. Barendregt and Bekker (2004) are similar to Gagne et al. (1992) with regard to instructional events. The nine instructional events of Gagne et al (1992) at each level of the learning processes of Anderson and Krathwohl (2001) could serve as a basis for designing game based learning environments. These games must be progressive with built-in assessment tools, and scaffolding opportunities to help the learners solve complex problems which are aligned with meaningful learning objectives.

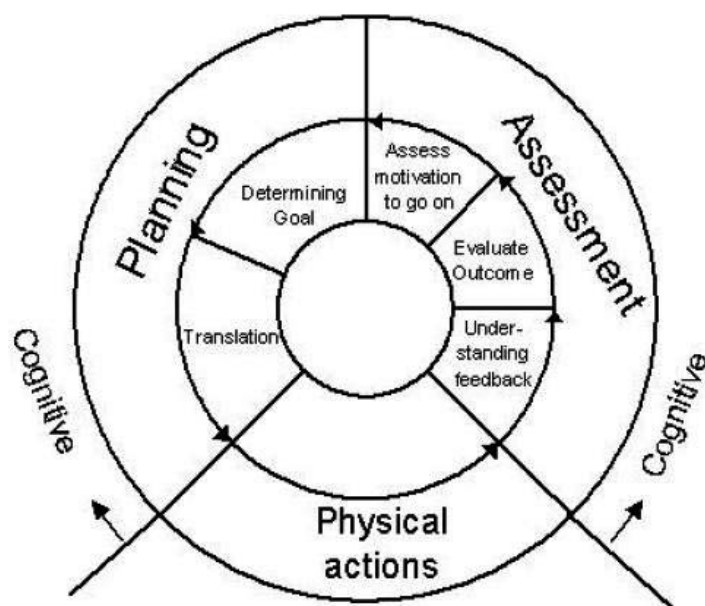


Figure 4.1. Interaction cycle for games from Barendregt and Bekker (2004, p-374).

In Figure 4.1 Barendregt and Bekker (2004) outline the motivating factors in each game cycle, which will be discussed in the next section.

4.3. Motivational Designs

The instructional stages that have been mentioned in the last section do not guarantee the effectiveness of the game if the learners are not engaged in learning. Engagement in learning requires students to be intrinsically motivated. Motivation energizes, provides direction and produces certain behaviours in learners (Wlodkowski 1989) and it is subject to many elements (Keller 1987).

“The term motivation in psychology is a global concept for a variety of processes and effects whose common core is the realization that an organism selects a particular behaviour because of expected consequences, and then implements it with some measure of energy, along a particular path.” (Heckhausen 1991, p. 9).

Malon (1981) asserts when students are intrinsically motivated they devote more time to learning with greater persistence which results in enduring learning. Many researchers, such as Malone (1981) and Dewey (1938), have asserted a positive correlation between motivation and learning.

John Keller (1987) in his ARCS model identified four components for motivation in a learning environment. He specified them as:

- (1) *Attention* to arouse the learner’s curiosity which consists of

- *Perceptual arousal* using multimedia, surprises and novel elements.
- *Inquiry arousal* through problem solving puzzles and questions that require deep thinking.
- *Variability* by providing a wide range of choices, unique multimedia at different stages, and introducing the competition element by involving learners with other teams.

(2) *Relevance* factor to attend to the needs and interests of the learners through:

- *Goal orientation* which presents the desired goals early on and aligns the challenges according to the final goals.
- *Motive matching*, connecting the learner's desires and values to different tasks and providing a game culture that enhances a sense of affiliation, for example through team work.
- *Familiarity* with the environment which uses a language that is related to the learner's past experiences and knowledge, moreover it is customizable according to the needs of the learner to create a sense of ownership.

(3) *Confidence* building which involves the provision of:

- *Learning requirements* that are clear and accessible at all times to avoid learner confusion and frustration.
- *Success opportunities* for all learners with different cognitive capabilities. Brighter students use challenges with considerable difficulty whereas struggling learners gain satisfaction by trying simpler problems.

- *Personal control* over the learning environment.

(4) Creating *satisfaction* and positive expectation which involves:

- *Intrinsic reinforcement* by means of incorporating the learner's inner emotional state into the design of the environment.
- *Extrinsic rewards* using a scoring system and multimedia feedback.
- *Equity* by fairly and justly assessing the learner's achievements.

Malone and Lepper (1987) described intrinsic motivation as actions that are carried out with no expectation of reward other than the enjoyment that accompanies those tasks. He has divided the motivation into the two categories of individual and interpersonal. According to Malone and Lepper (1987), the motivational elements when a person individually performs a task are as follows:

(1) The following factors has been recommended by Malone and Lepper (1987) to increase the learners' motivations when they are *individually* involved with the learning space:

a. *Challenges* increase the learner's motivation and confidence when they are derived from personally meaningful goals, their level of difficulty is optimum and they are accompanied by appropriate feedback. The following criteria have been suggested by Malone and Lepper (1987) when designing challenges:

i. The *Goal* for each challenge must be clear.

ii. These goals must be *personally meaningful* and relevant to the learners.

d. *Fantasy* can fulfil the emotional need of the learners by evoking imaginary places or people and situations or experiences that were otherwise impractical, difficult or impossible to achieve in real life. Fantasy in an educational setting must consider:

i. *Emotional* needs of the learners and identification with the characters and the context.

ii. *Cognitive* needs of the learners and building a strong relationship with the academic material.

iii. Fantasy must have an *endogenous* relationship to the learning content.

(2) The following factors have been recommended by Malone and Lepper (1987) to increase *interpersonal motivations* amongst learners:

a. During the *cooperation* the learner feels part of a group, they form stronger interpersonal relationships, and they help each other to reach their potential and achieve goals which lead to greater satisfaction.

b. While participating in a *competition* learners can compare their performance with other peers and continuously improve. This could enhance their self-esteem.

c. When the learner's achievements are visible to other peers, they feel more appreciated and respected. *Social recognition*,

reputation and power status can increase the learner's feeling of satisfaction.

The Barendregt and Bekker (2004) interaction cycle defines the basic processes involved between a learner and an educational game, and this interactivity must lead to active participation, and later on to deep thinking. Salen and Zimmerman (2004) have suggested this engagement must be an experience that involves the person emotionally, intellectually, psychologically and physically. Motivational factors suggested by Keller (1987) and Malone and Lepper (1987) could increase the learners' enthusiasm towards the learning space, to embrace their interest further. Said (2004) proposes an engaging multimedia design model which consists of:

- (1) Opportunity to role-play
- (2) Opportunity for construction
- (3) Immediacy of feedback and clear goals.

Moreover, Quinn (2005) has suggested an engaging educational game must contain the following elements:

1. The game's story must be contextual and simplify or exaggerate real life with feedback that is communicated by game characters.
2. The story's goal must be linked to the educational goal.
3. The game challenges must examine the learners' cognitive skills in measurable steps with graded difficulty levels.
4. The learners' actions must be relevant to the learning objectives with an opportunity to apply the knowledge.

5. The story must be relevant to the learner's previous knowledge, experience and performance.
6. The learner must be presented with complex situations that require committing to multiple choices.
7. Concrete choices are best presented in graphical format.
8. Feedback must be staged and part of the story.
9. An element of chance and unpredictability must be present.

When learners' are fully engaged in the game space, Gunter et al. (2008) called the condition the '*fully immersed player-learner*'. In this immersion model he has recommended that an educational game must be designed using the following components:

1. Instructional units must be relevant to each other and to the learners.
2. Story content must be tightly coupled with academic content
3. Environment must provide an opportunity for learners to apply information in other formats and different situations.
4. Learners must be able to assimilate information in terms of what they already know and be able to accommodate new information.
5. Learners must have enough opportunities for repetition and practice to naturalize the knowledge, and habitually master the necessary skills.

Csikzentmihalyi (1990) has called this perfect immersion and the optimal experience the '*flow*' state. The person's attention only selects bits of information that are relevant. Undesirable distracting thoughts are overcome and attention is fully invested in achieving the goal. The person is able to organise his/her consciousness and psychic energy to reach deep

concentration. This state harmonises the person with respect to the surrounding people and objects. The person's self grows both individually and also in union with others. This experience is considered novel and rewarding and is accompanied by a deep sense of achievement and enjoyment. However, Csikzentmihalyi (1990) emphasised that this state is not always automatic at the first try, nor is it necessarily achieved without effort. It must be cultivated often through years of practice involving highly disciplined mental or physical activities. The person might even be reluctant and initially has been forced into the process, but over the course of time these activities become autotelic and intrinsically rewarding. Csikzentmihalyi (1990) has suggested a number of recommendations to increase the feeling of flow in tasks:

1. Person must feel that the task can be completed.
2. Task must have clear goals.
3. Goals must be realistic and feasible.
4. Progress to reach the goals must be measurable.
5. Person must feel control over the task.
6. Chances for perfecting skills must be often present.

4.4. A Model for Converting the Instructional Content into an Educational Game

In this section, the steps to design the basic structure of an educational game are proposed. The instructional content needs to be categorised according to

the learner's cognitive processes and requirements. Then an appropriate game genre is selected that best embraces a game story with suitable rules, characters and puzzles at different levels. The educational games could be further enhanced by communication tools, cut scenes, hints and educational resources. The whole structure must be presented via usable menus and screens.

4.4.1 Prepare the educational content

It is very important that the learning game is relevant to the curriculum and includes accurate and appropriate content. Unrelated functionalities or content should be removed to avoid wasting valuable lesson time. The time spent on the game must be reasonable and help the teacher to cover the syllabus by the end of the defined period (e.g. end of term).

The learning objective can be categorised according to Bloom's revised taxonomy (Anderson and Krathwohl 2001) into the six groups as follows:

1. *Remembering*: objectives concerned with memory task and recall of information.
2. *Understanding*: objectives to examine the learner's conception of knowledge.
3. *Applying*: objectives that employ the information in a new way,
4. *Analysing*: objectives for differentiating between the different parts and thorough examination of a problem.
5. *Evaluating*: objectives for making decisions based on critical thinking and assessment.

6. *Creating*: objectives for generating novel artefacts or points of view.

Concept maps could be used as a template to organise the learning objectives into lower levels of *remembering* and *understanding*. Each small unit is further divided into smaller concepts and propositions. Novak believed this technique will facilitate creation of an effective learning framework (Novak and Wandersee 1991). The hierarchical framework is very important in increasing the learning capabilities in learners (Bransford et al 1999 and Tsien 2007).

An appropriate visual repertoire of scenes, people and objects must be gathered for each learning objective that is in concrete format. These images could later be used as part of the story or knowledge chunks. The information in alphanumeric images is retained much longer in the human brain (Sperling 1963) in the form of iconic learning (Shepard 1967). Gagne et al believed that encoding the content would help long-term memory retention.

Each learning subject is normally a collection of answers to a specific series of questions. These questions are often hidden in detailed answers provided in the form of textbooks. The textbooks mainly help the teachers to achieve a more detailed coverage of the subject rather than engaging the students. Answers and detailed content on their own will not result in thinking; they are rather stepping on the brakes of the intellectual engine (Kabilan 2000, Freire 1973 and Bruss and Macedo 1985).

Higher levels of learning objectives such as analysis and evaluation could be organised into a set of questions. These questions should encourage discussion, enhance questioning skill, and promote deep enquiry amongst

learners. The learners must feel they need to dig deeper, do further research and explore the gaming space further.

4.4.2 Determine the learners' preferences

Games must be relevant to the learner's cognitive level and emotional factors (Quinn 2005). They must consider the learner's previous knowledge (Gunter et al 2008) and appeal to both genders (Amory 2007).

4.4.3 Select a game genre

Collaborating games have been stated to produce a greater degree of engagement in the learning process (Amory et al. 1999, Ju and Wagner 1997, Quinn 1994, Aldrich 2004, Gouglas et al. 2006, Yee 2006 and Dickey 2006). Adventure games are based upon learning environments that allow the player to solve puzzles and become involved with narrative and a variety of characters. The elements of surprise, cognitive curiosity and exploration are a major component of these games (Amory 2001, Ju and Wagner 1997 and Dickey 2006). Role playing games help the gradual development of the learner through a series of quests (Gouglas et al. 2006, Yee 2006). The strategy games emphasize skillful thinking and planning which could contribute to a higher level of thinking (Rollings and Adams 2003, pp. 321-345). Simulations are accurate physical models of a real life objects so that their measurements and tolerances are precise. They help the learner to experiment in a safe environment (Crawford 1997).

4.4.4 Write the story

The academic content must be tightly coupled with the story (Malone and Lepper 1987, Quinn 2005 and Gunter et al 2008). It must be designed according to the learner's emotional state (Malone and Lepper 1987 and Quinn 2005) and consistent with their cognitive aspect (Malone and Lepper 1987).

4.4.5 Assign the rules

The game rules must be fixed and clear, and cater for the game's limitations (Salen and Zimmerman 2004). The game must have a range of different scores, each examining a certain skill or cognitive process. Then rules must be constructed that allow each score to contribute in certain way to the cognitive progress of the learner.

4.4.6 Designing different game characters

Virtual characters tell the story and the learner can internalise the game events (Fullerton et al 2004, Hefner et al. 2007). They can be categorised into:

- (1) The game hero that performs the actions and takes part in solving the problems (Bates 2004)
- (2) The game mentors that help the game hero (Isbister 2006) and also the enemies that try to stop the game hero from achieving his/her goals (Bates 2004).

4.4.7 Designing thematic game levels

In learning games it is best to divide the games into different game levels. Each level should have different graphics, characters, text and level of difficulty. Levels must be designed in hierarchical order each targeting a separate cognitive process.

4.4.8 Designing thematic puzzles

Puzzles are the means by which the learner's knowledge can be examined, and provide challenge. They must be designed in the zone of proximal development and their difficulty increased gradually. In their best form they fit naturally with the game story (Bates 2004).

4.4.9 Designing thematic communication tools

Educational games must provide opportunities for working with others and collaboration to synthesise the information (Malone and Lepper 1987 and Amory 2007). Competition could also help learners to compare their work with others and increase their self-esteem (Malone and Lepper 1987, Lazzaro and Keeker 2006, Vorderer et al. 2003). It is advisable to provide a means for social identity and self-recognition (Malone and Lepper 1987, MacIntyre 2004) by making the scoring visible to the public.

4.4.10 Designing thematic cut-scenes, hints and resources (knowledge chunks) for each level

Cut-scenes are mini-movies to elaborate the story or reward the learner (Hancock, 2002 and Crawford 2003). Hints will help the learners if they are

stuck without revealing the answer directly (Choi et al 1999). Learning resources could be in many different forms such as extra text notes, maps or websites.

4.4.11 Designing introduction screen, help screen, and main menu for the game

Traditional game screens such as introduction, help screen, high score list and main menu must be designed so that learners feel as if they are playing with a computer game.

4.5. A Model for Incorporating the Motivational Factors in the Game Structure

A good educational game captures the learner's concentration and imagination and provides the proper stimuli to absorb the learner in the learning activity to employ and apply the relevant skills. In this section, motivational factors such as goals, challenges, feedback and guidance have been grouped to show how an engaging/immersive learning environment could be achieved that flows naturally.

4.5.1 Gain learners' attention, concentration, curiosity and sense of exploration

The learner's curiosity must be captured using animation, graphics and sounds. Their cognitive curiosity must be aroused through exploration and information seeking behaviour (Gagne et al.1992, Keller 1987, Malone and Lepper 1987).

4.5.2 Introduce clear goals and inform learners of objectives

The goal must be naturally linked with the story, clearly presented and accessible at all times (Gagne et al.1992, Czikszentmihalyi 1990, Malone and Lepper 1987 and Quinn 2005).

4.5.3 Use appropriate challenges and assessments

Challenges must relate to learning objectives (Quinn 2005) and stimulate recall of prior knowledge (Gagne et al.1992). They must have enough repetition to naturalise the knowledge and solve real life problems (Gunter et al. 2008). The challenges must be introduced at levels of gradually increasing difficulty (Quinn 2005) in order to increase the learner's self-esteem (Keller 1987, Malone and Lepper 1987).

Assessments must have the same rigour as conventional classroom methods to ensure useful learning is taking place, and to avoid trivialising or deviating from the targeted skills in the syllabus. Adaptation of games must be appropriate and help the teacher meet their professional responsibilities. The game learning system must be transparent to the teacher and provide access to the learner's progress. Teachers don't need to play the game, but there must

be a mechanism for the teacher to look inside, provide feedback or receive a report.

4.5.4 Provide feedback, reinforcement and a sense of satisfaction

Feedback must be staged and presented in the game story's theme, to prevent distractions to the player (Quinn 2005). It must notify the learners if their goals have been completed and how they are progressing (Jones 1998, Sweetser and Wygeth 2005, Bixler 2006). The feedback could be in the form of a reward which could be highly motivating and increase the learner's sense of satisfaction (Keller 1987). Feedback on incorrect answers must guide the learners in the right direction and increase their curiosity (Revelle et al 2001).

4.5.5 Create a real experience

Variability in the games could help the learners to feel that they are in a believable environment. This could be achieved by increasing the range of choices that learner can make (Keller 1987). Unpredictability, an element of chance (Quinn 2005) and uncertain outcomes (Malone and Lepper 1987) have also been mentioned as contributing to the sense of a real experience.

4.5.6. Increase learners' sense of control and provide direct manipulation for learners

The game navigation system must be effective and efficient. The game shell must be easy to use including many different choices and functions for the learners (Malone and Lepper 1987).

4.6. Conclusion

Most games that have been used in educational settings do not entirely reflect the learner's cognitive processes, instructional design, motivational factors or incorporate the components of good game design. In the instructional/motivational paradigm we have sought to merge these factors and synthesize the various concepts into a usable design model which is based on sound principles for both game and instructional design. This protocol has the potential to be employed as an analytical tool with the power to assess the success of a game proposed for educational environments. This protocol requires the incorporation of defined instructional principles into the design of educational games, ensuring that the conceptual framework for establishing content and curriculum are incorporated at a basic level, and with academic rationale as the underlying basis. Such an approach provides an easier method for assessing and verifying educational efficacy, and should provide a common denominator for the co-operation of designers and educators. It will also allow game designers to more efficiently add educational content to games, and allow educators to more productively incorporate games into their curricula.

Chapter 5

Evaluation of the Innovative Augmented Reality Games in Mobile Learning

5.1 Introduction

Augmented reality games take advantage of the real-world context. In order to obtain the players' context, each player's mobile device must be augmented with an array of sensors, such as GPS device, RFID reader or devices such as Bluetooth, Infrared or camera. A formal design paradigm that embraces both sound educational and good game design principles is also needed. Specifically, this chapter evaluates four well documented mobile AR games used in educational settings according to the essential elements that exist in instructional design, motivational design and game design. After discussing the findings, an instructional/motivational paradigm for designing mobile AR games will be defined that uses these elements with special features of the real world, in order to take full advantage of the integration of virtual and physical environments for educational purposes.

In this section, several Augmented Reality (AR) games used in mobile learning have been evaluated (Fotouhi-Ghazvini et al. 2009 b). According to the theories outlined in the last section, two sets of questions have been designed to determine how different instructional/motivational factors are presented in these AR games. The first set ascertains each project's goals and learning objectives and how they have been integrated into the basic game structure. The second set seeks to find out how the motivational factors have been added to increase the learner's engagement and enjoyment. In the next step, a collection of existing games were selected. The collection was created from reliable sources that utilize the latest wireless technologies with proper documentation, and have been used in the academic community with the objective of innovating game play and education. The following games were part of the collection:

- 1) Live Long and Prosper, a PDA participatory simulation mediated by peer-to-peer beaming to teach about genetics (Klopfer 2008).
- 2) Environmental Detective which uses a Pocket PC equipped with a GPS device for role playing an outdoor game by MIT students to find out the cause of toxic spill on the campus (Klopfer 2008).
- 3) Outbreak@MIT an indoor game, participants work in teams to investigate a simulated disease outbreak on the MIT campus using Pocket PCs networked with wireless networking (Wi-Fi) (Klopfer 2008).
- 4) Savannah designed by NESTA Futurelab for children aged 11-12 who use Pocket PCs equipped with GPS and WiFi to learn about life in Savannah acting as lions (Facer 2004).

According to the MEMRG scale in chapter 2, these games have an acceptable level of context, however because most of these games have used a PDA as a mobile device their degree of mobility is low (see appendix A, Table A.1 and A.2). Moreover according to chapter 3's conversational framework they have ranked poor (see appendix A, Table A.1 and A.2).

5.2 Evaluation of Instructional Aspects of AR

Games' Structure

5.2.1 What kind of knowledge and learning objective is incorporated in the game's structure?

Live Long and Prosper emphasizes a basic understanding of topic concepts as well as an understanding of experimental methodology. Students pair their devices which contain new sets of genes with devices from their most likable mate (applying) to see if the two can successfully mate (analysis) (PSims). Environmental Detective encourages data collection, analysis, and decision-making for an environmental investigation (Klopfer 2008). Chemical concentrations are sampled in the groundwater by using virtual digging and sampling (analysis). The essential information about the meaning of toxins is gathered via virtual interviews (understanding) (Klopfer 2008). OutBreak is an opportunity for data collection and analysis, with experimental procedures to investigate a source of disease. This game targets procedural knowledge and meta-recognition for managing an epidemic. The game is used to interview virtual people, obtain and analyse virtual samples, medicate and quarantine

players who might be infected with a disease, with integrating applying and analysis of cognitive processes (MIT b). Savannah is a game to develop conceptual understanding of animal behaviour and survival in Savannah and to learn research methodology. They are provided with audio and visual clues at appropriate locations (analysis) in order to stay away from danger and track their prey (applying) (Facer 2004).

Learning through enquiry and exploration has been principally targeted by these AR games; the technology used was the most appropriate for implementing procedural knowledge. Developers and instructors extended these games applications for teaching knowledge of principles, and models of particular discipline areas for younger learners, but the games lacked the necessary components to fulfil their purpose. For adults the essence of meta-cognition (i.e. self-monitoring and evaluation) was intended to be achieved in these games, but is still not realised. The fundamental problem in these games was that they didn't fully implement the hierarchy of the learning objectives in the game structure. Objectives for remembering or understanding basic concepts were not introduced during the game. Evaluation and creation were assumed to be the obvious consequence of the game. Klopfer indicated the shortfall in terms of promoting the "*skill of being able to make decisions with information that is less than complete, or managing faulty solutions*" (Klopfer 2008, p.101). The overall result was that the games were only employed for applying and analysing the objectives. A solution for addressing this problem has been proposed in 5.2.7.

5.2.2 Have the learners' preferences been determined and integrated into the games?

In Live Long and Prosper, the game had a simple structure, so the instructor had the flexibility to use it in different contexts, or change its level of difficulty and adjust the game's direction according to the students' interest and prior knowledge (PSims). In Environmental Detective, students played the game on their own university campus which increased their sense of ownership, and they could use their prior knowledge of the location (Klopfer 2008). Outbreak was played with a number of diverse audiences, ranging from high school students to professionals in public health. *"Each of these audiences entered the activity with obvious differences in skills and background, but also with differences in expectations as to both what and how they should learn through this game"* (Klopfer 2008, p.139). In Savannah, primary school students were selected according to their intelligence (i.e. gifted and talented, under-achieving, and mixed abilities) and on the basis of friendship and gender. A questionnaire concerning mobile phone, digital games and the learning subject was completed by students (Facer 2004).

Factors that increased the level of game customisation for learners were: simplicity, loosely defined game structure, familiar physical locations and real objects, each groups' intelligence homogeneity, friendship, gender-division, familiarity with playing digital games, and mobile devices. The games were gender-inclusive and the use of activity-based inquiry or experiential interactions was promoted with indirect non-confrontational outcomes.

5.2.3 What kind of genre are the games targeting?

Live Long and Prosper was a participatory simulation of the player's genome (PSims). Environmental Detective and Savannah were role playing games, playing as environmental engineers and lions where every member of the team played the same role. Both games were also to some extent strategy-based adventure games (Klopfer 2008, Facer 2004). Outbreak had a greater degree of role play: the roles of medical doctor, field technician, public health official differentiated among the players. The game took place in a simulated environment of a viral disease (MIT b). Mobile AR games have mainly been used to simulate or role-play real life. Strategy-based adventure games have also been implemented in real life settings.

5.2.4 What aspects have been considered when writing the stories?

In Live Life and Prosper, students must learn what each gene stands for and how each set of genes are matched with another to be able to reproduce. The game can be used each session with a life story of different creatures such as a fly or a human (PSims). In Environmental Detective, the story was near to reality and the location was the key element of the narrative. Pedestrians, or local people, or player's background information, was incorporated inside the game with the real details of buildings, locations, real name of people, smells and sounds (Klopfer 2008). In Outbreak, there is an outbreak of SARS in Boston. A suspicion is growing that two members of Massachusetts Institute of Technology (MIT) have contracted the disease. These people must be found

and the spread of the disease must be controlled. The game takes place in the real environment of the story which is at MIT. The game simulates a model of disease transmission and is linked to others' game environments via accessing each player's location. Virtual medical items and sampling tools are available to give the playing area a real feeling of an outbreak (MIT b). In Savannah, the player acts as a lion pride, displaced into a new area. Savannah is simulated in outdoor environments by integrating different virtual sensory simulations such as real pictures, sounds and smells (Facer 2004).

These games are less fantasy-based, and they are not trying to simplify or exaggerate real life. On the contrary, they try to be as close as possible to real life and to the environment where it is taking place, or the environment it is simulating. This process occurs by integrating virtual details of real locations, people, animals, objects and even scientific facts that exist in the story with the real location of the game. Stories are designed to be appealing to the emotional needs of learners and encourage identification with real characters or contexts. Stories are evolved from learning goals and objectives, but are often branching and interactive. The mixture of story and game play leads to multiple branching points and the potential for the story to have an increasing number of variations is high.

5.2.5 What kind of features do the rules have?

Rules are constraints or controls in the playing environment. Live Long and Prosper and Outbreak both constrain the player to the scientific principles involved in the simulation; for example if a certain set of genes cannot match

with another set according to genetic principles, the game rules must encapsulate this and the players' devices should not match and nobody should score (PSims and MIT b). In Environmental Detective and Savannah, the rules of the game environments were built into the geography of the MIT campus and Savannah itself (Klopfer 2008 and Facer 2004). In Savannah, for example, possible threats like fire and humans also acted as constraints in the game worlds. In the Savannah game, the sole emphasis of the game was on the energy level of players (i.e. lions); consequently, students end up killing for prey during most of the game, without learning much about the other characteristics of lions. To address this problem, the structure of the lions' behaviour must be analysed and integrated as rules in the game world. These rules must be fixed, repeatable, explicit, unambiguous and shared by all players at the same time by means of mobile technology, e.g. GPS or WiFi.

The introduction of AR games in education as Klopfer indicates promotes "*raw, partially formed materials*" (Klopfer 2008, p.79) and "*flexibility in the content*" (Klopfer 2008, p82) might increase the adaptability of games in a different context. On the other hand, students learn little about the complex relationships between different concepts. They only try to meet the objectives of the game. In Savannah, for example, they strive to increase their energy levels or stay healthy. Understanding different relationships needs to be included in the game model, and game rules should be sufficiently clear to encourage the learner's facility to learn. According to Facer's findings, even the methodology for research and problem solving in AR game environments must be taught explicitly to students. In summary, reflecting on the Savannah game, Facer

concludes “*The process of learning through game play involves a distillation of the complexity of real life into a set of abstract rules. These rules will drive all the learning in the experience, and if these are incorrect or inadequate to describe the phenomena that is being taught, then it is unlikely that players will develop an accurate picture of the phenomenon*” (Facer 2004, p.41).

5.2.6 Do the games have different game characters and how are they designed?

In Live long and Prosper, players could wear different coloured tags to represent a special set of genes (PSims). In Environmental Detective there are many interviews from virtual experts and witnesses scattered around the campus (Klopper 2008). In Outbreak players choose a role through the game interface, with different tasks to do, like medical doctors, field technicians and public health officials (MIT b). In Savannah, students played the role of a lion by receiving virtual inputs like pictures, sounds and smells from the game (Facer 2004).

Characters could be both real and virtual. When the real characters are used, players could easily change their roles as heroes, enemies or mentors. Characters could dress consistently for the part e.g. doctors, or wear a symbolic dress such as a red tag to represent certain sets of genes. There must be enough input from the game for the players to be able to identify with the roles they usually could not have in real life such as being a lion. Real objects could be easily viewed, touched and collected by game characters.

Dialogue between game characters is not fixed and it changes during different game sessions. Conversation between players does not destroy the game play or add any extra load on the mobile device; in contrast, it will amplify the essence of the experience. The virtual characters' dialogue must be crisp and to the point in order to reduce the load on the device and it must be thematic and evolve from the game story.

5.2.7 Do the games have different levels and how are they designed?

In Live Long and Prosper, the game does not have different levels; students play the same game repeatedly (PSims). In Environmental Detective and Outbreak there is only one level which is played over a few hours (Klopfer 2008, MIT b). Savannah had three different levels. Level one was only an introductory session where students play in the field to become familiar with the environment and the game play. Levels 2 and 3 had the same level of challenge i.e. avoiding death, gaining energy and reducing hunger (Facer 2004).

Employing only one level in AR games will result in the problems encountered in section 5.2.1. The cognitive process hierarchy must be implemented fully and sequentially using Bloom's Taxonomy (Bloom and Krathwohl 1956) and Gagne's nine events of instructions (Gagne et al. 1992).

5.2.8 Which kind of puzzles do the games include?

All games are one big puzzle. These puzzles fit naturally into the story and give the players the opportunity to learn more about the people, the setting, and the

world they are exploring (PSims, Klopfer 2008, MIT b, Facer 2004). Instead of making the game into one big puzzle, it can be divided into small puzzles in different game levels. Each puzzle should be designed to lead the player to specific information through the interactions with the puzzles. Bates (2004) suggests the following varieties of puzzles to be used for incorporating into game-play:

- 1) Object Puzzle, when the player has to use objects available in the game setting (real or virtual) to solve the puzzle or create new objects (Bates 2004).
- 2) Information Puzzle, when “*the player has to supply a missing piece of information.*”(Bates 2004, p.121).
- 2) Sequence Puzzle, when the player must “*perform a series of actions in just the right order*” in reality or virtually (Bates 2004, p.124).
- 3) Logic puzzles, when “*the player must deduce a particular bit of information by examining a series of statements and searching for something hidden*” (Bates 2004, p124).

5.2.9 Do the games have communication capabilities?

In Live Long and Prosper, “*interactions between players are mediated by peer to peer beaming. There is ‘organized chaos’ as they look for partners with whom they can meet*” (Klopfer 2008, p.67). In Environmental Detective, players freely communicate with each other and pedestrians by means of facial expressions and gestures. A group of students that did not belong to the university also took part in the game “*they were disconnected from that reality by being dropped into that location for a few fleeting hours.*” (Klopfer 2008,

p.118). They only collected the information and did not share the information to solve the problem (Klopfer 2008), “*much of their collaboration centered on game mechanics, and less on collaborating to work through scientific dilemmas*” (Klopfer 2008, p.155). In Savannah “*communication on the field is characterised by shouting, chatting and organising ...*” (Facer 2004, p.20). Different members of groups (leader, follower, collaborators) possessed different communication skills. There was also a “*difference in attitude and understanding of the purpose and collaborative nature of the task between the girls and boys...*” (Facer 2004, p.22). Players often had difficulty understanding the purpose of group missions (Facer 2004). In Outbreak, missions included creating a single world, limiting resource and giving distinct roles to players; all these “*encouraged conversation among them*” (Klopfer 2008, p.136) and “*...the fact that sharing information could reveal new things encouraged frequent digital exchanges*” (Klopfer 2008, p.160).

Playing in a team and communication among the players is an integral part of augmented reality games. In these games, social organization and status becomes more important and personal as it is happening in the real world and players are able to meet face to face. These games are synchronous and the action of each player has an immediate effect on the other player. These games often do not provide any means through the game world to restrict or control the content of what is communicated. Players can easily see and talk to each other and they create their own channel of communication, without the game intervening. Each team’s experiences from the game play could be different, depending how well their social skill and ability to

communicate with others is developed. A problem might arise from this loose communication structure, and people with different levels of communication skills will have difficulty adjusting to these games. The role of teachers in providing hints, help, feedback, limitations and rules is very important to help the learners in the communication process.

It is possible to let the system control the collaboration by assigning roles, power and abilities. However, this could lead to limiting the players' interactions and the focus of learning shifts to the end product rather than the process of learning as happened in Outbreak@MIT. Each student only concentrates on the task at hand and communicates with others when in need of certain resources. Students will start acting in a more organised manner but they could lose the necessary motivation that could engage them in discussion and negotiation for solving problems. This is often due to the fact that the group's goal is converted to personal goals that can be solved individually. Moreover when the group work is finished students have only become expert in certain topics that were assigned to do and therefore they do not acquire a full understanding of the overall concept.

5.2.10 What kind of knowledge chunks are designed for the games?

In Live Long and Prosper information, hints, and resources are provided by the teacher (PSims). Environmental Detective contains electronic resources for all players which are only presented to the learners at certain locations of the map (Klopfer 2008). Hints could also be picked up via the surrounding environment

and people. In Outbreak, each player has limited resources that other people depend on (MIT b). In Savannah, players could 'see', 'hear' and 'smell' the world of the Savannah as they navigate the real space outdoors. The second domain, the 'Den', is an indoor space where children could use resources such as books, whiteboard, internet, videos and toys; they used it to create personal lists, images, maps and lists of animals to attach to the field (Facer 2004).

In AR games, additional information and resources often needs to be added by teachers and it is possible for different players to receive different information and this makes each player play the game differently. Moreover, information is not always explicit but it could be indirect and hidden in everyday life. Players could access a homogenous level of knowledge at the right time and right place if their application is displayed as:

1. Cut scenes to further the storyline, introduce learning thematic objectives and to establish and support the mood and tone of the game.
2. Hints, when learners are stuck and cannot complete their missions game could provide levelled hints and not answers.
3. Resources, such as content experts, reference books, journals articles, overview maps and animated objects which should be used to obtain more supplementary information about certain events.

5.2.11 What kind of menus do the games have?

Live Long and Prosper has four simple black and white menus. They are designed for starting, exiting and playing the game; there is a menu for setting

the game preferences which is only set by the instructor (PSims). Environmental Detective has a main menu with a picture of a map and options to dig, collect samples, control GPS and access collected resources (Klopfer 2008). In Outbreak, there are four screens. In the room screen, there are options for the player's location, items for viewing, picking up and using lists of players; below, there are virtual characters to talk to. In the note screen, the player can access the collected resources such as interviews and measurements. The stuff screen tells players which items they have collected. The Info screen contains players' details. The IM screen can send and receive messages from players (MIT b). In Savannah, there are two menus; in the first one, players could see their level of health, thirst and temperature and in the other menu, they could see the picture of the animals around them and hear their sounds (Facer 2004).

In AR games, in addition to the introduction, help and the main menu, designers need to add menus for room location, area maps, list of virtual or real items or resource collections, with options to collect environmental data, control GPS, access Bluetooth or Infrared and message other peers. More traditional menus such as new game, settings, high scores, help, about (copyright, version, and vendor) and exit could be added to increase the usability of the game and efficiency of the navigation system through the game, allowing the players to move seamlessly between mobile real and virtual worlds. A response for every action must be produced depending on the screen type, while keeping the file size manageable. Similar user tasks must be kept spatially close together with a clearly designated beginning, middle and end.

The main sources of error such as entering and extracting contextual data should be predicted and simple error handling must be provided. Unexpected events in mobile environments should be tolerated and allowed. Internal locus of control must be provided by 'automatic pause', 'manual pause' and 'save' commands to help players preserve their data and cognitive progress. The game environment must be configurable for novice or expert players. These games must also be suitable for students with auditory problems and female students.

5.3 Evaluation of the Flow and Motivational Factors in AR Games

5.3.1 How do the games gain learners' attention, concentration, curiosity and sense of exploration?

In Live Long and Prosper, there is no use of sensory simulation. The interface is very simple, black and white and the graphics are poor (PSims). In Environmental Detective, real world stimuli and taking part in the quest gained the learner's attention and cognitive curiosity (Klopfer 2008). In Outbreak, which was mainly textual with limited graphics, cognitive curiosity stimulated the learners to be able to manage the disease (MIT b). In Savannah, students became engaged in the game by sensing the world of Savannah through pictures, sounds, music and smells in their own environment and doing some physical activities like running around acting like lions (Facer 2004).

These games bring about association through stimulating multiple human senses and perception. On the other hand, they are not fast paced and require a lot more virtual data and design to secure a wide range of student attention through arousing sensory curiosity. They also need well-designed usability aspects. By asking learners to solve problems and take part in missions, the cognitive curiosity of learners is simulated.

5.3.2 Do the games introduce clear goals and inform learners of their objectives?

In Live Long and Prosper, the main goal was presented by the teacher and there was no introduction (PSims). Environment Detective has a 60 second digital video-briefing from the University president where they are enlisted to investigate the spill of the toxin (Klopfer 2008). In Outbreak, the story of the game is presented in the introduction screen, in the form of text. The players must decide for themselves what their goals should be throughout the game (MIT b). In Savannah, the introduction to the game was carried out by presenting a video about animal life and the game master explained how the game functions. Between each level, students either had free research time or were introduced to the next level (Facer 2004).

In these games, either the goals are presented by instructors or the learners guess them through playing the game. Many instructional designers such as Malone and Lepper state that educational games must have clear, fixed goals (Malone 1987). Overriding goals must be provided in the introduction, and intermediate goals for specific missions must be presented by in-game cut-

scenes. Learning objectives could be presented in the form of "*Upon completing this game you will be able to. . .*" or part of the backstory and description of the victory condition in the help menu. If at any time the learner needs to read the objectives or instructions again, the help menu should be easily available.

5.3.3 Do the games use appropriate challenges?

Live Long and Prosper, Environmental Detective and Outbreak contain one major challenge i.e. to find the matched set of genes, find the source of toxin, and manage an epidemic disease. The consequent plot twists are situations where the knowledge really needs to be applied, so the challenges are related to the main goal of education. These challenges are too general and are unable to fulfil the detailed learning objectives of the study. Savannah is presented in two levels but the intensity of the challenges is the same for both; consequently, learners are not able to accumulate their previously learned knowledge. Problems in designing the right challenge for mobile AR games refers back to level design which has been discussed in 5.2.1 and 5.2.7

5.3.4 Do the games provide feedback, reinforcement and a sense of satisfaction?

Live Long and Prosper does not give the players any quantitative information at the beginning. Gradually the teacher calls the students after each round of the game and asks what they have discovered so far, and what they would like to know. As the game progresses, the teacher must focus the group in the right direction. At the end, students take part in class discussions to apply their

learning in new situations (Klopfer 2008). The same applies for Environmental Detective and Savannah with the difference that they receive some virtual feedback through the game. Outbreak is the only self-contained game. In these games, precise individual rewards or punishments are not obvious and learners must work for the group goals.

Most augmented games cannot manage without a skilled instructor. Augmented games must include self-monitoring features which are currently lacking in existing games. Feedback should help the learner understand why their answer was wrong, or point them gently in the right direction (Keller 1987), and provide feedback on performance outcomes so that the learners can be notified when goals or mission objectives are completed. They should also be able to check the status of their goals, sub-goals, completed goals and scores.

5.3.5 How do the games create a sense of real experience?

In all of these games, as soon as players enter the game they see other players in near proximity and share the same world. In Environmental Detective and Savannah, the game state is continuously updated by the events in the real world, such as non-players performing their daily activities, sounds, smell weather conditions etc. Real life activities are part of the game play and their unpredictable changes can change game conditions and produce uncertain outcomes. The boundary between real life activities and game play becomes blurred and consequently produces a sense of real life experiences during the game play. In Outbreak, the player's actions affect other players and they must

coordinate appropriately (MIT b). “*The use of the body in the learning activities is critical*” (Klopfer 2008, p85). The common experience, variability, unpredictability and uncertainty of real life and use of human multi-senses provide a unique sense of reality to these games.

5.3.6 How do the learners sense control over the games?

In all these games the game play area was easily configurable. Players could define their own game worlds at any location simply by changing the physical space by technologies available to the game - locating the game elements within that environment. The navigation through the game was by simple physical navigation. The player had to move or turn around in physical space to win the game. On the other hand, “*the real space provided real barriers and caused the students to make some decisions of the kind not faced in a virtual world where the consequences are merely virtual*” (Klopfer 2008, p.99). The technology plays a significant role in controlling the game and the distance proximity between players; game characters and the game objects must be decided by GPS, WiFi, Bluetooth or infrared. Players could encounter limitations in these technologies which affected them in some way, namely (a) GPS data is only accurate within 10 meters, (b) when playing Infrared beaming games, everyone in the class must start together, they cannot join an already running game whenever they want, and (c) there is too much variability in Wi-Fi signal strength. Navigation through these games is easy; and the game shell is easy

to use. The learners are able to make frequent choices but their real power at *all* times depends on the constraints of mobile and wireless technologies.

5.4 Conclusions

It is concluded that AR adds a real sense of learning to mobile games by providing models of real world settings for learners. The learning objectives must be integrated into the game rules, story and the different levels. The game model must be close to the real world and appropriate feedback and challenges must be present throughout the game environment. The following are the main problems of the existing AR games:

- (1) Hierarchy of learning is ignored and learners cannot use their previously learned knowledge
- (2) There is not enough attention given to each cognitive process so consequently higher level thinking is not usually developed
- (3) Game rules cannot assess a wide range of skills and knowledge
- (4) Face to face dialogues are loose and unorganised
- (5) Games lack levels and challenges are too generalised
- (6) Games do not liberate learners to access different resources
- (7) They do not have efficient user interfaces and have low visual appeal
- (8) They do not have a self-assessment system
- (9) Teachers cannot regularly check the learners' progress

By solving these problems educators can effectively incorporate these games into their curricula.

Chapter 6

A Design Methodology for Mobile Language Learning Games

6.1 Introduction

Mobile devices and desktop computers have a number of differences both in the way they operate and in the way they are perceived by users. These may be summarised as follows – mobile users operate in a varying environment with occasional connectivity problems whereas desktop users are normally in a fixed position when performing a particular computing task or application. Mobile users often use only one hand and may be multi-tasking. However, given that mobile phones cannot easily handle multiple applications on the same screen, their operation must have the capability to ‘exit’ an application or a menu without losing data.

The mobile device hardware also has major limitations. Mobile phone screen size ranges from 2 inches to a maximum of 4.3 inches, which is still significantly smaller than 15-19 inch screens on laptops and desktop PCs. Mobile phones are normally pocket size and the phone must be easily held and operated by the hand. Mobile phones often have a small keypad to enter data

where the user must press a key several times to type the desired letter or they have a touch screen which can also be cumbersome to use when entering text data. Applications such as games quickly use the device's limited battery resources and the processing power and limited memory prevents developers from utilising extensive, high resolution graphics. In addition, expensive, slow and irregular network connections such as GPRS can restrict users to accessing the mobile internet for short amounts of time for specific purposes.

In this chapter we describe the design principles which can overcome some of these inherent barriers of technology and provide support to resource-limited users. Different mobile language learning games can be designed which employ technologies that are widely available to most mobile phones with highly portable and adaptable results.

To begin the design process it is very important to have a thorough understanding of the user, the user's culture, skill level and goals, why he/she needs the product, what they are trying to achieve, when, where, how, how long and in what circumstances it will be used. We need to be able to predict the user's behaviour in different circumstances, where it is possible to do so. Good design takes advantage of platform and tools' strength; and concentrates on main goals while being clear visually, invisible and intuitive with a natural feel.

The experimental groups in this research were chosen from University students. In Fotouhi-Ghazvini et al. (2007 and 2008a) an analysis of potential mobile learners was performed, as an example of a 'developing world' context. It was concluded that incorporating mobile games into lectures and students' private study time could play a significant role in increasing their motivation and enthusiasm in learning technical English.

Students in computer engineering consider mobile technology a useful tool for training and learning and are experienced users. Our representative survey (Fotouhi-Ghazvini et al. 2008 a) concluded that 63% of students would like to receive second language (L2) learning content via their mobile phones. Technical English course units are very important for Computer Engineering students, to enable them to understand their textbooks, which are mainly written in English. Due to the nature of the field, they have to use the Internet extensively, also mainly in English. The role of English in passing MSc and PhD entrance examinations is also significant. Despite its importance, it is offered for only one semester during the student's four years of study and for only 2 hours per week. Unfortunately there are few lecturers that are competent both in English Linguistics and Computer Engineering. In addition, the students' attitude towards these classes is negative because they have very little appeal. Incorporating mobile games during the lectures and student's private study time could play a significant role in increasing their motivation and enthusiasm in learning Technical English.

The games that have been designed in this research could be used in various contexts contributing to different language learning applications. Students have the same age, nationality and are highly familiar with mobile phones. They often use smartphones and spend around £100-150 on their mobile phone. The average screen size of their phone has 240 x 320 pixel display resolution.

When students are playing with the mobile games they no longer have to be situated in a fixed position, isolated from other people and real life. Adventure Quiz games, MOBO City game, Maryam in Smiley Rescue game

and Butterfly game are designed for users to be played while travelling, waiting for a train, sitting in a library or in a restaurant. The surrounding could be noisy and prone to the interruptions and distractions. Students often do not have a long time to perform interactions, playing game is not their primary activity and they need to distribute their attention across other tasks as well. Thus each game session is designed to be short, between 5-10 minutes. These games quickly start and are easy to learn. Their importance is due to the fact that they are effective in recalling and understanding information (see chapter 8). They help recalling the information because they offer quick fun with an environment which is highly re-playable. They help understanding the concepts by using images, icons and concretising the learning objectives. However these games are not considered MEMRG (see appendix A, Table A.1 and A.2). They do not retain information, have simple rules and feedbacks.

The detective game gives more attention to graphical design and richer interaction with the user. It contains a large variety of rules with an intuitive guide throughout the game play. It has a wide range of functionalities with an efficient navigation system that uses contextual information, continually letting the players move between mobile, real, and cyber spaces. The game environment is updated accurately and in a timely manner to increase the quality of the interaction.

In this chapter we first look at the importance of English vocabulary and why it has been the main focus of the research on educational games. Then different second language acquisition (SLA) theories and their main features are introduced. Next a short summary of games are presented. Then the most advanced game, Detective game is analysed according to the instructional,

motivational framework. Finally it is analysed according to the principles of 'User Interface Design'.

6.2 Vocabulary Importance

To help students to understand technical material more easily, the strategy in this research is to zoom in to vocabulary learning. Nation (1990) shows that in comprehension tests, knowledge of vocabulary is very important. The main feature of English vocabulary is that it is very large. Consider, for example, the set of objects and actions that in English are labelled as: book, write, read, desk, letter, secretary and scribe. They are all semantically related to writing, however they all look different. This indicates that a second language learner must learn all the different vocabularies. On the other hand, in languages such as Arabic, semantically related words look very similar. For example, all the words related to writing in Arabic have a shared set of three consonants - k-t-b. Absence of this characteristic in English increases the cognitive learning load on English language learners. Furthermore over the years, different vocabularies from Latin, French, German and Greek languages were added to English. As a result the English vocabulary is very large. Webster's Third edition contains 54,000 families with native speakers being familiar with 20,000 (Goulden et al. 1990). Students preparing to study in English at university level need to know 5,000 of the most frequent and academic words all together to study effectively and also use in everyday life (Laufer 1992).

In Asian countries vocabulary acquisition is given little attention. Students' insufficiency of lexical knowledge has led to poor performance in their

written and speaking examinations (Fan 2003). Current English training in Asian universities is based upon a communicative approach but teachers mainly concentrate on memory strategies to teach new vocabularies rather than social and collaborative strategies (Sarani and Kafipour 2008) and (Hamzah et al. 2009).

Words are central components to transmit human messages. Grammar is an instrument to improve expressing those thoughts and ideas and is a supporting framework in communication. Vocabulary acquisition plays a fundamental role in second language learners' fluency. It is an essential component of communicative competence in the construction and understanding of a second language (Coady and Huckin 1997). Rivers (1981) argues language learning without vocabulary acquisition is impossible "*One would learn about a language through some symbol system which would demonstrate relations and how they are realized, but this would be like examining the skeletal remains of a dinosaur and believing that one had actually encountered the creature*" (p. 469).

6.3 Second Language Acquisition and its application in Mobile Learning

For a long time, second language learning was based upon understanding the essentials of grammar and translation 'Grammar and Translation Method'. Grammar was taught deductively and emphasis was on grammar exercise, dictation and translation (Celce-Murcia and McIntosh 1979). Then it was the 'Direct Method' or 'Natural Method' aiming to teach second language the same

way as a child learns first language focusing only on building oral skill. As Diller (1978) pointed out grammar was taught inductively, new words were learned by teacher's demonstrations and pictures, no translation and use of native language was allowed, the emphasis was on accuracy and correctness.

Then the behaviourist approaches such as those advocated by B. F. Skinner and others became popular. Skinner believed if an organism reacts to stimuli in certain way, positive reinforcement leads to repeated behaviour and negative reinforcement halts the behaviour. In his influential book "Verbal Behavior", he stated, "*We have no reason to assume, that verbal behaviour differs in any fundamental respect from non-verbal behaviour, or that any new principles must be invoked to account for it*" (Skinner 1957,p.10 In Ellis 1990).

In mobile learning behaviourists methods of instruction have been practiced extensively. In Ally (2007) adult English learners learn English grammar through "*constant practice using a variety of question types such as true/false, multiple choice drop downs, changing the order of sentences, and matching*". Thornton and Houser (2005) and Levy and Kennedy (2005) sent vocabulary learning contents, quizzes and feedbacks in the form of short SMS messages to second language learners. In Su-Jin et al (2004) learners answer language questions via the mobile web. If the answers are correct, this will be reflected in the growth of a cyber pet otherwise it will get weaker. Thus the pet acts as a visible reminder of progress, or otherwise, and by implication the learner is encouraged to nourish and develop for language abilities, as they would care for their own pet. Uther et al. (2005) presents learners with spoken words, then they have to "*identify which word they heard by clicking one of two buttons.....Learners receive feedback for correct or incorrect choice with a*

chime or a buzz.” The TANGO System is designed for vocabulary learning, different real objects are tagged by RFID (Radio Frequency Identification). A mobile device provides correct annotation as well as question and answer for each object when the learner comes close to them. It is assumed after a number of exposures that the learner associates certain vocabulary items with the appropriate objects (Ogata et al. 2010). Kukulska-Hulme and Bull (2009) “*support language learners in noticing and recording noticed features 'on the spot' and help them develop their second language system*” (p.12). Tschirhart et al. (2008) offer visually attractive, interactive exercises through Adobe Flash which allow for the combination of sound, images, graphics, videos and text within a single activity. Learner feedback and support features are included at a wide range of levels.

Then the ‘Audiolingual Method’ (http://en.wikipedia.org/wiki/Audiolingual_method) was introduced based upon behaviourist theories. The audiolingual approach mainly emphasized drilling and memory assessments via tape recorders in language laboratories. Attention to the learner’s interest and motivations was irrelevant since repetition was deemed sufficient. Language learning was a simple progression of automatic habit construction. Students over-learned the target language, through teacher led dialogues. Structural patterns were taught using repetitive, out of context drills (Prator and Celce-Murcia 1979). The audiolingual method could not promote its communicative nature due to its excessive attention to mimicking, memorisation and introducing limited vocabularies in small dialogues.

The ‘Audiolingual Method’ has been practiced in mobile learning. Collins (2005) introduces “*short dialogs, read-alongs, recorded audio stories, picture*

dictionaries, and phrase books for travelers and preparation tests such as TOEFL for language learning". Joseph and Uther (2006) produced a pronunciation guide "*for language learners to know exactly how to pronounce a new word that they are not familiar with and a pronunciation correction to determine whether the pronunciation of key sounds are uttered in a near native-like manner*".

These approaches were deemed to be acceptable until Noam Chomsky proposed that everyone owns a Language Acquisition Device (LAD) or "*little black box*". LAD starts working when we are infants and extracts our local language based upon a universal grammar. Noam Chomsky argued

"Language is not a habit structure. Ordinary linguistic behaviour characteristically involves innovation, formation of new sentences and patterns in accordance with rules of great abstractness and intricacy" (Chomsky 1966 p.153 In Stern 1983 p.300). Chomsky's theory of '*Transformational-Generative Grammar*' with his complex grammatical rules led to the field of formal language theory and study of language systems. However it could not produce any practical solution for second language acquisition.

Many researchers such as Hymes (1972) argued that the Chomsky theory was too idealized, being purely based on linguistic competence and grammar with no emphasis on human interaction and the social context of learning. Hymes (1972) introduced the notion of '*Communicative Competence*'. He explained it as grammatical competence in different contexts and brought sociolinguistic considerations to Chomsky's competence. Krashen (1982) builds on '*communicative competence*' and regards '*communication*' the main function of language. Krashen and Terrell (1983) believe that main focus of

language acquisition must be on *'lexicon'* as a vehicle for understanding the communication meaning. This was the first time second language learning shifted towards vocabulary learning. He has shown that *'acquisition'* happens when someone comprehend a message. He contributes to Chomsky's LAD concept by proposing that adult also have active LAD, except its phonological aspect. They continue through their life building their knowledge to abstract problem solving and consciously processing grammar.

Krashen (1982) explains *'acquisition'* as *"a process similar, if not identical, to the way children develop ability in their first language. Language acquisition is a subconscious process; language acquirers are not usually aware of the fact that they are acquiring language, but are only aware of the fact that they are using the language for communication. The result of language acquisition, acquired competence, is also subconscious. We are generally not consciously aware of the rules of the languages we have acquired"*(Krashen 1982 p.10). He proposes *"We acquire by understanding language that contains structure a bit beyond our current level of competence (i + 1). This is done with the help of context or extra-linguistic information"* (Krashen 1982 p.21). Context here could be a text from a comprehension, a story or narrative form based on episodes of real communication.

Communicative approaches to language learning have been applied to a number of innovative mobile learning projects. In research conducted by Anderson et al (2008) a mobile device connects with GPS allowing learners to annotate maps of the area with the multimedia that they create. Learners *"share their experiences with one another"*. *'GeoLearn'* uses GPS to virtually tag information for real locations in a city. After initial lessons on vocabulary,

learners are encouraged to travel around the city and make a conversation with local people to solve their problems (Chang-Chih 2007). LOCH “assists learners of Japanese while involved in real life situations. Using the provided interfaces the teacher assigns tasks to the students to go around the town, interact with native speakers and bring back their findings and/or questions”(Ogata et al 2008). PALLAS is a personalized language learning system which can be used as part of the contextualisation process in communicative learning. It introduces parameters such as defining the user profile and the location of learners (Petersen and Markiewicz 2008). Meyer and Bo-Kristensen (2009) have demonstrated the use of mobile Internet, Google Maps and geotagging for language acquisition, supplementing and encouraging informal learning environments through ‘real life’ communication. Lin (2008) designed a collection of software through a Learning Management system to “facilitate students engaging in face-to-face collaborative learning in class activities” (p.202). In ‘Mclass’ learners collaborate with peers for solving problems using the capabilities of mobile phones “to record their voices, send multimedia messages with pictures and sound, and online video conferencing” (Shih 2005). Cesar dos Reis et al (2009) utilized software “to organize the learners interaction to support the mobile collaborative learning, through synchronous and asynchronous multimedia messages” (p.871). In Tai and Yang (2008) describe a platform which “allows users to edit learning materials collaboratively in a Wiki system. Here learners can study online with a handheld device.” Perifanoun (2009) integrated micro-blogging technology with micro-gaming language activities for Italian language acquisition which, it is argued, “enhanced motivation, participation, collaboration” and practice among

learners. Robison et al (2009) described the success of the recently completed AMICITIAS project, whereby users are encouraged to take their mobiles into six contrasting European locations, and provided with tools to enable ambient language learning.

In this chapter five games are introduced. The Adventure Quiz games follows the behaviourists' method of teaching, a set of quizzes are presented repetitively to the learner during a fun game. The game story is not related to the quizzes and each follows their separate goals. MOBO city package consists of MOBO City game I, MOBO City game II and Butterfly game. The first two are based upon constructive approaches to learning offering microworlds and digital environments as Papert (1980 a) advocated. This involves practice and immersing the learner in authentic environments (e.g. Brown et al. 1989) to learn technical language implicitly while playing the game (see chapter 3 for constructivist theories). These games promote meaning-based learning, acquisition of language learning happens incidentally, through exposure to conversation with virtual characters, appropriate context and task. It produces fluency on vocabulary comprehension; however often lacks precision and does not provide knowledge of form and spelling (see chapter 8). It seems that students make the same spelling error after many sessions of incidental learning. The Butterfly game has been added to this package to emphasize that recognition and recall and is based upon explicit learning. In this package second language occurs through the cooperation of implicit and explicit learning, each playing a different role.

The Detective game is a mixed reality vocabulary learning program which is more focused, goal oriented and provides effective learning. The

game can access a rich instruction set and provides continuous cognitive assessment, where a reasonable amount of time is spent on each word such as its meaning, spelling and form (see chapter 8). Moreover it uses Krashen's (1982) communication approach in a natural, simple manner while players converse with real experts and virtual characters throughout the game. A series of puzzles are used to deliberately assess different aspects of vocabulary, while taking advantage of the communicative nature of implicit learning. The game strategies make the best possible use of implicit and explicit processes to achieve specific learning goals while learners consciously apply metacognitive strategies in acquiring new vocabularies (see chapter 8).

6.4 Mobile Language Learning Games

Description

Surveys undertaken showed that engineering students often liked problem-solving classes that are analytical and stimulating as well as communication with other peers (Fotouhi-Ghazvini et al. 2008 a). Using games could increase students' interest and simultaneously augment their practice of language. Game learning could be achieved by designing experiences and putting learners into a context where they can get involved in the normal flow of learning. What makes game learning so distinctive from other types of learning is its essence of flow, context, control, immersion and engagement, which is hard to achieve with other types of learning. The goal of an educational game is to teach a specific body of knowledge. By exploring the game areas, the learner gains and uses knowledge in a way that defeats the game system or the other learners. During

the game play, students become completely involved, focused and concentrated on learning. Educational games could create an optimal experience in learning by activating learners' intrinsic motivation, sense of ecstasy, serenity and timeliness.

6.4.1 Phase I. mobile Adventure Quiz games

Two different mobile adventure games have been designed (Fotouhi-Ghazvin et al. 2009 d). The goal of these games is to rescue as many friendly characters as possible and answer the questions to achieve a score to win the game. Obstructing the way of the player are enemy characters. The player has a limited amount of energy that decreases each time it runs into an enemy character or when the wrong answer is given to a question. However, there are supplies that the player can pick up to regain lost energy. Games end when the player loses all of its energy. These games involve a map that is much larger than the mobile screen, which is called tiledlayer. The map is scrolled as the player navigates and can explore different parts of the map. This takes advantage of two tiled layers that together form the complete map for the game. A land layer serves as the background, but on top of that is a scenery layer that includes trees, houses and mountains placed throughout the map that serve to obstruct the path of the player. These games display pertinent information related to the state of the game, such as 'Life Points', which is initially set at 3, and score, which is initially 0. Figure 1 shows the general layout of the game screen.



Figure 6.1 Mobile Adventure Quiz game: example screens.

At random points during the game a multiple choice question concerning “Technical English vocabulary” are presented to the user: the question and answer are retrieved from a database. The player chooses the right answer by directional keys and the select key. If it is the right answer, the player will gain one life point and one score. The game finishes when the player loses all life points; the music stops and scores are saved. Alternatively the game is also programmed to end when the player scores 50 points. A summary of the relationships between different game’s screens is shown below:

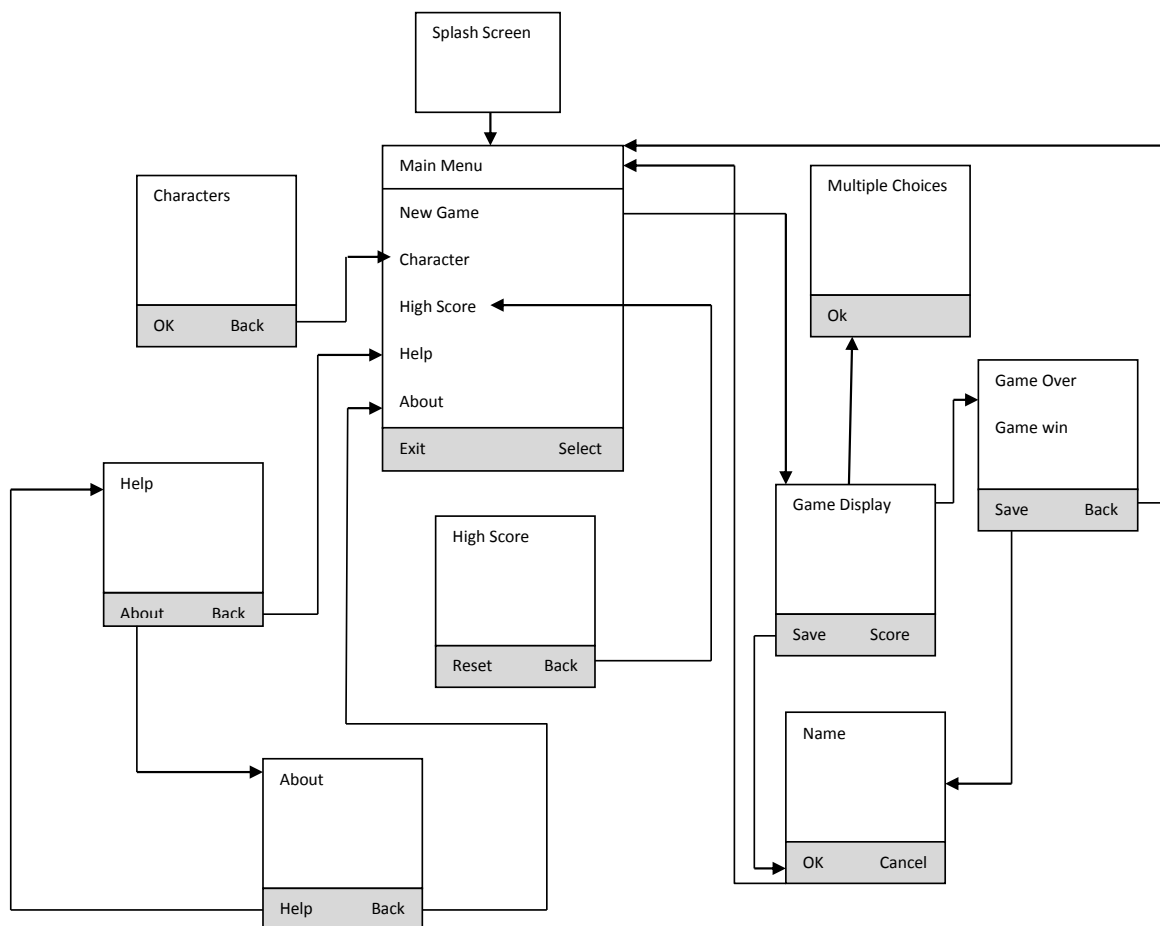


Figure 6.2 Navigation system for mobile Adventure Quiz games.

6.4.2 Phase II. MOBO city package

This work was published in (Fotouhi-Ghazvini et al. 2009 a). To ease the integration of the game in the classroom and increase the teachers and students usability the game was divided into two parts and some improvement was added to the user interface. During the game play students were taught some non-language related subjects in a second language. The assumption was that the learners would acquire the second language simply by using it to learn the subject matter content, without the second language being the focus of explicit instruction. In this phase we produced a scheme that pursues this line of theory. To teach technical English vocabulary to students, we chose to

teach a technical subject (motherboard components), and we introduced the necessary vocabulary indirectly during our instruction.

6.4.2.1 MOBO city game part I

MOBO city represents Motherboard City because the game's main theme is that of a motherboard. The metaphor is of a city where at different locations, electronic components are located, just like in a real motherboard. The complex task for the motherboard is to move data in the right order and right manner, to the right recipient. The main character is a red bus, which represents a 'motherboard bus' whose duty is to transfer information across the relevant components. The game is an adventure where the player presumes the position of a character within a fantasy space (MOBO City). The player can move within the fantasy world and control their character, and explore and interact with any object.

The story begins when the red bus receives a new task, for example *"There is some data just arrived from scanner ship, pick them up from USB port and take them to monitor theatre, where they have to perform a show that has been organized by Viewscan Corporation"* which illustrates how scanned data is shown in a monitor, using viewscan software. There is a clear goal that the player will be trying to achieve, i.e. to successfully send data to its destination, the monitor. This goal will provide a motivation for the action and a metric for attainment. The questions normally asked in the game are related to the computer's common processes, such as accepting input, executing instructions, generating output and displaying or storing results. However it must be in accord with the game story, providing a task for the city bus. The bus has to

move data through MOBO City passing through different components in the right order.

The bus must reach its destination in order for a player to win a game. The game displays pertinent information related to the state of the game such as life points, which is initially 15, and the score, which is initially 0, in the information bar displayed along the top of the game screen. The game finishes when the player loses all their life points. The game is not static; other characters such as virus ships can move around. The bus must be aware of virus ships at all times, because they try to destroy the data bus. If hit, the player loses 1 life point. On the motherboard, next to each main component, there is a bus station or bus stop. A congratulatory message will be shown each time the bus passes through a correct bus stop, the player scores 5. If the bus passes through the wrong component a 'you are not allowed!' message will be shown and the player loses 2 points. If the player passes through a component too early, a 'come back later!' message will be shown. Player will lose the game when has lost all the life points. Figure 6.3 shows the different messages presented to the bus at different bus stations.



Figure 6.3 Different screen shots from MOBO city Part I.

6.4.2.2 MOBO city game part II

In MOBO city part II. Different concept maps were used as a framework or platform to assist us to structure and put in order the computing knowledge (see Appendix B). As a result the subject was divided into small components of interrelated concepts and propositional arrangements. Then various kinds of images (modified from Emofaces Site (2008) and Spriter Resource Site 1 and 2) were integrated into the concept maps. The idea was to enhance iconic

memory via conceptual frame-working. Therefore we used both visual and verbal mental imagery for vocabulary acquisition.

After organizing the sources about motherboard components into concept maps their corresponding environments and characters were designed and then the necessary vocabulary was inserted inside the game as verbal feedback and guide throughout the game (see Appendix B).

The 'Agent OS' is the main game character, OS is an abbreviation for operating system. When the player selects the 'New Game', there are five options presented. The player can use the device's keypad number to rescue any of the 'sound card', 'modem card', 'hard disk', 'CPU' or 'graphic card' members from the virus attack in MOBO city. When an option is selected the player moves inside a building with interconnected rooms. Each Environment has its unique characters, each responsible for different kinds of jobs. The security men in front of each room help the player to get an idea of what job characters in each room are involved in. The player is constantly being followed by different viruses that have attacked the MOBO city. If she is attacked by one of viruses, the player loses one life points. Each time the player rescues a MOBO city member, he or she scores five points. Player loses the game when h/she lost all life points and wins when rescues all the CPU's members. The game's environment and the dialogue where the Agent OS gets involved with different characters are shown in the figure 6.4. Figure 6.5 shows the game's navigation system which is similar to the MOBO city I, except in the first game when the player selects the 'New Game' different options are presented to the player. These options are: 1: There is some data just arrived via the Printer ship. Take them to the Input/ Output Controller Hub! 2: There is

some data just arrived one bit at a time by the Mouse boat. Save them immediately in the Hard Disk Storage! 3: There is some data just arrived via the Modem ship through the www channel. Take them to the Speaker stadium! 4: There is some data just arrived from scanner ship, pick them up from USB port and take them to the monitor theatre, where they have to perform a show that has been organized by Viewscan Corporation.



Figure 6.4 Different screen shots from MOBO city Part II

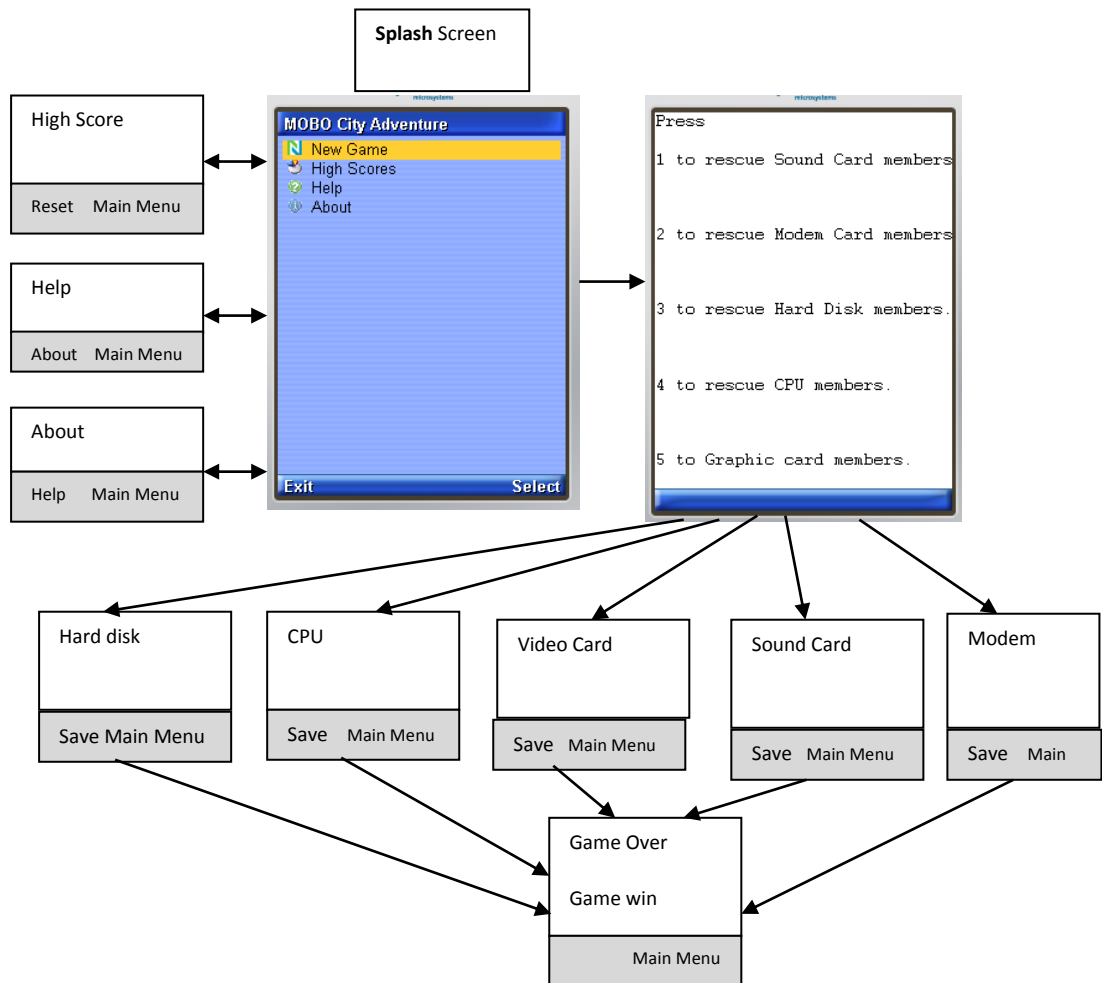


Figure 6.5 Navigation system for MOBO city Part II.

6.4.2.3 Butterfly game

As a further refinement to MOBO city package a word game 'Butterfly Game' was added focusing only on technical and non-technical vocabularies that students encountered in MOBO city games. Consequently deliberate vocabulary learning was also added to our package to help students address their common errors. The Butterfly game is a version of hangman games. The meaning of a random word is given at the bottom of the screen; a complete alphabet is represented as balls rolling with the help of an animated duck. The

game has been modified from Butterfly Scape game (<http://www.butterflyescape.com/>) for language learning. If the balls leave one side of the screen, they will re-enter the other side correspondingly. The duck sprite has two frames to show it moving when the midlet starts, background music starts to play (see Figure 6.6).



Figure 6.6 Butterfly game window.

There is a butterfly that represents the player; by shooting a red bullet (with sound effect) from the butterfly towards the rolling balls, one can choose one's desired letter. Whenever the bullet sprite collides with one of the balls, it is checked whether it is correct and, if so, it will be placed on the correct blank dash at the bottom. The butterfly can move to the right and left but it cannot leave the screen. Each time a bullet hits the wrong letter, the butterfly will lose a wing. This is implemented using a butterfly sprite with 7 frames. On losing all of its 6 wings, the game stops and a 'you failed' image appears with an appropriate sound. If all the letters are guessed correctly a 'you win' image will be shown, with an appropriate sound.

6.4.3 Phase III Detective Alavi in MOBO City Mystery

Adventure

In this stage we implemented a mobile language learning game according to 'Conversational Framework' (see chapter 3) that was designed to teach technical computing vocabularies in the context of the computer's central processor unit (CPU). It was published in Fotouhi-Ghazvini et al (2011 a). An engaging learning experience is produced within a "mixed reality" environment. The player controls its central character (which for the purposes of the story is a detective seeking to solve a mystery) and moves between virtual and real worlds, investigating and interacting with objects that are encountered. The virtual component of the game is a fantasy adventure within which players are notified when goals and learning objectives are completed, are able to check the status of their completed goals and scores, and receive frequent, clear, constructive feedback after each activity. The 'real-world' component of the game is added via the mobile phone's camera and Bluetooth.

Items of information are provided from the real world using Quick Response (QR) codes. QR codes are two dimensional bar codes that are read on camera phones using the QR reader software. Once they are accessed, they allow players to complete an action. QR codes launch and redirect a phone's browser to an embedded URL, or initiate a phone call, or send an SMS, or simply present some text. Access to these features within the game space are to further the storyline, introduce thematic objectives or provide hints when players need assistance and are unable to complete their tasks with the help of their co-players. Players could seek the connections between pieces of

information in order to solve a problem. QR codes link the physical world to the virtual world. This adds value by improving access to information. It aids efficiency and effectiveness within the game environment, and encourages collaborative learning. Scoring within the game is visible to all players by accessing the gamers' relative locations using Bluetooth data. This creates a feeling of being "a member of a learning community" and also promotes competition. It was found that this motivates and enhances learners' motivation particularly when they are able to make comparisons of their own performance with that of others. The shared experience aspects of the game increase the appeal of learning and the game's 'persistence'.

In the game-space the game's main character Detective Alavi talks to the game characters and solve puzzles to reveal clues for solving a mystery in CPU complex.

6.4.3.1 Game structure

The game is divided into six sections; the first is the game introduction which narrates the game story via text and graphics. The next five sections are the five different levels of the game, starting from 'easy' and going up to 'difficult'. These follow Bloom's taxonomy (Bloom and Krathwohl 1956) of educational objectives at each stage, seeking to evaluate the answers to the following questions:

- (1) *Remembering: can the learner recall or remember the information?*
- (2) *Understanding: can the learner grasp the meaning of ideas or concepts?*
- (3) *Applying: can the learner use the information in a new way?*
- (4) *Analysing: can the learner distinguish between the different parts?*

(5) *Evaluating: can the learner make decisions based on in-depth reflection, criticism and assessment?*

(6) *Creating: can the learner create a new product or point of view?(This cognitive process is examined at the end of each level).*

Separating levels into different sections helped the teachers to incorporate the game sessions easily into their classroom. It also increased the game's speed considerably. By using this strategy, the amount of graphics and text was reduced significantly. These five levels are connected to each other and contribute towards the students' hierarchical construction of knowledge. The players need to build on their prior experience and they expect to see this process being reflected in their game scoring. This has been realized by allowing each section to access the game details, such as the total number of clues, the clue numbers for specific levels, the total reporting points, the reporting points for specific levels, the total number of meanings, spellings, the form (i.e. word form) and electronic (i.e. technical knowledge of CPU) skills and the total job opportunities. These values are collected for the next initialization process for the next level of the game.

6.4.3.2 Game introduction

Players often only have a short time to access the game content and prompting them with the game 'introduction' each time prevents them from accessing the necessary content too rapidly. Therefore the 'introduction' is presented as a separate component to the main game. It provides an opportunity for the player to easily skip past the introduction each time he/she restarts a 'new game'. It also offers the facility to the players to revisit the introduction at any stage

during the game. In this introduction, players are informed how to play the game, and the objectives and rules of the game. It is a mixture of graphics and text and is an advance on more traditional textual 'help' (see Figure 6.7). Images are from Spriters resources for game boy advance devices (Spriter Resource Site 3 and 4).



Figure 6.7 Different menus and screens of 'Introduction' to Detective Alavi's game. Starting from left to right: (a) Mr Alavi and Inspector Focus (b) Mr Alavai and Lady Watchful (c) Mr Alavi and Policeman.

6.4.3.3 Main playing environment

When the player chooses the 'Play Game' option they are transferred to the game's main playing environment (see Figure 6.8). This environment consists of a couple of rooms in each level; images have been modified from Spriter resources (Spriter Resource Site 5, 6 and 7). The player is in control of the game's main character Mr Alavi, and moves him around the room. He finds different chunks of information and speaks to the CPU staffs and robots in different rooms which are the game's nonplaying characters. Dialogues exchanged between Mr Alavi and the game's characters is presented in a black

rectangular area in text format at the bottom of the game canvas. The player must speak to the virtual characters to be able to acquire the necessary knowledge of the specific CPU part or function. The player is guided towards a certain puzzle to find the necessary clue in a certain order (Appendix C consists of all the puzzles). This is the order of the learning material that must be presented and examined. If the player visits a location too early they are instructed to come back later. A record of people and puzzles he has visited and solved in each room is maintained and next time the player passes by the same location this puzzle will not be presented at the visited location. This will ensure the hierarchy of the learning material and preserves the spiral curriculum model of Bruner (1960) during the instruction.



Figure 6.8 Print screens from the Detective Alavi's Main Play Environment.

There are helps available in dialogue form where assistance does not stop the game and it is integrated in the normal flow of the play. Dialogue text content is reduced considerably to conform to the limited capacity of the device, only the necessary texts that are related to the learning objectives and feedbacks are presented and they do not contain repeated content. Use of a large block of text and scrolling is avoided and the player only sees three line of

text at a time. The player's game status is presented above the game canvas as Job Chances and Clues. At the bottom of the game environment there is some game commands designed to access different game facilities.

The option menu is situated at the bottom of the game canvas (see Figure 6.9). It contains items that can be triggered at different points in the game. The order of items is consistent with their priorities. Items are not too technical and are understandable by the player. The game environment freezes when the player chooses to use the 'Option' command. 'Camera' option uses the phone's mobile camera to capture the clues from the QR puzzles. Player could enter the clues manually using 'Enter Clue Manually' option if the camera failed to capture the clue.

During the game when the player is satisfied with the number of clues that he has discovered and wants to solve the cryptogram, he/she can choose the 'Solve Cryptogram' option from the menu (for Cryptogram see Appendix C, section C20). A phone call will be activated to someone that has the secret code to winning the game. If the player guesses the cryptogram he/she will be presented with wining screen and the game finishes. However if the player guesses incorectly he/she will loose 1 point from his/her 3 JobChances. By loosing all three JobChances Detective Alavi will loose the game.

Three items will help the player to move to the other sections of the game environment for extra helps they are 'Police Station', 'Language Academy' and 'Intel Corporation'. The 'Language Academy' and 'Intel Corporation' help players with an understanding of the game's vocabularies. In police station players are able to read the CPU complex's staff profile. These

places are substitutes for the more traditional 'Dictionary' option. Information in these three locations is both in Farsi and English.

The player can use 'Read Report' when finished searching all of the clues and wants to exit the level. He/she by selecting the 'Read Reports' activates a phone call to the 'Chief Constable' and then reads a report collected while playing the game. The player is able to save the game and go to the Main Menu at any time during the game.

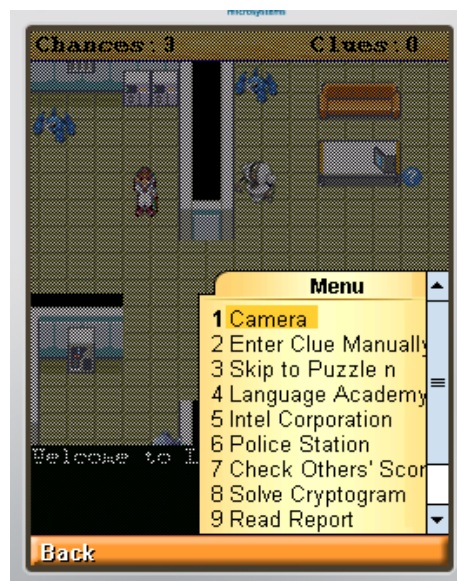


Figure 6.9 Detective Game's Option menu.

6.4.3.4 Capturing the clues

Each clue can be discovered from different kinds of puzzles, such as games, multiple choice or comprehensions (see Appendix C, section C19). At different stages during the game play, the player is asked to find the necessary clue. The camera option is activated in the option menu. The player captures the clues by the camera and then the player uses 'check clues' option to check if he/she has captured the right clue (see Figure 6.10).

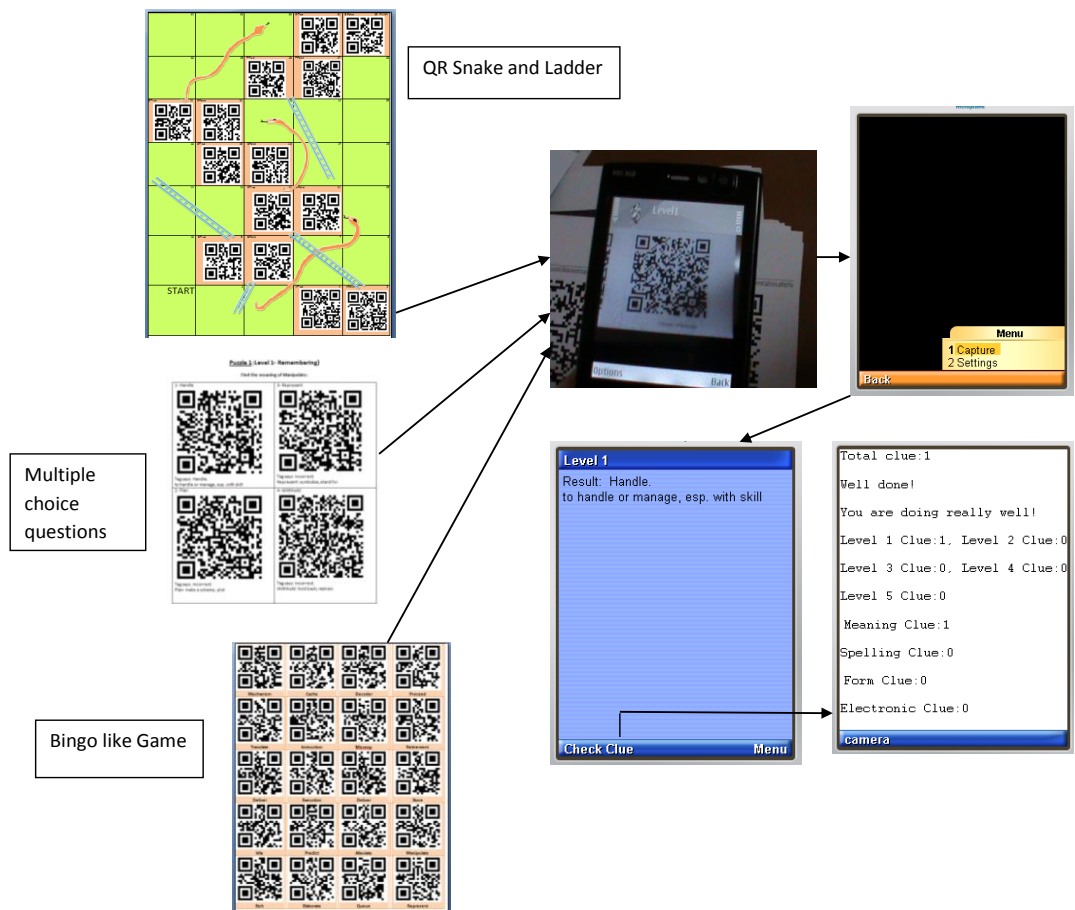


Figure 6.10 The process of capturing a clue.

The player could be indirectly guided to the clue, by presenting the player with a chance to search the web (see Figure 6.11 (a)). This option is often presented to the player when he/she has failed to discover the clue. The player also can be guided to the clue, by presenting the player with a chance to send an SMS to a knowledgeable person (see Figure 6.11(c)). The same approach is used to make a phone call to a knowledgeable person such as teachers/experts or more competent peer (see Figure 6.11 (b)).

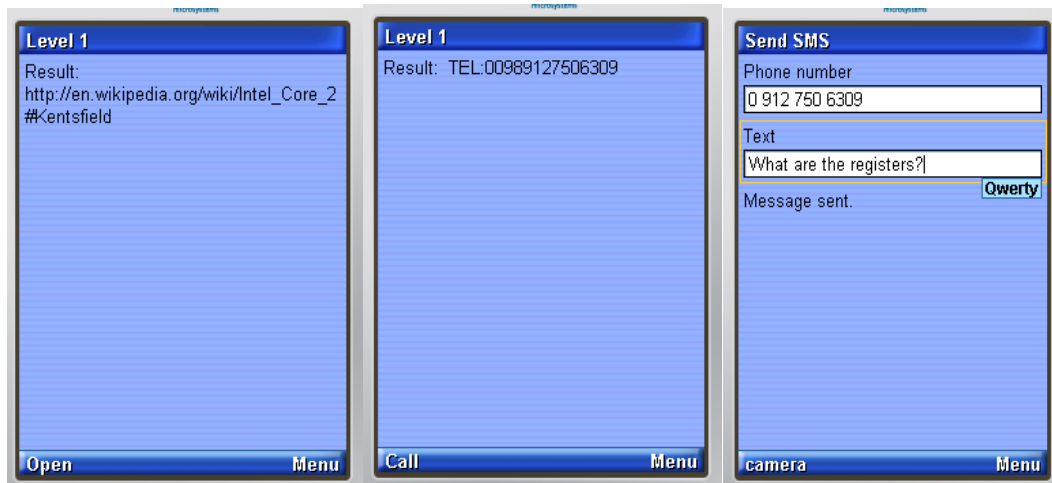


Figure 6.11 QR decoding results when guiding the player to (a) an appropriate web site for browsing, (b) an expert’s telephone number (c) an SMS to a knowledgeable person.

6.4.3.5 Game navigation

Navigation between different game’s screens is clear, simple, consistent and straightforward. It uses directional keys and does not trap the players in certain section of game. Hierarchical level of branched screens is minimal and is maximum two screens away from the main game. Idle screens are avoided. They all return back to their previous state and finally to the main game environment. The navigation system used is shown in Figure 6.12.

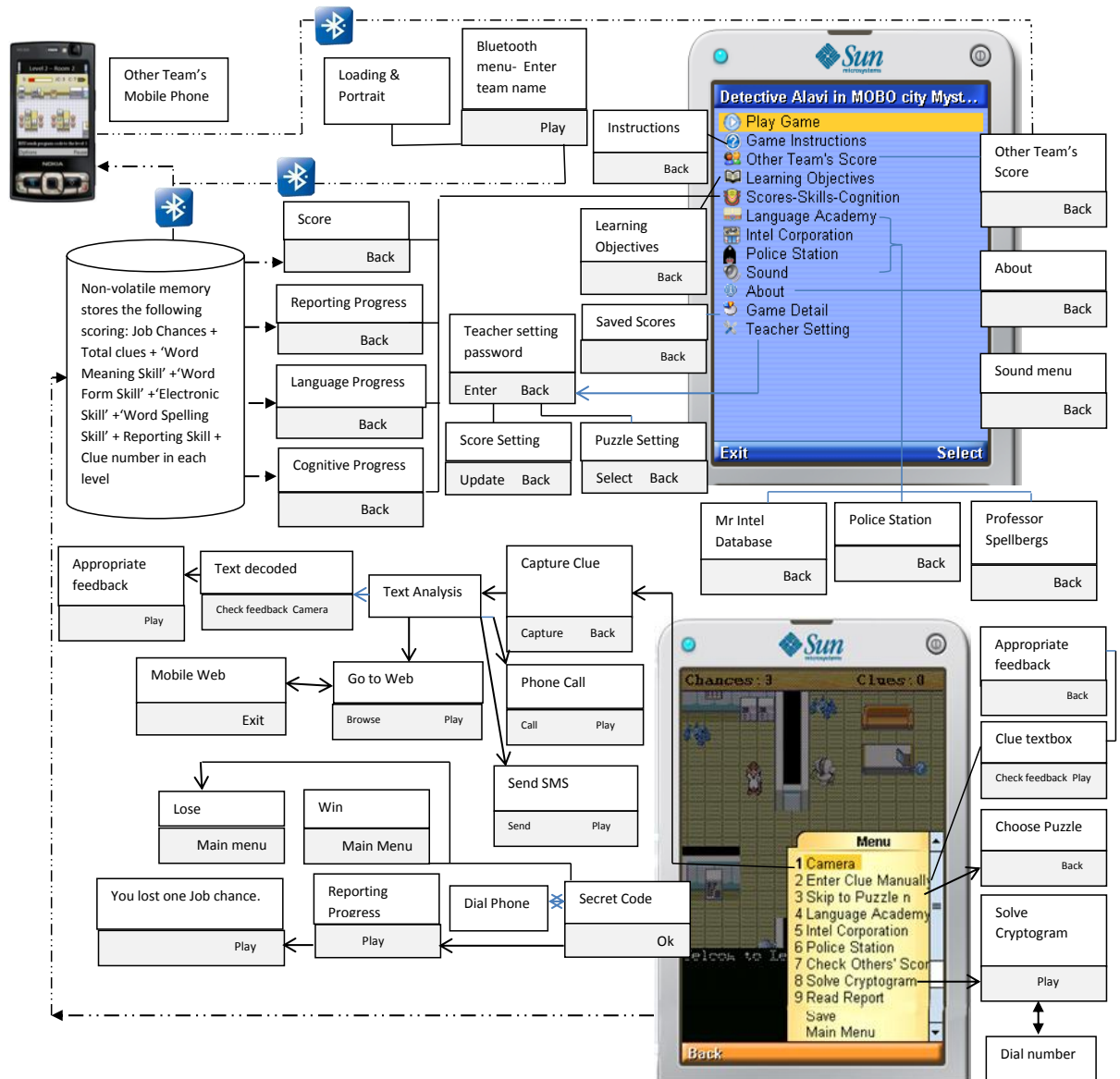


Figure 6.12 The Detective Game's navigation system.

6.5 Instructional Factors in Detective Game

In this section we discuss how Instructional factors are integrated in the design of the Detective game.

6.5.1 Knowledge type

Factual knowledge about CPU elements such as *Data bus, cache, bus interface unit, branch target buffer, fetch/decode unit* in level 2 are introduced and the meaning and spelling of the most important vocabularies such as *manipulate, operate* or *execute* are learned (see Appendix C, section C7-C9). *Conceptual knowledge* such as the 'order of operation in different CPUs' in microprocessors *Intel* and *Athlon* is available in puzzle 10 (see Appendix C, section C.10) and puzzle 12 (see Appendix C, section C.12) are taught. Concerning *Metacognitive Knowledge*, learners are aware of their own knowledge and by applying strategic and reflective approaches they are able to solve problems such as '*the memory-addressing capabilities of processors*' in puzzle 16 (see Appendix C, section C.16) or realize the technical functions of '*Multicore processors*' in puzzle 18 (see Appendix C, section C.18).

6.5.2 Goals and learning objectives

The overriding goals are provided in the introduction. Intermediate goals can be read at any time if the learner needs, for example in level 4 when the learner chooses 'Learning Objectives' from the menu they are presented with : Clock speed, Data Width, MIPS, CPU speed and width, memory-addressing. Educational objectives are categorized in the five levels according to

remembering, understanding, applying, analysing, evaluating, and creating cognitive processes. These are mapped into five levels of the game. The learning objectives of each level are as follows:

1. **Remembering:** objectives for recalling or remembering the meaning of the most important vocabularies (see Appendix C, section C.1-C.6).
2. **Understanding:** objectives for grasping the concept of the 'CPU order of operation' and further familiarity with important vocabularies through examining their shapes and spelling in a QR word search (see Appendix C, section C.7-C.9).
3. **Applying:** objectives for using the information about the CPU operation in a new way for Intel Pentium 4 and Athlon processors. Moreover synonyms of most vocabularies that are learned so far are examined in a Bingo like game. It requires special attention to spot the correct vocabularies (see Appendix C, section C10-C12).
4. **Analysing:** objectives for distinguishing between the different parts of a vocabulary to become acquainted with word forms through a board game. The tables from the Intel processor specification must be analysed to solve problems (see Appendix C, section C.13-C.16).
5. **Evaluating:** objectives for making decisions based on in-depth reflection, criticism and assessment about word forms and complex CPU operations (see Appendix C, section C.17 and C-1.8).
6. **Creating:** objectives for creating a solution to a very complex cryptogram and writing reports from each stage of the game play for presentation to the teacher. The report is part of the game play and it is an account of the occurrences and events in the game that Detective Alavi writes for

the Chief Constable. The ‘creating’ cognitive progress is examined at the end of each level (see Figure 6.13).

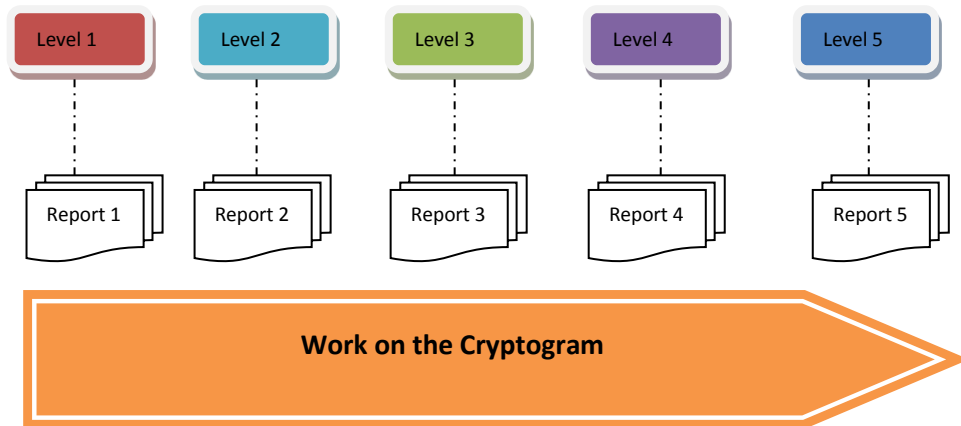


Figure 6.13 Integration of ‘Creating’ cognitive process in the game structure

6.5.3 Game rules

In contrast with the games discussed in Fotouhi-Ghazvini et al. 2009 (b), the virtual world of the Detective game contains restricted rules for the learning objectives to be achieved. Semantic information is distilled precisely from real life through the QR decoder which is incorporated into the game structure. This is unlike the raw, partially formed material of the games in Fotouhi-Ghazvini et al. 2009 (b). This technique helps to prevent a potential clash of rules between the physical world and the virtual world.

There is always a JobChance option available in each room in the game, if the player needs to guess the cryptogram and finish the game early. If the players guessed the cryptogram at lower levels, then the player will win the game but his job ranking will only increase by one. For example if the player guessed the cryptogram with 31 clues found, his job ranking rises from “Chief Superintendent” to “Assistant Chief Constable”. This will encourage players to try all the game levels and find as many clues as they can to increase their job

rank. At the same time it provides a technique for players to end their game whenever they want. Three incorrect guesses of the cryptogram will result in a player losing the game.

6.5.4. Game levels

There are 5 levels designed according to the remembering, understanding, applying, analysing, evaluating and creating cognitive processes, which are responsible to improve player's 'word meaning skill', 'electronic skill' (i.e. knowledge of CPU), 'word form skill' and 'spelling skills'. These skills are expected to be acquired through the conversations takes place between the player with game characters and solving the puzzles.

6.5.5 Different puzzles

In contrast with the view that mixed reality games must be one big puzzle (see Fotouhi-Ghazvini et al. 2009 (b)) the Detective game consists of many small puzzles. Each puzzle leads the player to a specific clue through interaction with the puzzle and one learning object from the category of 'meaning', 'spelling', 'form' and 'electronic' is inspected. The variety of different puzzles from simple multiple choices, the word search game, the board game, and the snake and ladder game to problem solving games are incorporated in the structure of main game.

6.5.6 Appropriate challenge

Challenges and puzzles relate to the learning objectives in each level. Each puzzle is presented after the necessary information is accessed by the player.

The challenges are gradual. They start by simple multiple choices, then they change into games that need group work to solve them, and towards the end there is a complex situation to understand and all the puzzles lead to a challenging cryptogram to decode at the end. The level of challenge increases as the learner progresses through the game and this will increase the learner's confidence and self-esteem, if they succeed at each level. The Detective game stimulates the recall of prior knowledge and refers backs to things learned before, for example:

In level1, puzzle 1 examines meaning of the verb "*manipulate*" via a multiple-choice question. In the following conversation with a virtual character the meaning of the noun "*manipulation*" is introduced which represents an "*act of manipulating*" and this will help students to become more familiar with the derivatives of the verb "*manipulate*". Once more at level1, puzzle 3 examines meaning of the verb "*operate*" via a multiple-choice question, but in practice it includes the verb "*manipulate*". In addition, each puzzle QR contains an extra guide to the meaning of the verb. This repetition and practice will help to embed the knowledge and provides the learner with the ability to use the information habitually and consistently.

6.5.7 Semantic information

This game can access a number of different information repertoires and extract the necessary semantics from real space, mobile space or cyber space. In Detective Alavi semantic information are '*real space textual semantics*', '*cyberspace semantics*', '*mobile semantics*', '*real space location semantics*' and '*virtual space semantics*'. The *cyberspace semantics* are in the form of

graphic, audio or text from a Web site. For example, if learners give incorrect answers first time around, they are free to use hints via QR tags incorporated in each puzzle. For instance in puzzle 10 learners can access an article from a website about Pentium 4 Architecture, and the QR tag contains the following URL: <http://www.hardwaresecrets.com/article/235>. The *mobile semantic* is in the form of audio or text from a telephone conversation or an SMS. For example, in puzzle 12 learners can send an SMS to an Athlon CPU expert's mobile number, with a maximum number of characters of 160. In puzzle 13, 15 and 16 learners can make a call to a CPU expert's mobile phone (see Appendix C). *Real space textual semantics* are the game clues and knowledge chunks. For example in puzzle 3, the mobile phone camera captures a certain QR tag that contains '*Function. act, function; manage, use*' text. The word 'function' is our real space semantic; the rest of the text is only for giving hints to students and is discarded. The word 'function' is compared with array of strings in the game space. If the answer to puzzle 3 is 'function' then a suitable output is shown for the learner to show that knowledge has been acquired otherwise a feedback is deduced for wrong answer. *Real space location semantics* is extracted using Bluetooth. The Bluetooth of each mobile phone uses device discovery process and service process to access the location and game data of other device. *Virtual space semantics* is the game scoring system that is used to assess the cognitive progress and language skills of the learners.

6.5.8 Game communication capabilities

This game is played between two groups of students, where they compete against each other. Each group could have up to three members which

collaborate with each other. Each group members have different capabilities in '*meaning*', '*spelling*', '*forms*' or '*electronic*' skills. One N95 Nokia phone is provided for each group. Inside a group, the phone is carried out by the person in the middle, so all three will be able to view the process of the game. For example, puzzle 11 comes in 3 sheets (Appendix C, section C.11); each sheet of puzzle belongs to one of the team members. Clues are distributed among all three members, consequently they have to work together to find all of the clues. Each sheet contains 20 vocabulary spaces and their equivalent QR code, hiding 4 clues. In the puzzle 14 learners must find a compound word from the vocabularies and suffixes given in the table provided. This puzzle comes in 3 sheets (see Appendix C, section C.14); each sheet of puzzle belongs to one of the team members. Clues are distributed among all three members, consequently they have to work together to find all of the clues. Each sheet contains 4 hidden clues.

There are three possibilities for interaction or conversation in the game. One possibility is for the game to take the place of the teacher as in traditional schools. It introduces conversational possibilities with the help of a virtual expert character. The second possibility is for the game to provide an environment that facilitates conversations between learners, and also learners with real teachers who are located at a distance, through the use of QR puzzles.

The student can discuss problem solving plans with other member of team who direct, inspire, disapprove, and guide the student in the direction of enhanced understanding of the topic in question. They can also use SMS, and phone calls to connect with people that are not in the same physical vicinity. This collaborative learning environment develops higher level thinking skills;

stimulates critical thinking and fosters metacognition in students (see chapter 8). In the Detective game, interaction supplies learners with the opportunities to discuss and obtain feedback when the other members of the team reply, give the correct solution, or ask for further explanation. This allows learners to “notice the gap” between their own knowledge and that of their partners.

6.5.9 Game competitive features

When one team starts the game, the device searches for other devices that are running the same game. When the other team is found, their status becomes online. During the game scores are sent to other team. Other players are able to recognize and appreciate the learner’s accomplishments. The process of playing the game is visible to all members. This creates the feeling of being there with many other people.

This sense of involvement, even presence, facilitates the learning process. Evidence for this has been found by Welch (1999) and Mantovani and Castelnuovo (2003) and others, and is reflected in the way that flight simulators are used to train aircraft pilots to certified levels of proficiency identical to those required in real aircraft.

6.5.10 Game help menus

In the introduction the player receives a view of MOBO city, speaks to Inspector Focus and lady Watchful, and receives letters from the Chief Constable and the mysterious villain to explain the game story, its purpose, the method of play and the challenges ahead. It can be skipped in the second round of game play.

There are three screens that provide help, but they are not called help.

They possess thematic names as follows:

1. 'Staff Database in Police station', which provides a data base of CPU characters, their work experience, personality, research and interest.
2. 'Professor Spellberg's Database in Language Academy': It consists of all important vocabularies and their meaning in Farsi and English.
3. 'Mr Intellectual's Database' explaining all the game's technical terms

There are other menus for using Bluetooth and QR code which is discussed in the next chapter.

6.5.11 Game feedback

Feedback is provided in many ways, including scores, displays, and verbal feedback. Learners are notified when the goals or mission objectives are completed. For example 'Well done!' when the answer to a puzzle was correct and 'Sorry you missed the clue' when the wrong answer is given. Learners are able to check number of clues gained for each specific level and skill (see Figure 6.14). The feedback for each incorrect response supplies a small piece of extra support for the learner as they carry on trying to work out the correct answer. This extra feedback comes from the QR text content. Feedback helps the learner to become aware of the reason for their answer being wrong, and gently guide them in the correct route.

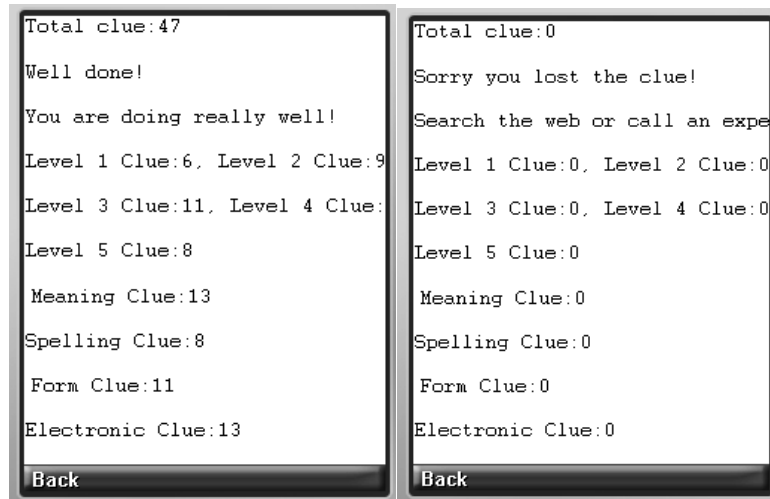


Figure 6.14 (a) Feedback for the right answer (b) Feedback for the wrong answer.

6.6 Motivational Factors in Detective Game

In this section we discuss how we have integrated motivational factors in each level of the Detective game.

6.6.1 Game genre

The adventure format of an educational game has been developed. It is a role-playing game wherein the player takes the position of a detective within a fantasy setting of the CPU. The player is in charge of his character and is able to make the character walk in the game environment, and examine and act on things he comes across. The character is able to hold a conversation with other characters in the game. The game challenges are mostly composed of puzzles to be answered or concealed knowledge chunks to be discovered. There is no need to set the reaction time or take quick decisions. Time is mainly spent in carefully looking around and inspecting the environment. Place and context are two most important points in the game. The game is built upon a series of

connected physical contexts such as office rooms in the CPU complex. In each room a set of tasks need to be accomplished.

6.6.2 Game story

The game's electronic content for creating conversations is from White (2008). In this game, the story is a natural form of communication which supports the construction of meaning. Narrative captures possible relations among the elements of the CPU. As Bruner (1990) explained, narrative is "*a unique sequence of events, mental states, happenings involving human beings as characters or actors: these are its constituents. But these constituents do not, as it were, have a life or meaning of their own. Their meaning is given by their place in the overall configuration of the sequence as a whole- its plot*" (Bruner 1990, p.43).

Unlike typical game discussed in Fotouhi-Ghazvini et al. 2009 (b), the Detective game is fantasy based. In real life it is not possible to see inside a CPU, it consists of millions of microscopic transistors. In our game, we designed the CPU as a large complex, with specialized staff and transistors as robot workers. Robots stopped working and a detective is called to investigate why. Detective Alavi is very competent, he is invited to solve this mystery and if he does so he will be recruited into the police force with a job rank as high as 'Chief Constable'. His skill to interview different people in CPU is very important; he has to carefully pay attention to his conversation with suspects. In the conversations he could discover clues to puzzles scattered around the CPU complex. The source of these puzzles is a mystery; he/she left a letter explaining that he is responsible for transistors malfunction. A complex

cryptogram must be solved in order for the CPU complex to return to its normal functions. Each word in the cryptogram corresponds to each puzzle's solution. The more of the puzzle that is solved; the more detective Alavi is closer to solving the cryptogram. The mysterious person has left a phone, which is able to capture the clues of cryptogram, search the web, and send and receive an SMS or phone call. The phone is incorporated into the design, because the use of QR codes could be easily integrated into the game and the flow of the game is preserved. The story provides appropriate metaphors for linguistic and technical learning and has a crucial role in the material to be learned. The story is relevant to the learner's knowledge at each level and slowly increases in complexity.

6.6.3 Game characters

The main character of the game is detective Alavi. He was a famous detective in a TV show. Students are familiar with him and can relate to his character easily. There are characters such as the retired chief constable, detective Alavi, inspector Focus, and a police officer, that weave the story together and make it into a detective game. There are characters that represent language learning aspects of the game like Professor Spellberg who has created a database from the CPU complex's important vocabularies. Other characters such as Mr Intellectual, Lord Buffer, Mr Registrar, Mr Cryptic, Mr Inspection, Dr Intel, Dr Athlon, Professor Speedfast, professor Multicore provide a sense of realism in the game. These characters have interesting backgrounds and work experiences, for example professor Speedfast is an old lady who is a master of

kickboxing. Her life time ambition is to raise the speed of the CPU clock so that the CPU can work faster.

There are characters that remind us of unusual people in a detective story such as Lady Watchful and Miss Precisely, for example lady Watchful is one of the CPU complex's senior staff. She acts as an amateur detective in her spare time and lives in the village of St. MOBO.

There are characters with suspicious personalities such as Mr Fraudulent and Mr Safeguard, for example Mr Safeguard used to live in Britannica city, but nobody knows about his past. He has passed his training excellently. His love of words motivated him to help Professor Spellberg and Mr Intellectual to build an excellent vocabulary databases. He is now in charge of protecting the complex from intruders.

Characters such as Dr Binary and Mr Shortsighted act as prime suspects in this game; Inspector Focus believes the CPU complex's disruption is their fault. Players can search for their profile and discover that inspector Focus is incorrect in his judgment, for example in Mr Shortsighted's profile in the police station it has been recorded that he has been trained in the Intel Corporation to become a competent robot technician. His tutor believed he will be a trustworthy and hardworking employee.

All these characters with different personalities and characteristics create important elements of an engaging detective game and help players to become absorbed in the game story.

Mr Alavi's character job rank increases as the learner progresses through the game and acquires new knowledge. The character's dialogue is in the form of conversation. It is thematic, concise and to the point.

6.6.4 Game graphic

The players' sensory curiosity was aroused by using Pokemon's two dimensional graphics. These graphics were carefully chosen to depict an office, with each room containing chairs, desks, libraries, books, piece of papers, PCs, laptops and items that could be called transistors. Then the graphics have been converted to a tiled layer (i.e. game background) to be useable for the mobile game canvas. The cognitive curiosity of players was aroused by stimulating the information seeking of the players in the conversation with the virtual characters, and in discussions and solving puzzles.

6.6.5 Real world experiences

The player has a chance to play with other team members and compete against other group. They can also ask questions from their own teacher or contact an expert via a telephone call or an SMS.

6.6.6 Game control

Navigation between different menus is easy and they have to simply choose the desired option from the menu. The QR decoder and Bluetooth discovery have been integrated into the game structure to increase the sense of flow. The options available to the player during the game, and the places that Mr Alavi can pay a visit, are 1- "Language academy" to refresh his language skill by the

help of professor Spellberg, see Professor Spellberg's database, 2- "Intel Corporation" if he needs to answer "electronic" puzzles, see Mr Intellectual's database, 3- "Police Station" and read about the current staff's profile, staff database at the police station.

In this game all the puzzles are printed on the sheets of paper and given to students, consequently the QR codes are all placed on the desk. However there is no limitation on placing the QR codes at different locations in the building and providing learners with a map to find them. Figure 6.15 (a) shows the application using QR tag in an outdoor setting.



Figure 6.15 (a) Scanning a QR Code to retrieve information (from Rouillard and Laroussi 2008) (b) Giant snake and ladder game (Giant Snakes and Ladders 2008).

Additionally the board games in puzzle 11 (Appendix C, section C.11) and 14 (Appendix C, section 14) and the snake and ladder game which are integrated with QR tags can be used in an outdoor context. The players can actually walk through them and whenever they need to capture a tag they can point their phone camera towards it. Figure 6.15 (b) illustrates the use of QR tags in outdoor games.

6.7 User Interface Design Factors in Detective

Game

This section discusses the design considerations in the Detective game which will be published in Fotouhi-Ghazvini et al. (2011 c). There are eight principles that have been extracted from well-established user interface design guidelines that are widely used for desktop computers. Approaches are proposed with regard to how to utilize these strategies in mobile educational games. Principles summarised in 6.7.1, 6.7.2, 6.7.6 and 6.7.8 are set out in Nielsen (1994); 6.7.1, and 6.7.3-6.7.8 are set out in Shneiderman (2004); and 6.7.2, and 6.7.5-6.7.7 are set out in Stone et. al. (2005).

6.7.1 Consistency

An appropriate balance is maintained between the size of the game characters and the size of the background objects. Players see an overview of a scene in order to understand their position at all times. Game background, characters and text are chosen in proportion to the screen size of the phone. The foreground stands out from the background. The background is not too busy or too empty with unused blanked spaces. Dialogue, commands and the main game view are clearly distinguishable from each other and there is sufficient contrast. The game interface, graphics and characters are consistent with the physical environment within which the story is taking place, for example office rooms in a building complex. Different screens such as forms, lists and canvases have the same feel. They are all scrollable and they make it possible

for the players using mobile devices with any screen size to view the screen's content. Consistent sequences of actions are required to speak with game characters and access the main menu, Bluetooth, QR, web, phone calls or SMS. Identical information is linked to the same interaction throughout the games, for example whenever the player selects 'play', he/she will be transferred to the main game canvas to play. The capitalization and fonts are kept consistent. This helps to avoid a player's confusion with regard to the meaning of different words and also makes the game easy to play and remember. The game environment depicts an office in the Detective game and these representations match the virtual world with the real world that the players experience in a real building, and follows 'real world' conventions.

6.7.2 Aesthetic and simplicity

The interface was kept as simple as possible. The common tasks such as accessing the camera, capturing the QR tags and updating the scores in the Bluetooth menu simply require the user to select the option 'camera', 'capture' and 'update'. These words were kept natural and as short as possible. Dialogue between virtual characters did not contain irrelevant text, in order to increase the visibility of the relevant text.

6.7.3 Shortcuts

The QR codes decreased the number of operations needed to access, enter, search and activate certain actions. The use of Bluetooth for the automatic sending and receiving of the game data helped the players to concentrate on the game play while keeping an active connection with other devices. The

option menu situated in the main game canvas allowed players to access the game camera, search the device's resources, check other team's scores, read a report to a distance teacher, save the game, and go back to the main menu. The player's score and cognitive progress were preserved when they moved between different screens.

6.7.4 A Response for every action

The player is always kept aware of their scores, language skill progress, cognitive progress and reporting skill progress. This helps the player and the teacher to remain informed and up to date about the academic progress of the player. In less powerful mobile environments, exotic graphics are avoided during the feedback to keep the size of the application manageable. However it is important that for every action there must be a response to the player to indicate that progress is being made. The Figure 6.16 (a) shows a progress page when the game is loading Figure 6.16 (b) shows when the player selects to move to certain puzzles Figure 6.16 (c) is displayed to assure the player he/she actually reset the game at certain level, Figure 6.16 (d) shows when an SMS is send a 'Message Send' text will be displayed on the screen, to confirm the SMS was send. Depending to the screen type the feedbacks often could be displayed on the same screen as the action taken place or separate screen. In Figure 6.16 (b) the screen has the 'list' format and only allows selecting items, but figure (d) represents a 'form' type screen that can actually hold variety of different elements.

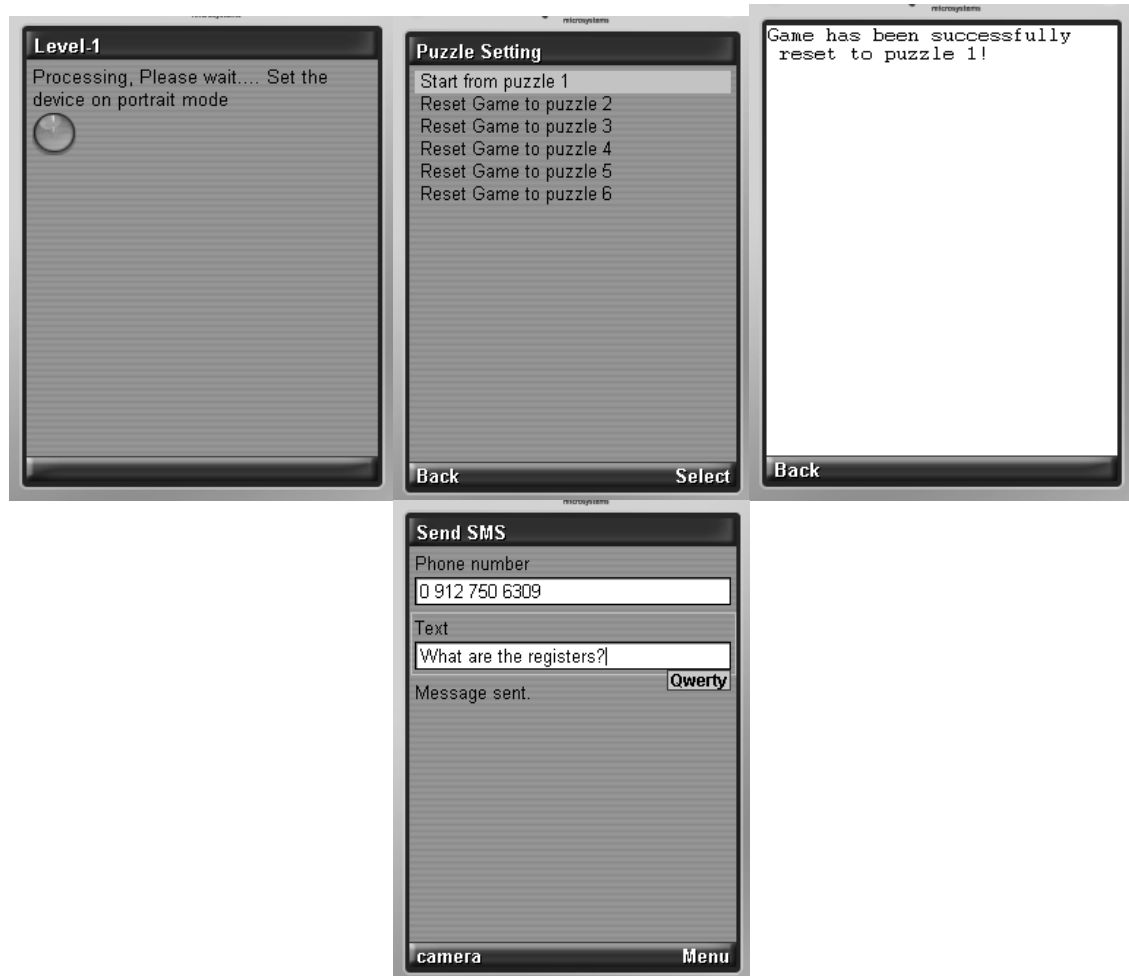


Figure 6.16 (a) Game loading progress page (b) Puzzle setting (c) Feedback to puzzle setting (d) Send SMS screen

6.7.5 Logical grouping of tasks and yielding closure

Similar options were kept close together. In 6.17 (a) 'Camera' and 'Enter Clue Manually' are adjacent to each other, and both are used to input the clues to the device - the first one automatically by a camera and second one by typing it manually into a text box. 'Language Academy', 'Intel Corporation' and 'Police Station' are kept close to each other, because all of them help the player to access more information about the game. This helps the player to achieve their goals and find information more quickly. When each option is selected a series of actions takes place that contains a beginning, middle, and an end. For

example, to capture a clue from QR tags and return, the series of actions are 'Camera', 'Capture', 'Check Clue' and 'Camera'. The first 'Camera' option begins the capturing process and the second one ends it and returns the player to where they started (see Figure 6.17 (b), (c) and (d)).

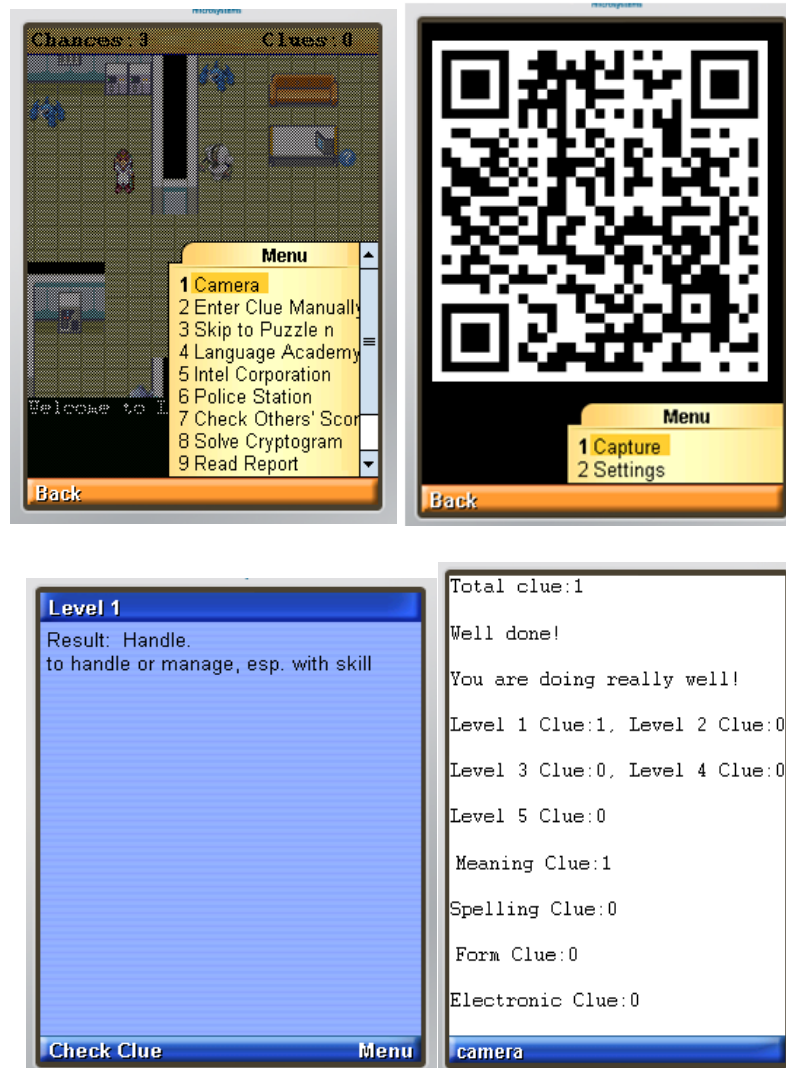


Figure 6.17(a) Game option menu, (b) Capturing a Clue (c) The captured clue (d) Feedback on the clue.

6.7.6 Error prevention and simple error handling

A main source of errors and indeed tedium for mobile players is in inputting text data. The use of QR codes reduced this problem considerably. However if at

certain instances it was necessary to enter data, precautions were taken such as lists being used as much as possible to enter the data. If a telephone number needed to be filled in a text box, only numbers were made available, thus avoiding the need to scroll through alphabetic characters. Mobile devices often encounter unexpected errors in the processing of applications. The devices are especially prone to errors when trying to extract contextual data from the environment. When the mobile phone was seeking to capture the QR tags it could produce a decoding error. These errors were predicted during the development process and it was explained to the player via the game environment that 'Decoding failed! Please try again' and an alternative way to enter the data was provided. In this situation, the QR content could be entered manually to the game so that the player did not feel loss of control see Figure 6.18.

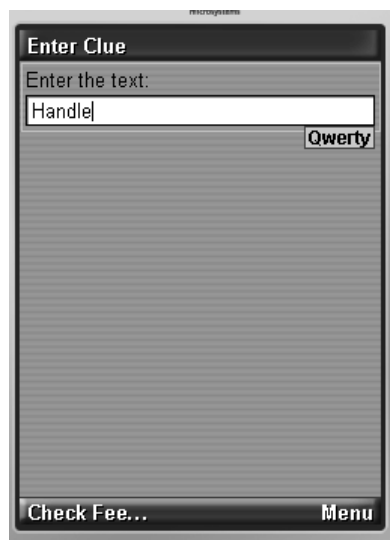


Figure 6.18 Manually Entering the Clues.

6.7.7 Tolerance and reversal of actions

In the main game environment the player was able to jump to any puzzle by selecting 'Skip to puzzle n'. This option activated all the necessary resources to run that specific puzzle. Players had the option to capture the QR puzzle as much as they desired. Mobile devices are prone to unexpected events, such as the camera not capturing a good enough image, or the QR decoder could fail, or a telephone number could be busy, or an SMS could fail to send, or the network connectivity to the internet might fail. Restricting players too much could cause disappointment and loss of interest. If players accidentally exited the game without saving the current state, or the device encountered a crash, the teachers could enter the player's scores in 'Teacher Setting' so the player did not need to repeat all the earlier games (see Figure 6.19). This option was password protected so that it could only be accessed by the teachers. These features overcame the anxiety of the players significantly.

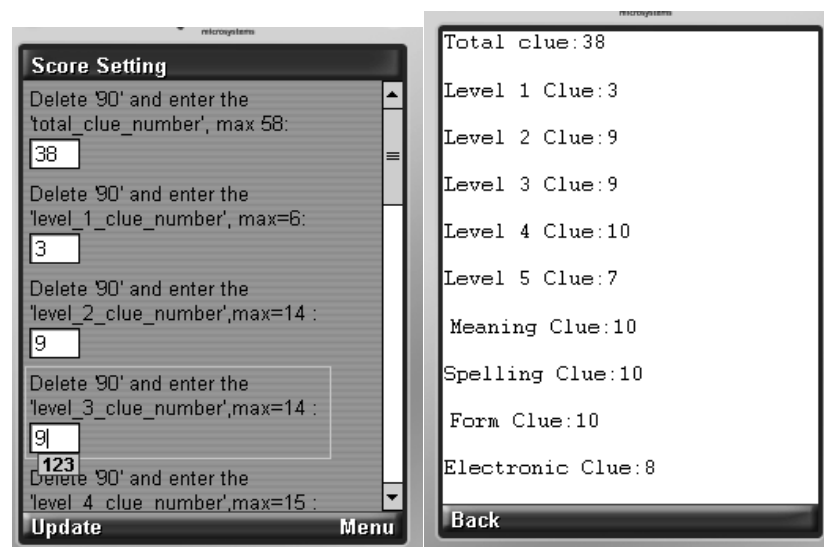




Figure 6.19 Teacher Setting (a) for changing scores (b) feedback after changing the scores (c) changing the puzzle setting (d) feedback after changing the setting.

6.7.8 Internal locus of control

The navigation is designed to be simple and understandable. The player always starts from the main game canvas and after executing some actions, such as solving a puzzle, they return to the main game canvas. User testing has demonstrated that the player knows at any time during the game where they are and where they can go. Different stages were implemented to help the player change focus from the game whenever they felt it was necessary. During the game if the 'Application key' on the mobile phones's surface is pressed, the application is paused automatically and switches to the background. If there is a phone call, text message or battery warning, then the game pauses automatically. Additionally, the pause command in the game interface provides the player with a control over the game environment in the case of external social interruptions. The characters stop moving, the music stops and the game no longer accepts keypad input. The 'Pause' command is

changed by the 'Resume' command. Players could return to the game play by pressing the 'Play' command.

On the other hand, if it was necessary for the player to leave the game for a significant period, they could quit the game. The save capability is available, so the next time the player returns to the game they haven't lost their data and they are able to resume from where they left off. The number of clues discovered and cognitive progress are stored in the non-volatile memory of the device. Although these features are standard to many modern computer games, achieving these within the limited capacity of the devices can be difficult. However these features are very important to ensuring continuity of user experience and to ensure learning isn't adversely affected by technical frustrations.

6.8 Mobile Educational Games and Diversity

One of the important elements in the design of a user interface is to recognise the type of user who will be using the system. Are they novices or experts? Do they have any cognitive impairment? Do they have any disabilities? Do they have any special preferences? In desktop designs it is possible to design two sets of menus on each screen, one with extensive help and the other suggesting shortcuts. Due to the small size of mobile devices screen this approach will result in an overcrowded and confusing screen layout. One possible solution is to divide the game into different sections. In Detective Alavi the players start with an introduction that explains the game story for the novice. The game itself is divided into 5 levels starting from easy to difficult in a hierarchical manner. This structure allows the expert user to skip the easier

levels quickly and concentrate on harder levels. The slow learner often benefits from deconstructing the overall tasks into smaller tasks. They can then concentrate on one task at a time. It is also possible to decrease the intensity of the challenges within each level. In a previously published mobile game i.e. MOBO city I it was possible to increase the initial values of the life points and decrease the number of viruses in each level to allow more time for players to consider what their next move could be. It is possible to remove the penalty when players visit the incorrect station in MOBO city in order to increase the self-confidence of slow learners. The level of feedback and detail at each location can be increased or decreased. In MOBO city II, the sequence of the operation can be removed to allow players to concentrate solely on text and iconic figures.

The automatic input of data by using QR tags significantly reduces the cognitive burden of the games. Automatic assessment can help the learner to build self-awareness. The assessment of the rate of progress could be changed for each individual learner in educational games. For example, if a slow learner scores 12 clues and a fast learner scores 23, they both receive the same amount of praise from the system. Providing one to one assistance via mobile phone calls and SMS could also help learners with social difficulties.

Additionally, the Detective game can work in muted mode. Although the audio enhances the game experience, the game play does not depend on sound. Learners with auditory difficulties could significantly benefit from these games. All the communications via the mobile phone calls could be replaced by SMS. The classroom interactions with teacher and other teams could take place in a chat environment. This feature could easily be incorporated into the

game play. A Bluetooth chat environment could be connected to the game interface and the learners could check any feedback from the menu option ('other team's score') in the main game canvas.

Specifically considering female players, mobile games developed in this research could introduce a friendly environment which is not time-limited nor needs previous game playing skills. This helps females to build their game play competency and confidence. In contrast to most video games where women are under-represented, these games have an equal number of male and female characters. Characters do not behave in stereotyped or hyper-feminine ways with an emphasis on dependence or submissiveness. One prominent feature in Detective Alavi is social interaction between the players, and players with characters. User testing has shown this is viewed very favourably by female students.

6.9 Conclusion

This chapter presented a design methodology by introducing the descriptions of four different kinds of educational mobile games and three important factors namely instructional, motivational and user interface design. The instructional factors could be incorporated in the game structure by considering the learning objectives in the game story and the game play. Moreover the game rules must be precise for puzzles and challenges in different hierarchical levels. The contextual environments must have communication capabilities. The motivational factors depend on the game genre, and a good realistic story with novel characters and interesting graphics. The user interface was consistent with the use of simple language, designing appropriate responses to the

actions, grouping similar tasks, and appropriate and supportive error handling and recovery. The diversity factors were also important for teachers with learners having differing abilities and capabilities. By removing time constraints, incorporating simple language, removing irrelevant information, and increasing guidance and assistance, teachers were able to involve all their students in the game-based learning process. Electronic, pedagogic, and social connectivity are the keys to success.

Chapter 7

Implementation of Mobile Educational Mixed Reality Game

7.1 Introduction

Most Nokia, Samsung, LG, Research In Motion, Sony Ericsson and Motorola devices have the Java Virtual Machine installed on them and support Java 2 Micro Edition (J2ME) applications. Each type of device not only supports J2ME's native Application Programming Interfaces (APIs) but it also has extra APIs specific to its manufacturer that help to build an application with an improved user interface. A large number of devices are currently in circulation that run J2ME and it is deployed more than any other platform. J2ME applications which are built using the Limited Connected Device User Interface (LCDUI) work on many low cost mobile phones in developing countries. These phones often use a slider or bar design with a keypad to input the data, which is often the primary function of a mobile phone in developing countries. Consequently most J2ME applications use the keypad to input data and they are usable with a small screen. J2ME is open source so there is no software

licensing cost associated with developing fully-featured applications such as games. There are also free powerful development environments such as Netbeans IDE. Applications are fairly easily installed on devices either via wireless or via Bluetooth. No 'jailbreaking' is required to install 'unapproved' applications. It is advisable for developers, especially in poorer countries, to invest in developing their applications using J2ME to target the mass market and the largest possible range of consumers.

Two platforms that do not support J2ME are Android and iPhone OS. Apple has introduced iPhone OS which has a generally superior 'form factor' such as a bigger screen with a multitouch capability which provides a more satisfying user experience. It is ideal for much web browsing and those games which require larger screens in order for the content to engage the user, however, it is deliberately differentiated from other mobile environments in accordance with Apple's usual business model. Porting the present game to this environment would thus require significant reworking of the software: this is not overly challenging, but has not been a priority in the present work.

Different device manufacturers such as Acer, HTC, Google Nexus, LG, Motorola, Samsung and Sony Ericsson have started using the Android OS, which was developed by Google from 2009. Android's services and touch capabilities are similar to those of the iPhone. Different versions of Android OS (1.5, 1.6, 2.0, 2.1 and 2.2) have been published relatively quickly and hardware configurations vary considerably from device to device. Considering only dozens of these phones have been released to the public, Android suffers from significant fragmentation and this makes the developer's job time consuming,

with bugs that are not produced in emulators. The main route of Android applications' distribution is the 'Android Market' which is available via the 'Market' application in the Android phone. The Android market provides both free and subscriber applications as well as allowing the developers to sell their applications. The market checks the phone's carrier, IP address, GPS and WiFi data and limits its services to certain countries. For example only developers in Australia, France, Germany, Italy, Japan, Netherland, Spain, UK and US are able to sell their applications through the Android market. The applications themselves are not accessible in countries which face economic sanctions. Therefore even though the Android's market penetration is high in countries like the UK and US, it is very small in most other countries (http://en.wikipedia.org/wiki/Android_Market).

Apple on the other hand has ultimate control over its hardware and software. It has only released high end devices (iPhone, iPhone 3G, iPhone 3GS and iPhone 4) and tries to be the 'premium' product to achieve a better user experience and avoid fragmentation. The user must download applications through the App store and unlicensed third party software that does not have the Apple cryptographic signature is not able to run on the iPhone, except by changing the OS by 'jailbreaking' and infringing Apple's copyright. Developers must pay a \$99 a year to publish their applications on the Apple App store. Mobile carriers often offer SIM-locked versions of iPhones such as the UK's Orange or Vodafone at a cheaper price with monthly instalments which include buying their mobile services. These deals often are only available via Apple's approved carriers which often do not include country-specific mobile

carriers. The full retail price of the iPhone in its SIM unlocked version is very expensive (see Table 7.1.)

Table 7.1 Different smartphones' prices from <http://www.shop.ir/>. (15th August 2010)

Phone Models	Price in GBP
Nokia N95 (JAVA enabled)	244
Nokia 5530 XpressMusic (JAVA enabled)	134
Apple iPhone 4	932
Apple iPhone 3GS	611
HTC Desire (Android OS)	475
Sony Ericsson XPERIA X10 (Android OS)	373

7.2 Java Portability to other Platforms

The Java language is designed to be platform independent and this factor facilitates its portability. However J2ME applications often need modification to be able to run in different Java enabled handsets. Each year hundreds of different mobile phones are released, each with a different set of J2ME APIs, memory, processing power, camera resolution, OS version and user interface. There is no single agreed standard. Developers have to produce an application that uses basic J2ME APIs and is able to run on most devices. However they can make additional improvements to the game using each device's particular properties, and adding new features and improvements to each device independently. Each device requires individual testing and adjustment but more than 90% of the coding remains the same and can be reused.

When a J2ME application is produced it is able to be modified for Android and iPhone applications. J2ME to Android is possible using two tools –

- MicroEmulator (<http://www.microemu.org/>) which is open source and produces pure Java codes
- Netmite (<http://www.netmite.com/android/>) that does not change the source code but produces a J2ME MIDP Runner for running J2ME applications.

J2ME applications can be changed into iPhone applications by using alcheMo (<http://www.innaworks.com/alcheMo-Benefits/>). However iPhone 4 prohibits any ported applications such as Java and Flash. It only allows applications written originally in Objective-C, i.e. the iPhone application's programming language (McLean 2010).

7.3 Advantage of J2ME

J2ME offers a variety of different APIs that make implementation of mixed reality games possible in mobile phone such as game API, Bluetooth API, Location API and Media API. At the same time J2ME provides high security. A J2ME application cannot affect other applications in the device and it cannot crash the device. The application cannot use the hardware resources directly, for example it cannot send an SMS, make a phone call or connect to the internet without the user's permission. This avoids virus infection and helps to protect the device.

J2ME program codes are compiled to bytecode class files which are in binary format. The codes' compilation is finalised using a Java interpreter with the name of 'Kilo Byte Virtual Machine' (KVM). It interprets instruction sets into commands when the Java game needs to be executed. KVM provides a compatibility layer with any hardware, and Java games could run on devices

with different electronic components, maximizing the portability of the application.

7.4 Disadvantage of J2ME

The J2ME database system is very primitive as it only uses byte type records. Even primitive data types like integers must use two wrappers to convert to byte type. When the device is saving a J2ME program in persistent storage during runtime there is a noticeable delay and it seems to be a very process intensive to the device. As a result, the database is very small (i.e. few Kilo Bytes) and access is very slow. Only the data that is absolutely necessary must be saved in the record store. Another shortcoming of J2ME currently is the high level user interface is very rudimentary. The low level interface is a complex task to program and it provides the screen for most of the games in this research. Every single element must be programmed to use custom graphics, scroll up and down, write text and access key presses. J2ME only accepts PNG and JPEG graphic files. The Mobile Media API has no volume control and cannot move forward and backward. In J2ME applications, unnecessary codes must be eliminated, the number of objects must be limited and the large resource files and images must be trimmed. Large applications would not run. The following optimisation techniques have been used in this research to increase the speed and reduce the size of mobile games:

- The maintainability has been increased by:
 - Avoiding unnecessary objects.
 - Reusing objects.

- The speed and responsiveness of the game has been increased by:
 - Explicitly calling the garbage collector when moving between screens, and releasing memory back to the run time.
 - When possible arrays were used instead of vectors.
 - Unnecessary evaluation was avoided.
- The size was decreased by:
 - Using a minimum number of classes
 - Removing unnecessary classes and unnecessary features
 - Reducing the resource file
 - Removal of decorative menus with no content

7.5 Device Specification

Nokia N95-8GB was the device used for testing the mobile games. Devices with the following specifications are able to run the games (these specifications could also be used by other mobile phone developers to produce mixed reality games):

- 1) Phones that support the 240 x 320 pixel display resolution, *'also known as Quarter VGA (QVGA). QVGA resolutions are common enough to be recommended as primary MIDlet design targets'* (Forum Nokia 2011). Mhjerde (2008) has discussed the trends in different screen sizes: Figure 7.1 shows the popular screen sizes that comprise the bulk of mobile phone market. It is clear that 240 x 320 pixel screen size is on the rise and its market is growing very fast. Mhjerde (2008) recommends to developers that *'this should be the target screen size'* which will be the

'dominant screen size in the future'. Unusual and small sizes are increasingly less common. The user interface could be resized between landscape and portrait mode in the Symbian operating system, but the games are designed for portrait mode. It is possible to complement the later version of game implementation with portrait functionality, by changing the softkeys' locations and adding different sizes of graphics.

- 2) Phones that possess two softkeys, four arrow keys and alphanumeric keyboard with digits from 0 to 9 as input keys.
- 3) Phones with a built-in camera with 3.0 megapixel CMOS sensor and above.
- 4) Phones with messaging capabilities of SMS.
- 5) Phones with a web browser with support for HTML.
- 6) Phones with built-in Wi-Fi, with access to the Internet (through a 802.11b/g wireless network) or connection to the Internet through a carrier packet data network such as GPRS.
- 7) Phones with built-in Bluetooth 2.0 technology,
- 8) Phones with the ability to install and run third party Java ME. The following APIs need to be present in the mobile phone so the detective game functions appropriately: Java Technology JSR 139 Connected, Limited Device Configuration (CLDC) 1.1; JSR 118 MIDP 2.0; JSR 82 Bluetooth API; JSR 135 Mobile Media API; JSR 205 Wireless Messaging API 2.0.

In theory all devices with the above specifications can run the games, but execution in different devices can result in different performance levels.

Occasionally the same APIs could act differently and there are different heap sizes allocated in different devices.

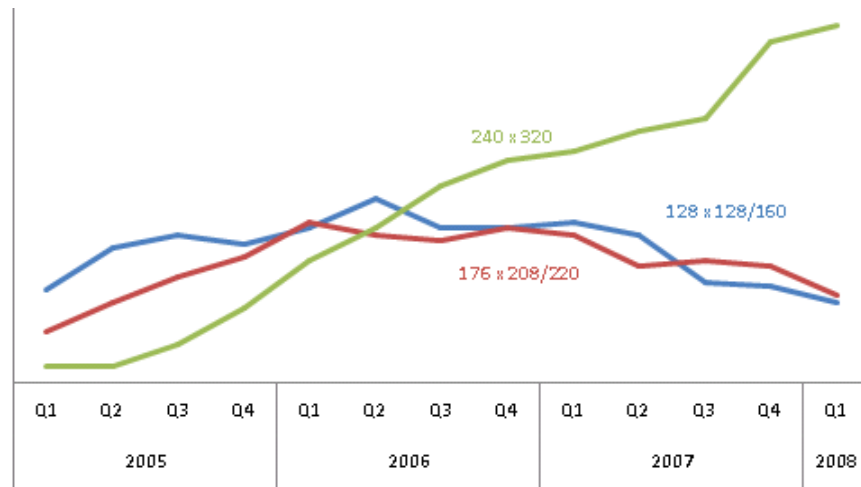


Figure 7.1 Popular mobile phone screen sizes from 2005 to 2008 (from Mhjerde 2008).

Students have reported that the games run in Nokia (N95, N900, N82, 6220i, X5 and E52) and Sony Ericsson (J108i, W580, w810, W890i, K550, K710, K750 and K770 models).

7.6 Hardware Consideration for MEMRG

In this section hardware considerations for mixed reality games (i.e. Detective Alavi in this research) are discussed. The other games that have been discussed in chapter 6 only relate to 7.6.2, 7.6.3 and 7.6.4 subsections, since they did not have any connection to the mobile web, and they have not used the phone camera and Bluetooth connection was not incorporated.

7.6.1 Mobile and wireless communication services

Mobile operators use radio frequencies to send and receive data. There are often limited amounts of radio spectrum (i.e. range of frequencies) available to

the operators. Operators use different digital telecommunication techniques to use the available spectrum more efficiently and increase the number of bits transmitted per second which in turn give rise to the different generation of the mobile services. In universities, teachers and students have access to the wireless local area network and are able to connect to the internet via WiFi. Although the 3G services have been offered in Europe since 2003 (<http://en.wikipedia.org/wiki/3G>), there are no immediate plans from operators to update to 3G services. In the following sections different types of mobile services are discussed. 3G and GPRS offer top-down service provider approach, WiFi and WiMax is a decentralised approach which is more user-centric.

7.6.1.1 General Packet Radio Service (GPRS)

GPRS is an extension of second generation mobile telecommunication services. It offers a data rate of 56-114 kilo bit per second with network latency of 600 to a few seconds (http://en.wikipedia.org/wiki/General_Packet_Radio_Service). Network latency is the time required for a packet to be sent from source to destination. Users often get the impression of dialled up connections when using the services. It is always on and offers SMS, MMS and mobile web. Its low transmission rate is due to the 'Time Division Multiple Access' technique for transmission of the signal. According to a specific time scheduling system each user must wait for the radio spectrum to become free. When it is available, the user utilises all the bandwidth to send the data for a certain duration of time. Network bandwidth is the amount of data a network can send at a given time.

7.6.1.2 Wireless Fidelity (WiFi)

WiFi connectivity enables mobile devices in a private space like a university campus to connect to the existing wired internet backbones using a 'Wireless Access Point' within 100 meter radius (http://en.wikipedia.org/wiki/Wireless_access_point). They could offer a similar experience to a broadband connection.

7.6.1.3 Third Generation (3G)

3G has a higher data rate than GPRS, but different operators have offered 3G with a different transmission rate. According to the 3G specifications the minimum data rate is 200 kbit per second, the maximum data rate in stationary state is 2Mbit per second, and in moving state about 384 kbit per second (<http://en.wikipedia.org/wiki/3G>). Its network latency is 100ms to a few seconds according to the signal strength (Mobile Broadband Advice 2011). 3G speed could vary greatly, depending on the local condition, network congestion and quality of signal. To transmit a signal, 3G networks use the 'Code Division Multiple Access' technique. Numerous users are able to use the spectrum simultaneously each possessing a unique code.

7.6.1.4 World Wide Interoperability for Microwave Access (WiMax)

WiMax refers to the Fourth Generation (4G) of mobile services. It offers 100Mb/s transmission rate in moving state and 1Gb/s in stationary state, much

higher than 3G services (<http://en.wikipedia.org/wiki/WiMAX>). Its network latency is less than 5 msec (Goldsmith, 2010). WiMax has much higher coverage than WiFi and could reach a few kilometers (Goldsmith 2010) and forms a Wireless Metropolitan Area Network (MAN). Fixed WiMax is often used as an alternative to DSL connection. Mobile WiMax lets the user move through the coverage area of a Base Station (BS) and incorporates connection hand off from a BS to its adjacent BS but in lower transmission rate of 15 Mb/s (Goldsmith 2010). It uses advanced signal encoding where the spectrum is divided into small range of frequencies (i.e. sub-channels) and each user could send data at a specific frequency using the 'Frequency Division Multiplexing Technique'. Consequently the bandwidth efficiency is high and many users could use the spectrum simultaneously with no waiting time.

7.6.2 Application processor

Application processor has the responsibility for the main computing functions in mobile phones. It constitutes a CPU, GPU/2D/3D graphic accelerator, sound chipset, memory controller, memory, CMOS camera interface, peripheral devices for Cell, WiFi and Bluetooth radios. All are packed together to reduce the distance between circuits to save power. Mobile phones are only allowed to consume a few mili Watt in order to allow the phone's battery work for a complete day. Most mobile applications have ARM architecture (<http://www.arm.com/>). Companies like Nvidia, Samsung, Texas instrument, Qualcomm and Marvel use ARM architecture to build low power consuming chipsets for mobile phones (ARM Company 2011). Mobile phone processors in developing countries range from 200 MHz to 600 MHz speed. In developed

countries the mobile phone processor speed range from 600MHz-1GHz, for example iPhone 4 uses ARM processor architecture that has 1 GHz processor (http://en.wikipedia.org/wiki/Apple_A4).

7.6.3 Memory

Memory is a temporary storage place for programs to run while the processor needs them. If the power is lost all the data stored in RAM is lost. Low power draining DDR RAMs are used in mobile phones (http://en.wikipedia.org/wiki/DDR_SDRAM). Mobile phones in developing countries often have memory ranging from 12MB to 128MB. In developed countries it ranges from 128MB- 512MB. N95 has 128MB RAM (http://en.wikipedia.org/wiki/Nokia_N95) and iPhone 4 has 512MB RAM (http://en.wikipedia.org/wiki/IPhone_4). An amount of internal memory is called 'heap size' that is reserved for the 'Java virtual Machine' in mobile phones. It takes care of newly created objects at program runtime. If the object exceeds the heap size the program will generate a 'memory out of bound' error. Some Nokia devices have limited heap size or limited JAR size. If the application's file size exceeds a certain limit often the device generates an 'out of memory' error. On the other hand, ROM is a permanent storage memory to save files and programs. It determines how many programs could be kept in the mobile phone. N95 has about 8 GB ROM and iPhone4 has about 32 GB ROM. The removable storage cards such as 'micro secure digital' (SD) cards could be used to store media. SD cards go inside the card slot and are usually 1GB to 4GB, SDHC (High-Capacity) cards have up to 32 GB and SDXC (eXtended-

Capacity) cards up to 2 TB capacity
(http://en.wikipedia.org/wiki/Secure_Digital).

7.6.4 Audio subsystem

The audio subsystem of mobile phones is placed on the main processor (TechAutos 2010). It must work with various sampling rates and mix and route analogue and digital signals to reduce power consumption. Hi-Fi audio quality is necessary with 16 bits resolution and sampling rate of 44.1 KHz for music playback, streaming and ringtone (http://en.wikipedia.org/wiki/Digital_audio). Telephony audio with low resolution and sampling rate of 8 KHz is compulsory for phone calls (http://en.wikipedia.org/wiki/Public_switched_telephone_network). The audio system has therefore much lower audio quality than dedicated chips on PCs.

7.6.5 Bluetooth radio

Bluetooth is a single radio chip that creates 'Wireless Personal Area Network' (WPAN) for mobile phones. It forms PAN within a short range. Class 1 Bluetooth ranges up to 100 meters and class 2 up to 10 meters (<http://en.wikipedia.org/wiki/Bluetooth>). Seven devices could be connected with each other simultaneously. They use a broadcast connection system to send and receive data. Transmission rate for Bluetooth version 1.2 is 1Mbit/sec, for version 2 it is 3Mbit per second and for version 3 the transmission rate is 24 Mbit /sec (<http://en.wikipedia.org/wiki/Bluetooth>). Signals are omnidirectional and can pass through walls with no line of sight required. Bluetooth hardware has low power consumption and is low cost with services that are offered free of

charge. Any Bluetooth device in discoverable mode can provide its name and class for other devices and advertise their own services.

Mobile phones use Java API Bluetooth Wireless Technology (JABWT) to implement Bluetooth applications. JABWT has 3 main profiles: 1- 'Generic Access Profile' for the local device, remote device, Bluetooth address, device discovery 2- 'Service Discovery Profile' to access a service available in remote devices 3- 'Serial Port Profile' for using streams to send and receive data.

A player can send their game scores within a PAN to other players. If one team send their scores, all other teams will receive the score. Players can join and leave a PAN at any time.

The Bluetooth connection uses a client/ server architecture to form a peer-to-peer gaming model. Each device running one instance of the game can act as a server and client simultaneously. When the game starts, it acts as a client by searching for other discoverable devices that are running the game and does a service discovery to obtain the URL of the scoring service. Once connected it starts acting as a server by making its scores available for future clients to share. These games could connect to the Bluetooth chat application to receive some feedback from the teacher. Figure 7.2 shows how three students with three instances of the game are connected to each other at the same time as being connected to teacher's chat application (BlueChat) to receive occasional assistance.

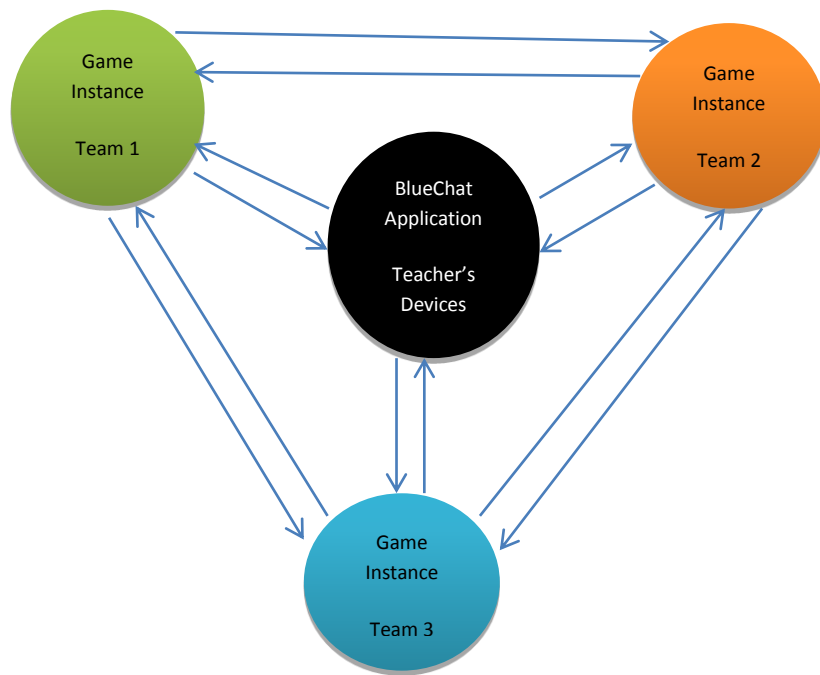


Figure 7.2 Bluetooth Gaming architecture in Classroom Wireless Personal Area Network.

7.6.6 Mobile phone camera

We have incorporated Mobile Media API (MMPI) for capturing the images, which is available on almost all J2ME phones. Camera resolution, aperture and sensor are important features that could contribute to a better quality image in our games. This section discusses what the necessary features of a mobile phone camera are to capture a satisfactory image from a QR code. Refer to the 'Future Work and Improvements' section to find out when the camera zooming and auto focus capabilities become important in selecting devices for the game play.

7.6.6.1 Camera resolution

The camera's resolution is the amount of detail a camera can capture. It is measured in million pixels or mega pixel. In the QR codes the tiniest detail is

important, and a higher resolution could make a difference between a right and wrong bit. The most advanced camera phones could have 12 megapixel resolutions such as N8 (http://en.wikipedia.org/wiki/Nokia_N8), but the 5 megapixel resolution has relatively good result on QR codes.

7.6.6.2 Aperture

The aperture is the opening of the camera that controls the amount of light that reaches the camera's sensor. The wider it is, the better the close up pictures which could be taken especially indoors (such as in a classroom) with low light, which is clearly very useful. The aperture's diameter is measured in F-Stops. The lower is the F-stops, the wider is the aperture. In camera phones the aperture is usually f/2.8 (<http://europe.nokia.com/find-products/devices/nokia-n8/specifications>).

7.6.6.3 Camera sensor

Charged Coupled Device (CCD) sensors produce high quality and low noise images compared to Complementary Metal Oxide Semiconductor (CMOS) sensors. However, due to the necessity for less power consumption in camera phones, often CMOS sensors are used.

7.6.6.4 Sensor size

The larger the camera's sensor, the greater the received light which has major impact on the quality of the image. N8 has one of the largest camera sensors which is 1/1.83" (<http://europe.nokia.com/find-products/devices/nokia->

n8/specifications) with significantly better image quality than other mobile phones.

7.6.6.5 Camera focal length and zoom

The camera's focal length is the distance between the camera's lens and the surface of the sensor. When it increases, it magnifies the object and brings it closer. In camera phones, focal length is often fixed in contrast to digital cameras. This is due to the fact that phone camera's lens is fixed, but in digital cameras the position of lens could change, which is called 'optical zoom'. Two focal lengths must be given for the optical zoom which is calculated by dividing the longer focal length over the shorter one. In extremely long focal length, a distance object could get really close but the camera becomes susceptible to shake which requires a tripod or image stabilisation to be used. In the camera phone market often digital zoom is advertised which is frequently of little use. It crops a section of a small image then enlarges that section of the image. In this process the number of pixels remains the same and they are only stretched which produces low resolution and poor quality images.

7.6.6.6 Auto focus

Cameras with an autofocus capability have an algorithm that computes the contrast of the actual object to its background using contrast detection.

7.7 Detective Alavi's Cost

This section estimates how much 2 hours of the Detective game play costs. The other games discussed in section 6 include no extra cost at run time. The Detective Alavi game was distributed completely free of charge to the students. However they needed to pay the cost of internet connections, SMS messages and phone calls. The cost of GPRS, SMS and phone calls are obtained from a mobile company (<http://mci.ir/> on 15th August 2010).

GPRS expenses for each Kilobyte of communication from 8 am to 11 pm are 8 Rials. Each Farsi SMS costs 89 Rials and each English SMS costs 222 Rials. Mobile phone call charges for 1 minute to a phone in the same city from 8 am to 9 p.m is 447.5 Rial. Making calls to a phone in the different city from 8 am to 9 p.m is 760 Rials.

Table 7.2. Activities during a level of MEMRG game play and their corresponding duration and costs

Activities during a level of MEMRG game play	Time spend on each activity	Cost/Rials
4-5 web pages = 2000KB Using GPRS	20 minutes	16000
2 English SMS	5 minutes	444
Mobile phone call to the different city	20 minutes	15000
Use Game interface	20 minutes	0
Work on QR puzzles	35 minutes	0
Group Discussion and Report Writing	20 minutes	0

During 2 hours of game play each group spends 31444 Rials (1.90 GBP) which is shown in Figure 7.12. For a class of 30 students with six groups having 4 members and two groups having 3 members the cost of Detective game is 251552 Rials (15.2 GBP). If the students use the university's WiFi the price decreases to 123552 Rials (7.46 GBP) for a group of 30 students. These costs may be compared to the cost of lecturers that often travel from Tehran (capital city) to smaller cities to give lectures, and are very much less. Lecturers normally have to travel by plane where a return ticket costs 72.53 GBP, and they normally charge the university 40% more than normal lecturers. Detective Alavi when using GPRS is 80% more cost effective than normal lecturers and when using WiFi is 90% more efficient.

7.8 Implementing the Main Game Environment

Sections 7.8-7.14 cover the implementation of the 'Detective Alavi' game. The other games whose designs have been discussed in chapter 6 follow similar coding structure to section 7.8.

7.8.1 View window's components creation

The main game screen is built from a 'GameCanvas' type of screen from the `javax.microedition.lcdui.game` package. Its main advantage over other types of screen is its ability to control how to display and update different game elements. Moreover it has game-centric features that make the game development easier and more efficient. The initialisation process for different game canvas's resources takes place in `start ()` method.

The first step is to create different parts of the device's view window consisting of:

- (1) A score bar at the top to update the player with his/her progress.
- (2) A dialogue bar at the bottom to show the character's conversations.
- (3) A floor layer for the characters to move on.
- (4) A barrier layer to prevent the characters passing through rigid objects such as walls, tables, and computers (see Figure 7.4).

The floor layer and barrier layer are tiledlayers. A tiledlayer is a small collection of equally sized tiles that make a large background, at the same time avoiding high memory consumption (see Figure 7.3). Tiles could be arranged differently to create different designs for the backgrounds. Tiles have been obtained from (<http://www.sprites-resource.com/ds/P.html>) and modified for mobile phones.



Figure 7.3 Detective Game's tiledlayer

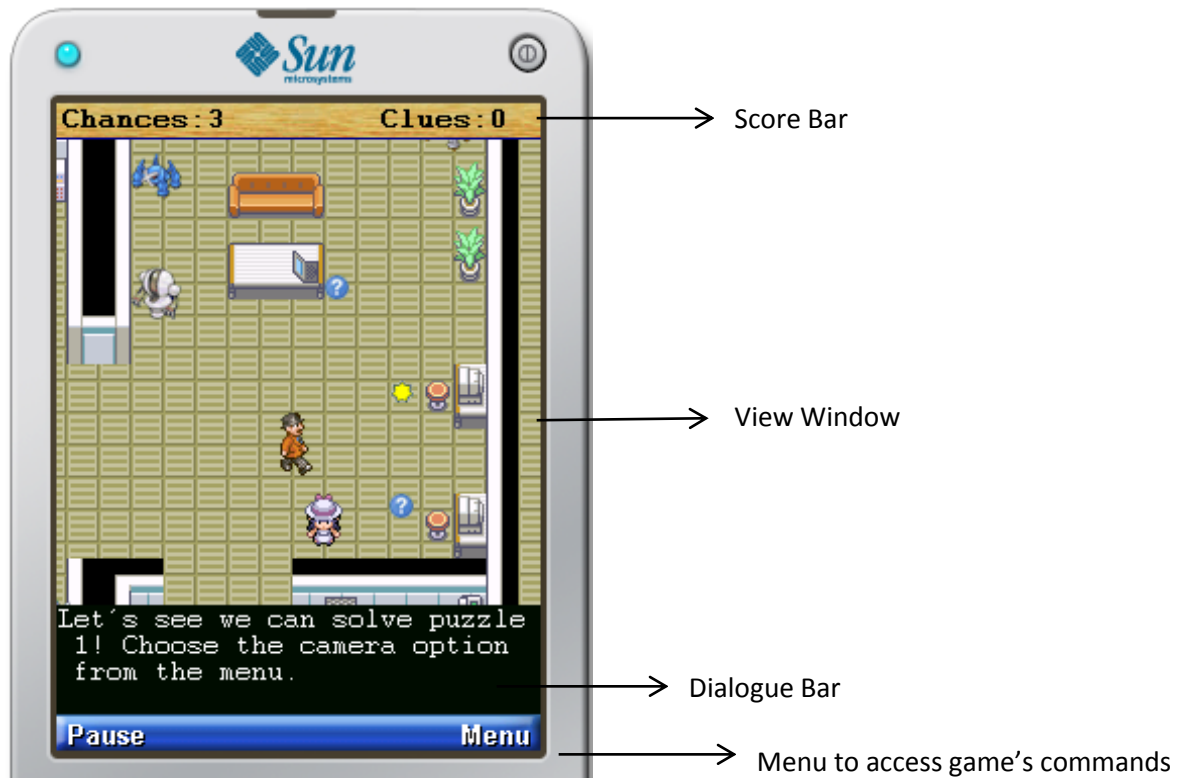


Figure 7.4 Detective Game's main game screen

7.8.2 Sprites creation

Then Sprites are created. They are basic game layers that could create a game's characters and game objects. Animated sprites have different frames, all equally sized in a single PNG image. Sprites can detect collision with other sprites and game's Tiledlayer and this helps to create realistic character movement and relationships. Sprites have been obtained from (<http://www.sprites-resource.com/ds/P.html>) and modified for mobile phones.

7.8.3 Layers and their visibility

The game background and sprites are added as layers by the layer manager. The layer manager manages the layer rendering and the visibility. It is

important to check if each layer is still visible or not, because the player might move between different game screens and the visibility of the characters must be preserved.

7.8.4 Initialising the game music and sounds

The music files are accessed as input streams and they are controlled through a music player. For example, the code below shows how the background music is created and is set to play all the time during the game by `setLoopCount (-1)`, where `-1` refers to forever (see Figure 7.5).

```
InputStream is = getClass().getResourceAsStream("Music.mid");
musicPlayer = Manager.createPlayer(is, "audio/midi");
musicPlayer.prefetch();
musicPlayer.setLoopCount(-1);
musicPlayer.start();
```

Figure 7.5 Snippet code for initialising the game's music and sounds

7.8.5 Setting the view window's position and size

The X and Y coordinate of the view window is set in such a way that keeps the player sprite always in the middle of screen. `getWidth()` and `getHeight()` methods calculate the screen's width and height respectively. The view window's height must make a note of the scoring bar at the top and the dialogue bar at the bottom and subtract their height from the screen's height (see Figure 7.6).

```
xView = playerSprite.getX() - ((getWidth() - playerSprite.getWidth()) / 2);  
yView = playerSprite.getY() - ((getHeight() - playerSprite.getHeight()) / 2);  
midlet.layers.setViewWindow(xView, yView, getWidth(), getHeight() -  
4*scoreBar.getHeight());
```

Figure 7.6 Snippet code for setting the view window's position and size

7.8.6 Starting the Game Thread

At this stage the game thread starts. It controls the game events and graphic rendering (see Figure 7.7).

```
Thread gameThread = new Thread(this);  
gameThread.start();
```

Figure 7.7 Snippet code for starting the game thread.

7.8.7 Checking the user input

The tick() method processes the player's input using getKeyStates(). In the detective game only left, right and up and down directional keys are used. Left and right keys change the x coordinate of the 'move' variable but up and down keys set the y coordinate of the 'move' input. Then according to the direction of the move, the player sprite's frames change to give the impression that the sprite is walking in a certain direction. It is important to check if the player will collide with the barrier tiledlayer or not, and if it does not player sprite can move.

7.8.8 Characters' dialogue and knowledge chunks

When the player sprite comes in close contact with another game character a dialogue will take place between them. Similarly when the player sprite touches certain objects extra information about the game's mystery is revealed to the player. This information and the dialogues are both presented at the bottom of the game screen, below the view window in the 'dialogue bar'. The close contact between the sprites could be identified by a collision detection technique using `collideWidth()` method. Then the appropriate dialogue sound is played, but to present the dialogue first a check is made to see if it is the right time to present the information. In instructional games the order of presenting information is important and this strategy is used to help students progress smoothly and avoid confusion. Each game character holds an sequencing number; in the example below integer 1 is the ordering number of character 1 (see Figure 7.8).

```
if (playerSprite.collidesWith(Character1, true)) {  
  
    if (midlet.soundFlag){try {dialoguePlayer.start();}  
  
    catch (MediaException me) {}}  
  
    PlayerNextMove= new Integer(1);  
  
    checkOrder(Character1,PlayerNextMove); }
```

Figure 7.8 Snippet code for checking the order of feedback when two characters come close to each other.

7.8.9 Feedback ordering

There are three integer vectors that are allocated to check the feedback ordering. Firstly, PresentFeedOrder is a vector that contains feedback orders that must be presented now. Secondly, PastFeedOrder is a vector for previous feedback. Thirdly, NextFeedOrder is a vector that contains the future feedback orders. When the player collides with another sprite, the sprite's ordering number is checked with the first element of the PresentFeedOrder vector. If they are equal, the first element is added to the PastFeedOrder and the first element of the NextFeedOrder is removed. The dialogue that is presented between the characters and the non-player character is removed (see Figure 7.9 and 7.10).

```
if (PlayerNextMove.equals(midlet.PresentFeedOrder.firstElement()))
{
    midlet.PastFeedOrder.addElement (PlayerNextMove);
    midlet.PresentFeedOrder.removeElement (midlet.PresentFeedOrder.firstElement());
    midlet.NextFeedOrder.removeElement (midlet.NextFeedOrder.firstElement());

    //Lord Buffer

    if (PlayerNextMove.equals(new Integer(1)))
    {
        midlet.textbelow = "Lord Buffer: The central processing unit (CPU) is the ultimate
        MOBO city's brain.";
        midlet.layers.remove(Character1);}
}
```

Figure 7.9 Snippet code for checking the feedback ordering.

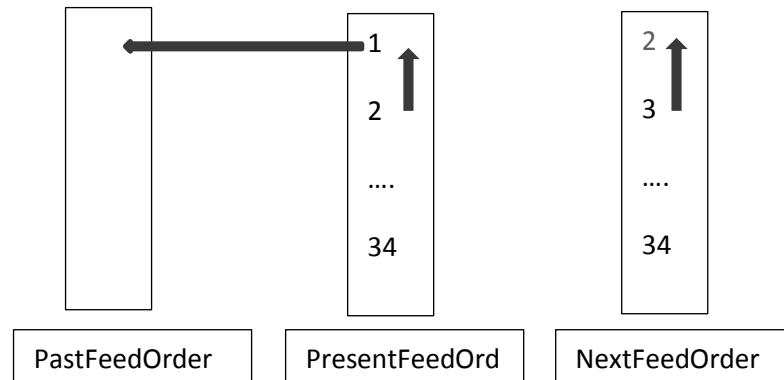


Figure 7.10 Feedback Ordering System

If the ordering number is present in the NextFeedOrder, the 'come back here later!' message is presented (see Figure 7.11).

```
else if (midlet.NextFeedOrder.contains(P))
midlet.textbelow="Come back later!";
```

Figure 7.11 Snippet code for the information that is too early to be revealed.

The PastFeedOrder helps the GameCanvas to check if a certain layer must be present or not (see Figure 7.12).

```
if(midlet.PastFeedOrder.contains(new Integer(1)))
midlet.layers.remove(Character1);
```

Figure 7.12 Snippet code for hiding a character involved in the past dialogues.

7.8.10 Calling commands

When the player chooses a command from the game's menu, the game thread and music must stop. The garbage collector is activated to remove all unused objects. In this way a smooth transition between screens is achieved and avoids the game being suspended due to the high memory consumption.

7.8.11 Preserving game status

When the player moves forward and backward between the different game screens, the game's status will be lost and the player must restart the play when returning to the GameCanvas. The character's position will be lost and initialised to the starting position, and feedback ordering is set to its original values and the player has to speak again to all the characters that he/she had already spoken to, and search all the places he/she has searched before. Consequently certain variables are selected and declared as Public in game's Midlet and they are protected until the player exits the game. These variables are:

- (1) The current position of the game's main character (i.e. Mr Alavi).
- (2) The layer manager which specifies the visibility of the game characters.
- (3) The character's dialogue text.
- (4) The order of the character's dialogue.

7.8.12 'Camera' command

This will be discussed in 7.9.

7.8.13 'Enter clue manually' command

Players could enter the clues manually in a text box in a 'form' screen. The entered string is extracted from the text field and is compared with different types of clue arrays, if a match is found, the appropriate variable is incremented

and appropriate feedback is shown to the player. The updated variables will affect the student's cognitive and language progress (see Figure 7.13).

```
cluebox = new TextField("Enter the text: ", "Clue ", 160, TextField.PLAIN);  
  
append(cluebox);  
  
int r1=clueSearch(midlet.TotalCluesArray, clue);  
  
if (r1!=-1){ midlet.total_clue_number = midlet.total_clue_number + 1;  
  
midlet.Message1="Well done!";  
  
midlet.Message2="You are doing really well!";  
  
midlet.sendmessage(); }  
  
if (r1==-1)  
  
{ midlet.Message1="Sorry you lost the clue!";  
  
midlet.Message2="Search the web or call an expert to help you!";}
```

Figure 7.13 Snippet code for entering clues manually and presenting an appropriate feedback.

7.8.14 'Skip to puzzle n' command

This presents a 'list' screen, with different choices of puzzles. Each item of the list activates a method that changes the ordering of the feedback by placing different values in PresentFeedOrder, NextFeedOrder and PastFeedOrder vectors.

7.8.15 ‘Language Academy/ Intel Corporation/Police Station’ commands

These commands present ‘form’ screens that appends text to a StringItem. The ‘form’ type automatically wraps the texts, but they could not be easily formatted and customised.

7.8.16 ‘Check Others’ Score’ command

This will be discussed in 7.13.

7.8.17 ‘Solve Cryptogram’ command

This presents a ‘form’ screen with a numeric text field to enter the secret code. The teacher is called by the platformRequest() method to provide the secret code. If the player chooses ‘Check Code’ from the menu commands, the secret code’s accuracy is checked. If it is correct, the player wins the game. Otherwise if the secret code is incorrect, one JobChances is lost and the result is sent to the other team members by Bluetooth. If it was the last JobChance and the player has lost it now, he/she loses the game (see Figure 7.14).

```

else if (command == CheckCode)

{int scode=getSecretCode();

if (scode==456)

{midlet.GuessedCrypto=true;

midlet.WinScreenShow();}

else {midlet.JobChances=midlet.JobChances-1;

midlet.sendmessage();

append("You have lost one Job chance!");

if (midlet.JobChances<1)

midlet. LoseScreenShow();} }

```

Figure 7.14 Snippet code for checking the secret code given by the teacher for solving the cryptogram.

7.8.18 'Read Report' command

This presents a form with a numeric text field to fill in with the reporting score. At the same time, a call to the teacher is made to read the report to and receive the score which looks like a secret code. If the player selects the check code from the menu bar, the appropriate reporting points will be gained and the reporting skill will be updated (see Figure 7.15).

```

if (command == checkcode) {

int scode=getSecretCode();

midlet.GainedPoints(scode);

midlet.ReportingSkill2Show();}

```

Figure 7.15 Snippet code for checking how much points gained after reading the report.

7.8.19 'Save' command

All the game scores are sent to the game UpdateScore() method in score class, and this process might take a few seconds. They are all stored in an integer array i.e. 'values []'. This array must be converted to byte type before it could be stored as a record. A data output stream object is made, and the integer elements from the 'values []' are written to the output stream using the writeInt() method. Any output buffered bytes are written to the stream using the flush() method. Then any resources in the stream are released using the close() method. A new byte array is created with the size of the output stream and all the content of values[] is copied into it. The array is written into a record store (see Figure 7.15).

```
try{for (int i = 0; i < values.length; i++)
{
    ByteArrayOutputStream bstream = new ByteArrayOutputStream(12);
    DataOutputStream ostream = new DataOutputStream(bstream);
    ostream.writeInt(values[i]);
    ostream.flush();
    ostream.close();
    byte[] record = bstream.toByteArray();
    this.getRecordStore().setRecord(i + 1, record, 0, record.length);} }
```

Figure 7.16 Snippet code for saving the updated scores.

7.8.20 'Main Menu' commands

The player can move to the main menu screens.

7.8.21 'Pause/Resume' Commands

When the 'Pause' command is called, the command 'Resume' is replaced by 'Pause'. The game thread and music is stopped. The characters will not be able to move on the screen and no sound is heard. By choosing 'Resume', the command 'Paused' is replaced by 'Resume'. The game thread and music starts.

7.8.22 Drawing the graphics

The score bar, dialogue bar, all sprites and layers are drawn in the render() method using a graphic object, drawImage() and paint() methods. The flushGraphics() method makes the graphics appear on the screen. The text in the dialogue bar is wrapped by LineEnumeration() method measuring the width of screen.

7.9 Camera Control

To control the camera within the game environment the 'Mobile Media API' (MMAPI) from 'javax.microedition.media' and 'javax.microedition.media.Manager' packages is used. A player is created to control the rendering of media content from the camera. It is then set in the 'realize' state to acquire the media resources from the device. Then the video player obtains the video control of the camera by getControl(). The video control initialises the mode using initDisplayMode() for camera to be displayed as a full screen in a canvas (see Figure 7.17). By default the camera is not

shown unless the video control explicitly sets it to visible using `setVisible(true)` (see the `StartApp()` method in game's midlet).

```
player = createPlayer();
player.realize();
videoControl = (VideoControl)player.getControl("VideoControl");
canvas = new CameraCanvas(this);
videoControl.initDisplayMode(VideoControl.USE_DIRECT_VIDEO, canvas);
videoControl.setDisplayFullScreen(true);
videoControl.setVisible(true);
```

Figure 7.17 Snippet code for displaying camera in a canvas

Whenever the 'Camera' option is chosen, the camera canvas is set as the game's current screen and the video player is started (see Figure 7.18).

```
display.setCurrent(canvas);
player.start();
```

Figure 7.18 Snippet code for starting the camera player.

7.10 QR Code Identification

There are five stages in identification of QR codes; these steps are image capturing, image pre-processing, image positioning, image sampling and image decoding. The implementation of these stages uses the open source QR code library and decoder from Wimmer (2008).

7.10.1 Image capturing

Whenever the 'Capture' command is chosen from the camera display's menu, the `capture()` method is called. It sets a form screen for the user while waiting for the image to be decoded. The decoding of the image has its own thread that must be started.

In the decoding thread, the 'video control' uses the `getSnapshot()` method to capture the image by enforcing the JPEG image type. The raw data of the captured image is stored in an array of 'bytes'. JPEG is the most compact type and reduces the memory usage. Then the camera canvas closes by stopping the player. Raw image data is converted into 'Image' type then sent to the QR Code decoder (see `DecodeThread.java`).

The following three sections 7.10.2, 7.10.3 and 7.10.4 are called image pre-processing stages.

7.10.2 Image to array of integers

The captured image is converted into a two dimensional array of integers (`intImage`) using `imageToIntArray()` method, where all of the image's pixels are obtained via `getPixel(x,y)` method and are placed in an array with the same height and width of the image (see `jp.sourceforge.qrcode/QRCodeDecoder.java`).

7.10.3 Gray conversion

The captured image by the camera is a colour picture, but the QR code is a set of black and white pixels. Thus the RGB colours are converted to grayscale by the `imageToGrayScale(int[][] image)` method (see `jp.sourceforge.qrcode.reader /QRCodeImageReader.java`).

7.10.4 Image filtering

In the process of image capturing, the QR code image is exposed to impulse noise and distortion. Here the median filters are used to remove speckle type noise and preserve the image edges. This is done by passing a cross window across each pixel of the image using `applyCrossMaskingMedianFilter()`. Then using `applyMedianFilter ()` function the pixels are sorted from low to high brightness. A pixel with median value of brightness is chosen. The centre pixel is replaced with the median value but the pixels on edges are preserved (see `jp.sourceforge.qrcode.reader /QRCodeImageReader.java`).

7.10.5 Image positioning by the finder pattern

The finder pattern determines the corners of QR code image, corrects declined angles and helps the QR code to be readable from all directions. To locate the QR code, the `findFinderPattern(bitmap)` function looks for 3 overlapped dark-light-dark areas with 1:1:3:1:1 ratio (see Figure 7.19). When a close enough match is found the three corners are declared. The centre of these corners could form a triangle when using the cosine law, the largest angle could be found which is referred to the upper left corner. The other two corners are

found according the upper left corner (see Figure 7.20. and `jp.sourceforge.qrcode.pattern /FinderPattern.java`).

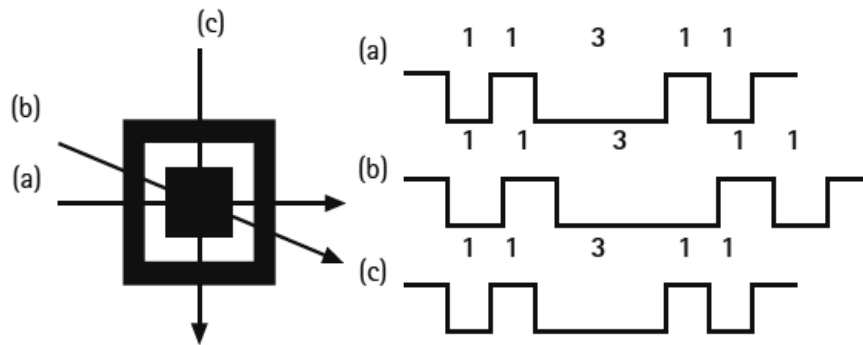


Figure 7.19 Finder Patterns (from Soon 2008).

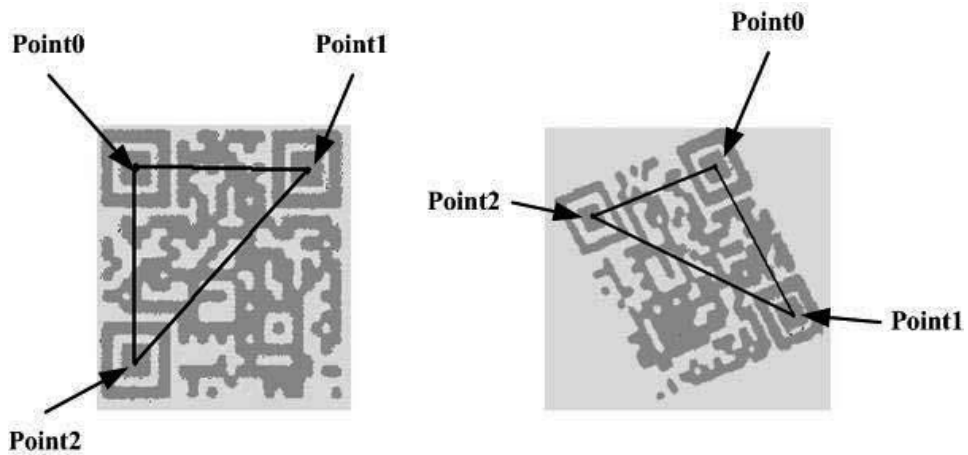


Figure 7.20 Locating QR Code orientation (from Liu and Liu 2006)

7.10.6 Alignment pattern

The alignment pattern helps the finder pattern to locate the position of the QR code and correct its distortion when the QR area is large. The larger versions of QR code have many alignment patterns arranged in regular intervals (see Figure 7.21 (b)). The `findAlignmentPattern (bitmap, finderPattern)` searches for dark-light-dark areas with 1:1:1 ratio through horizontal and vertical scan of the image (see Figure 7.21 (a)). The central coordinate of the alignment patterns

with three centres of finder pattern form a sampling grid (see jp.sourceforge.qrcode.pattern/AlignmentPattern.java).

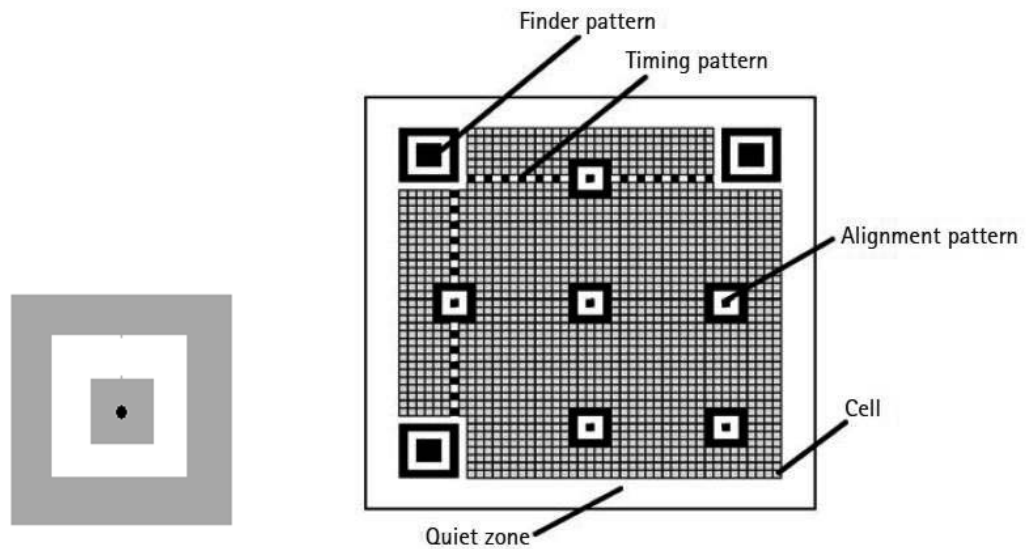


Figure 7.21 (a) The alignment pattern and its central coordinate point (b) The QR Code Structure with many alignment patterns (from Soon 2008).

7.10.7 Image sampling

The Number of QR codes' modules is calculated using a sampling grid that calculates an average estimated module size based on the position of the finder pattern and the alignment pattern. Next `getQRCodeMatrix()` function extracts a matrix (i.e. `qRCodeMatrix`) from the image matrix which only refers to the QR codes (see jp.sourceforge.qrcode.reader/QRCodeImageReader.java)

7.10.8 QR code version

The number of side modules in QR code could be obtained from the QR code matrix which in turn helps to deduce the QR code's symbol version,. For

example 25 side modules refer to version 2 and 177 modules to version 40 (see version variable in `jp.sourceforge.qrcode.data /QRCodeSymbol.java`).

7.10.9 QR format

The format area provides some information about the data mask mode which assists in making a balanced distribution of the black and white modules to avoid recognition problems at the decoder. The unmasking process is carried out by `readFormatInformation ()` to read the format information (`jp.sourceforge.qrcode.data /QRCodeSymbol.java`).

7.10.10 Error correction levels

There are four levels of error correction code available for QR codes, levels L, M, Q and H in which they restore 7%, 15%, 25% and 30% of errors. These levels determine the number of error correction bits that are added at the QR encoder which are called parity bits. The error correction level of the QR code is obtained by the `decodeFormatInformation()` method (`jp.sourceforge.qrcode.data /QRCodeSymbol.java`).

7.10.11 QR error correction and decoding

In the process of QR generation at the encoder, the data (combination of alphanumeric characters) were turned into 'Reed Solomon Codes' (RS codes) to help the decoding process to correct errors that normally occurred during the capturing process.

At the decoder, the retrieved QR matrix is checked for the existence of errors, and the location of errors and errors were corrected using complex mathematical operations such as 'syndrome calculation' (see `calcSyndrome()` in `jp.sourceforge.reedsolomon / Galois.java`) the 'Berkelamp-Massey Algorithm' (see `Decode ()` in `jp.sourceforge.reedsolomon/RsDecode.java`), the 'Chien Search' (see `chienSearch ()` in `jp.sourceforge.reedsolomon/RsDecode.java`) and the 'Forney Algorithm' (see `doForney ()` in `jp.sourceforge.reedsolomon/RsDecode.java`).

7.10.12 Showing the result

The result of decoding is in the form of alphanumeric characters that are stored in the string variable 'result', if the decoding fails the result shows a decoding failed message (see `DecodeThread.java`).

```
try {result = new String(decoder.decode(new J2MEImage(image)));} catch (Exception e) {}  
if (result.length() == 0) {result = "Decoding failed! Please try again.";}  
}
```

Figure 7.22. Snippet code for showing the alphanumeric characters encoded in QR code.

The result is shown in a form type screen (see Figure 7.23).

```
resultForm = new Form(midletName);
```

Figure 7.23 Snippet code for displaying the result in a form.

If the 'result' string starts with 'TEL:' a 'Call' command is added to the menu, if it starts with 'http://' an 'Open' command is added, if it begins with

'SMSTO:' an 'SMS' command is added otherwise a 'Check Clue' command is added.

7.11 Making a Phone Call and Starting a Browser

If the player chooses the command 'Call' or 'Open' from the result screen's menu a `platformRequest()` method is called. It opens a URL either in the form of a telephone number such as 'TEL:00989127506309' which initiates a voice call or a web address 'http://www.google.com' which starts a web browser (see `dispatchPlatformRequest()` method in game's midlet). During the platform request the game still runs in the background but the requested application is available in the foreground. This method could have financial impact on the player when using GPRS services or making a voice call. In either case the device asks the player to explicitly accept each request before the action takes place.

7.12 Sending an SMS

When the QR code is decoded as an SMS type, the player can choose the 'SMS' option from the result screen's menu. A form screen is displayed that contains two text fields - one that already contains a phone number and the other one to write an SMS text. Then the 'Wireless Messaging API', or WMA, from the 'javax.wireless.messaging Package' is used to send the SMS. Using this API, a message connection can be opened with an empty message that later on will be filled in by the player. The destination phone number is extracted from its text field and stored in the 'number' variable and then is

associated with the present message's address using setAddress() method. After the message is written by the player, it is stored in the 'text' variable and the setPayloadText() sets the message's body with a suitable encoding for the messaging protocol to transmit the characters correctly (see Figure 7.24).

```
connection = (MessageConnection)Connector.open("sms://:5000");  
  
TextMessage message =  
(TextMessage)connection.newMessage(MessageConnection.TEXT_MESSAGE);  
  
String number = "sms://" + smsNumber.getString();  
  
message.setAddress(number);  
  
String text = smsText.getString();  
  
message.setPayloadText(text);
```

Figure 7.24 Snippet code for preparing a connection for an SMS message and extracting the message and the phone number

The message is sent by passing it to the MessageConnection's send() method and player will see the 'message sent' on the form appended (see Figure 7.25). Before the message is sent the player must accept the action before it proceeds (see SMS.java).

```
connection.send(message);  
append("Message sent.");
```

Figure 7.25 Snippet code for sending the SMS message.

7.13 Check Clue

If the QR code is decoded as a text that might contain the 'Detective Game's clue', the player could choose 'Check Clue' from the result screen's option

menu to check if he/she found the right clue. Only the first word of the text which ends up with a full stop (.) is extracted and is compared to these arrays: TotalCluesArray, MeaningSkillArray, SpellingSkillArray, WordFormSkillArray, ElectronicSkillArray, Level_1_RememberingArray, Level_2_UnderstandingArray, Level_3_ApplyingArray, Level_4_AnalysisArray and Level_5_EvaluatingArray. If a match is found the appropriate clue type is incremented and the result is shown in the feedback screen (see Figure 7.26). The code below shows when the clue is checked with the TotalCluesArray and the two alternative feedbacks possible that are presented to the player (see `commandAction()` method in game's midlet).

```
if (c==checkClue){
String tx=clue;
if ((clue.indexOf(".")>0)
{tx = cutString(clue, ".");}
int r1=clueSearch(TotalCluesArray, tx);
if (r1!=-1){
total_clue_number = total_clue_number + 1;
Message1="Well done!"; // first alternative, when the clue is found in the array
Message2="You are doing really well!";
sendmessage(); // other team's will receive the total clue number by means of Bluetooth
}
if (r1==-1)
{Message1="Sorry you lost the clue!"; //second alternative, when the clue is not found in the array.
Message2="Search the web or call an expert to help you!"; }
```

Figure 7.26 Snippet code for checking the clue and presenting an appropriate feedback.

7.14 Bluetooth Connection

Implementing the Bluetooth capabilities for games require them to have the Bluetooth hardware and the `javax.bluetooth` package. Bluetooth sends and receives data as streams. Each device can act as a server advertising its services, waiting and accepting clients. At the same time it is possible to act as a client searching the nearby devices and services and using the server's services. The Detective game has the same capability built into it and can act as both server and client. It creates peer-to-peer connections with other devices in the vicinity and forms a Personal Area Network to send and receive game scores. This section uses Hui (2004) open source BlueChat application to build the Bluetooth connection and send and receive game scores.

7.14.1 Network layer initialisation

A player must enter a name before starting the game. When the 'Play' command is selected from the menu bar, the Bluetooth network layer is initialised. The local name of the device is user friendly and is set by extracting the name that has been entered by the player (see Figure 7.28). During the Network initialisation, a singleton instance of the local Bluetooth manager (`localDevice`) is obtained, and it is set to discoverable (see Figure 7.27). Other devices' Bluetooth managers could see the present device during their general inquiry (GIAC) by a `DiscoveryAgent`. Then the Bluetooth server thread is build and started (see `Netlayer.java`).

```
localDevice = LocalDevice.getLocalDevice(); // obtain reference to singleton

localDevice.setDiscoverable(DiscoveryAgent.GIAC); // set Discover mode to GIAC (General Inquiry Access Code)

agent = localDevice.getDiscoveryAgent(); // obtain reference to singleton

Thread thread = new Thread( this ); // Bluetooth server starts

thread.start();
```

Figure 7.27 Snippet code for setting the local device to discoverable mode.

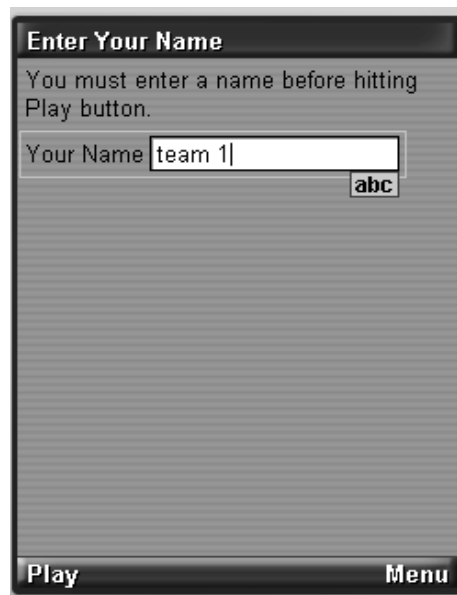


Figure 7.28 Asking for player's name when the game starts

7.14.2 Server connection formation

A server connection is established by `Connector.open()`. The Bluetooth server application implements their own custom service which is here 'sending and receiving player's score' using a universally unique identifier (UUID) which is exclusive to this specific service (see Figure 7.29). This service is then added to the service discovery database (SDDB) of the local device (see `Netlayer.java`).

```
private final static UUID uuid = new UUID("102030405060708090A0B0C0D0E0F010", false);
server = (StreamConnectionNotifier)Connector.open(
    "btspp://localhost:" + uuid.toString() + ";name=GameApp");
StreamConnection c = null;
```

Figure 7.29 Snippet code for server connection and advertising its service (i.e. player's score).

7.14.3 Waiting for client connection

When the player selects the "Check other team's score", the server is running and is waiting for a client connection and the application prints out: "Ready to accept connection. Wait..." (see Netlayer.java). The server accepts the client connections using `acceptAndOpen()` method.

7.14.4 Server accepts the new client connection

The server will then get the remote device which the connection is connected to (see Netlayer.java).

7.14.5 Sending the game scores

When the player scores in the game, or selects the 'update' option in the menu bar, the `total_clue_number` variable which is the player's total score and the player's `JobChances` is sent to all other devices and the message screen is updated (see the Figure 7.30 and 7.31).

```
String msg = "Score:" +total_clue_number+" + Chances: "+JobChances ;
btnet.sendString( msg );
```

Figure 7.30 Snippet code for sending total score and number of job chances.

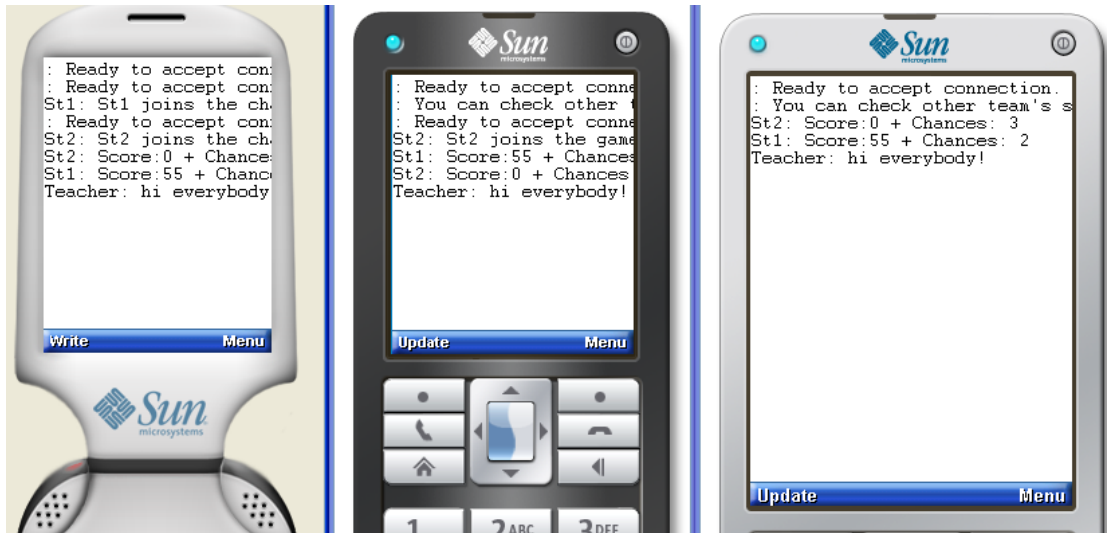


Figure 7.31 (a) Teacher's BlueChat application, (b) team St1's game application and (c) team St2's game application.

7.14.6 Start inquiry

The game application can also act as a client. It uses the `startInquiry()` method to start a general inquiry (GIAC) of all the Bluetooth nodes in the range and `DiscoveryListener` interface receives and notifies the application as the new devices are discovered (see `Netlayer.java`).

7.14.7 Service discovery

At this stage device discovery is complete. The game application in its client mode waits for 100ms and then starts a service discovery process on each of

the pending devices using a specific uuid. At this stage a "You can check the other team's score now" message is printed by the application.

7.14.8 Leaving the game

When one device leaves the game, other devices print that the specific device is leaving the game (see Figure 7.32). Here St1 leaves the game, but other teams can continue playing the game.



Figure 7.32 (a) Teacher's BlueChat application showing St1 team leaving the game, (b) team St1 leaving game application and (c) team St2's game application showing St1 team leaving the game.

7.15 Conclusion

In this chapter, the implementation of the Detective game which is a mixed reality game has been presented using the J2ME platform. J2ME's relationship to other environments such as iPhone and Android, the portability issues, advantages, disadvantages, and the hardware and software specification for the game deployment have been discussed. J2ME has a wide variety of APIs to

create mixed reality games and these games never impose any security threat to the device. The games are portable due to the KVM java interpreter. On the other hand J2ME's database is primitive and slow. The application size must be small to increase the speed and responsiveness of the game. The screen size requirements for an ideal game play must be at least a QVGA screen size. Connection to the internet is made either via GPRS or WiFi. The processor is often integrated with other chipsets and it has ARM structure processor. The cost of the game play is low which is not only pedagogical effective (see chapter 8) but also economical efficient.

In implementing the main game, the different components of the view window and the sprites must be created and their visibility checked. Then the music and sounds must be initialised. The view window position is set according to the player's position. The player must always be kept in the middle of the screen. When the players collide with other game characters or objects a dialogue is shown in the dialogue bar according to the feedback ordering. During the game, when the player is ready to capture a clue, the control of the camera is obtained by the game interface. The captured clue is a QR image that needs different stages of filtering, positioning and decoding to result in a text format result. This result could be the game's clue, a web site, an SMS or a telephone number. The text is analysed by the game interface and the desired platform is called and the game scoring and the player's cognitive progress is updated. This game is often played between two teams, and their scores could be exchanged via the Bluetooth radio connection. Each device in the

connection can act both as a server and client in a decentralised manner to build ad hoc networks to exchange scores.

Chapter 8

Assessment and Evaluation

8.1 Introduction

Any educational programs incorporating learning games into the curriculum requires assessment and evaluation. There are different techniques that can provide educators with an insight into participants' achievements, learning outcomes and effectiveness of the program. In this research, summative assessment in a test format was used at the end of game playing sessions according to the established criterion and standards in the curriculum. The questions asked about the same content as that for the challenges presented during the game based learning process, but in a different format. The Quiz games, MOBO city package and Butterfly game were played by the students in their spare time. However the Detective game was carried out in the classroom in groups. For this game a formative assessment was also carried out during the game play sessions, which was not graded. It was utilized to provide the teacher with a diagnostic tool for the students' progress and the learning process. Students were asked to use the think aloud technique to make their thinking explicit. The on-site teacher documented the evidence of

players' learning strategies which was demonstrated in the form of dialogues between students and educators. Then this documentation was used to provide the necessary feedback to the students and adapt the next game session's content appropriately.

During the game session, students could self-assess their own progress using game scoring. Each game challenge was designed to target a certain cognitive demand with a specific learning objective in mind, which resulted in an on-going specialised scoring system accessible in the game environment. Self-assessment provided a less threatening environment for students to appreciate their weaknesses, at the same time assisting students to judge what skills they have learned and to what degree. In budget-constrained developing countries, designing self-assessment capabilities into the mobile educational games is very cost effective (see chapter 7, section 7.7). It promotes student-centred learning and has the advantage of involving students in the assessment process in ways that support their own learning as well as their development as learners.

After the gaming sessions ended the students were interviewed to determine any changes to their thinking and learning, their game play experiences and the degree of involvement they felt while playing. These questions were intended to see if there had been any positive or negative changes. These changes could provide the right setting for the game based learning when incorporated into the classroom and assisted the educators and the educational game designers with regard to the important factors and challenges involved in the process of learning and motivating in mixed reality games. It must be noted that these games have been only tested on female

students due to the teaching responsibilities of the researcher on the female-only computer engineering course.

8.2 Ethical Consultations

In order to fulfil ethical obligations to the human subjects involved in evaluation and assessments, the following matters were considered-

1. Was the data to be collected anonymously?
2. Was the data to be kept confidential?
3. Data protection-how long would the data be kept? When would it be destroyed?
4. Were the subjects of legal adult age?
5. How did they express their consent? Verbally? In writing?
6. Could the subjects opt out if they wished to?

With regard to the above questions:

1. The data was collected anonymously.
2. The data was kept confidential.
3. The overall results reported in this chapter and the data are retained (by definition). All other data was destroyed therefore this is responsible dissemination.
4. All subjects were of legal consent age.
5. Their consent has been given verbally.
6. The subjects could opt out if they wished to.

In the data collection it was concluded that:

1. No human subject was harmed.
2. No-one was embarrassed.

3. No-one was shamed.

The work was therefore compliant with the university of Bradford's Ethical policy:

http://www.bradford.ac.uk/gateway/media/Gateway/Documents/Ethics/Ethics_Policy_Jan_2010.pdf.

8.3 Data Gathering

According to the Hawthorne effect (http://en.wikipedia.org/wiki/Hawthorne_effect), the performance of the participants in an experiment could be affected by their knowledge that they are part of an experiment. It could lead the participants to modify their responses or behaviour to be in line with expectations. It is possible to avoid this effect by not informing the participants of the true nature of the experiment and observing them by means of hidden cameras or mirrors. However this could have led to ethical issues. Therefore, students were informed of the true nature of the research, but it was explained that only honest behaviour would be valuable, as this would help to (1) reveal the shortcomings of the environment which could then subsequently be improved, (2) interpret the true nature of game based learning and (3) illuminate the best approaches to implement this mode of learning in formal education.

On the other hand, our use of the conversational framework for theoretical conceptualisation of mixed reality games gave equal weight to the teacher and learner during the game process. Therefore, the teacher and distance experts were advised to take extra care in order not to influence the

participants by their own expectations of the environment, and also avoid the authority role that is often present in the traditional classroom during the learning process. This was achieved to a large extent. In addition, the teacher and the experts provided feedback as part of the story while playing themselves in the game as a game character or a team member. Thus they were perceived by the learners as collaborators in the learning process rather than authority figures.

Students that acted as the control group had access to the same amount of resource and they were expected to work on the same tasks as the game playing students. They attended classroom lectures, teachers and experts provided the same amount of time for the control group to ask questions and receive appropriate feedback. The game based group did not have access to technologies superior to the control group. The traditional classroom students had access to mobile phones with similar capabilities. However they preferred to take part in traditional methods to carry out their class tasks.

8.4 Assessing Mobile Adventure Quiz Games

In 2007 Quiz games were tested with 15 students (Fotouhi-Ghazvini et al. 2009d). Students found playing these adventure games fun and engaging; however, the multiple choice questions concerning technical English vocabulary seemed to be irrelevant and disruptive to the game process. These games performed the core function of engaging students for reasonable lengths of time, but it was obvious they were unable to involve students in any kind of learning process. These games resulted in no cognitive change. The game story did not provide appropriate metaphors or analogies for the material

presented for learning. It did not possess an integral and endogenous relationship to the multiple choice questions.

8.5 Assessing MOBO city Package

In 2008 the MOBO city game package was tested (Fotouhi-Ghazvini et al. 2009a). In these games the academic content was coupled with the fantasy/story content and the games were capable of stimulating the information-seeking behaviour. They also provided repetition and practice so that the learner would be able to use the learned information automatically and consistently. The feedback was in the context of the story, i.e. a character in the story provides the feedback.

15 students from the third year of computer engineering whose levels of English were as equal as possible were selected. They were divided into three groups, the first 5 tried to read a comprehension describing motherboard components without using a dictionary. The second 5 were asked to use the dictionary and to memorize a list of vocabularies and the last 5 were asked to play with the MOBO city game (see Table 8.1). Then, a list of vocabularies that all three groups had encountered in their tasks was presented to them and their level of vocabulary understanding together with spelling was examined.

Table 8.1 Result of how to spell...? and what doesmean? from 46 vocabularies.

Students No.	Group using reading comprehension					Group using dictionary					Group playing games				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Spelling Results	22	28	24	25	25	26	26	25	27	30	26	25	29	23	22
Meaning Results (answers in context)	9	15	16	19	13	30	25	12	20	35	41	35	43	37	31
Meaning Results (answers out of context)	-	-	-	-	-	15	12	10	12	10	-	-	-	-	-

The mean percentage for spelling result was as follows: using comprehension 54%, using dictionary 58.2%, after playing with MOBO city 54.3%. The mean percentage with regard to meaning results was as follows: using comprehension 31.3%, using dictionary 53%, after playing with MOBO city 81.3%.

8.6 Discussion Concerning MOBO city

Effectiveness

The results show that the students reading skill is very low, but using the dictionary does help (Table 8.1). However it has two main drawbacks; first, it is a tedious job and students are often reluctant to use it; secondly they often only learn the first meaning and consequently it produces out of context learning. For example, in this study the word 'nucleus' referred to 'a central part about which other parts are grouped or gathered' but in some dictionaries it is described as 'usually spherical mass of protoplasm encased in a double membrane', in other dictionaries as 'the positively charged mass within an atom' and others as 'a mass of nerve cells in the brain'. This is the result when the

vocabulary is taught out of context. Computer students in the evaluation not only had difficulty with second language learning, they also lacked some technical concepts of the motherboard and this made understanding the related comprehension very difficult for them. For example, they were not familiar with vocabularies such as: AGP, PCI, Bios, and expansion slot. MOBO city, by helping them learn the subject matter, assisted them greatly in learning technical vocabularies. Below are listed the remarks of students' observations of the game:

- *"The objective of the game was clear; we knew what was expected from us."* Gagne (1965) suggested notifying learners of learning objectives and goals is very crucial. These goals need to be offered near the beginning, must be able to be noticed and understood by the learners (Malone, 1981).
- *"The storyline was both fun and educational."* Designers need to consider integrating educational principles in the game by harmonising the game goals which are fun with learning goals which are educational.
- *"It felt real, we got feedback for what we did and we should have been ready for dangerous surprises from viruses."* In the real world we can control events and get perceptual feedback concerning what we have done, we must constantly be ready for unexpected surprises. Perhaps, when this sense of vulnerability in usual online learning is absent, our whole experience is sensed as unreal. By means of educational games we can invent virtual worlds that simulate and promote a sense of reality for students.

- *“The learning experience produced by game was neither too difficult nor too easy!”* Difficulty level is an essential characteristic in games. When a game is neither excessively difficult nor too easy, the player can achieve a pleasant game play (McFarlane et al. 2002).
- *“When playing the game I lost track of time.”* What makes game learning so distinctive from other types of learning is its essence of flow, context, control and immersion and engagement in learning, which is difficult to achieve with other types of learning.
- *“After playing a game I could easily produce its concept maps, the learning really sticks in.”* On the other hand, when the learners’ ‘heart and mind’ are captured they are cognitively and effectively connected to a learning experience.
- *“For the first time I was exposed to such a vast number of vocabulary at once, I really got to learn many words”* In a first language , as the learner encounters most words on a frequent basis in a wide range of contexts, the words are often learned incidentally in an incremental way. A large repertoire of vocabularies is formed in a short time and they consequently contribute to the building up of new words.

In this research we sought to simulate the process of implicit vocabulary learning. A selected number of high frequency words were chosen and integrated in the game to help students learn incidentally. They were exposed to a large quantity of input, a condition that otherwise was impossible to achieve for non-native speakers. A cumulative learning environment was provided; different vocabularies were continuously encountered to allow evident acquisition of every word and improved understanding of each word.

In this game we demonstrated a simplistic illustration of components and different processes of computers. It is possible to provide extra features and expand this game for the future. For example, other kinds of buses such as control bus, address bus and power bus could be implemented. The motherboard can have different components, and some motherboards are designed for multiprogramming and multiprocessing. This approach could also be utilized in other discipline areas, particularly those where there is a high degree of structure involving well-defined processes. Examples are Biology, Physics Chemistry, and Engineering, and possibly Mathematics. When adding new features and new components, new environments and characters must be designed. In the process, different storylines will evolve. Further learning content such as this can help to enrich the game further and to teach students further vocabulary.

Learners in the MOBO city game continued to make certain spelling errors, even after playing a number of times (Table 8.1 and 8.2). In other words, a communicative approach between learners and virtual space helped learners to become fluent but was insufficient to ensure comparable levels of accuracy. It seems as if a certain amount of explicit instruction focusing on language form may be necessary as well. Examples of spelling errors were:

Table 8.2 Some common students' spelling errors.

Fundamental	Fandemental, Fondemental, Foundamental, Foundmetal
Nucleus	Neucles, nucluse, newcluse, neoclus
Major	Majer, mager, majore, magor
Peripheral	pereferal, peripheral
Throughput	Trueput, trouput

8.7 Assessing Butterfly Game

In 2009, twenty students from the third year of Computer Engineering were selected (Fotouhi-Ghazvini et al. 2009d). A pre-test for 100 technical English vocabulary spelling was given to 20 students to investigate their prior knowledge and then they were divided into two groups with the same trend of scores. These students continued to make certain persistent spelling errors (Table 8.3).

The first group participated in traditional classroom teaching and studied five different comprehensions by the tutor introducing new words. The second group were asked to play the Butterfly game for a whole week. Then a list of terms, different from the pre-test, was selected from the pool of 100 vocabularies which the two groups had encountered in their tasks. A post-test was carried out to discover how much students' spelling skills had improved by each method. A paired t-test was used to compare and analyse each student pre and post test in the two groups. In the first group that participated in a traditional classroom, the mean value of pre-test was 11.20 (out of 20) and the mean value of post-test was 10.80 (Table 8.3). The result was not only an improvement but also the technical vocabularies were very challenging. The

two-tailed P value was 0.5830 which was more than 0.05. This difference therefore could not be considered to be statistically significant.

Table 8.3 Students' scores before and after (a) traditional classroom instruction and (b) Butterfly game learning (B).

	Student	Pre-Test	Post-Test		Student	Pre-Test	Post-Test
A:	1	15	16	B:	1	7	14
	2	8	5		2	7	16
	3	11	13		3	8	13
	4	12	10		4	12	17
	5	7	4		5	13	18
	6	13	12		6	15	20
	7	14	15		7	14	19
	8	9	11		8	16	20
	9	10	12		9	15	20
	10	13	10		10	12	18
	Mean	11.20	10.80		Mean	11.90	17.50

In the second group that played with the Butterfly game, the mean value of pre-test was 11.90 and the mean value of post-test was 17.50, which was a considerable improvement. The two-tailed P value was less than 0.0001 which was therefore considered to be a statistically significant result in instruction.

8.8 Discussion Concerning Butterfly Game

Spelling errors are problematic for students in the reading, writing and listening sections of their exams. However, tutors are unwilling to concentrate on the 'rules' which is appropriate for spelling. This is because many exceptions and notions exist in English spelling.

Progress in spelling skill can be very slow for engineering students who otherwise are well motivated and generally good learners. By engaging

regularly in this enjoyable game, students improved their spelling skill significantly. They were willing to devote regular time to spelling and gradually gained understanding of features of spelling such as double letters, silent letters and unusual spellings. The over-rehearsing and repetition created a cognitive environment which periodically reminded students of different words as they played different games, allowing them to supplement their initial learning.

8.9 Assessing the Detective Game

In 2010, thirteen students from the third year of Computer Engineering were selected (Fotouhi-Ghazvini et al. 2011d). At first, the electronic concepts of the computer's central processing unit were taught in English via a comprehension during traditional classroom sessions. Then a pre-test was taken to investigate students' knowledge of technical English vocabulary, considering 'vocabulary meaning', 'spelling', 'word form' and 'electronic knowledge'. These skills were examined at different cognitive levels; the questions were designed according to the Bloom taxonomy of learning objectives (see Appendix E).

Then the participants took part in playing the 'Detective Alavi game that was intended for improving the students' technical vocabulary. The English game sessions lasted 2 hours for duration of six weeks. The games were played privately in a classroom. The teacher integrated the game as part of a lesson, letting students play one level of the game at each session for them to become familiar with the CPU structure, its functions and key technical vocabularies. Puzzles were printed by the teacher and supplied to the students (see Appendix C). Students were typically free to move around, as long as they

did not exceed a 10 metre distance between their devices (to ensure Bluetooth communication). The game play was also extended to the different rooms of the university building with computer rooms. Puzzles were distributed throughout the building hidden in different locations in each room. During the execution, rooms were chosen to show as close a resemblance to a room in the space as possible. Players could find clues using guidance from the game background layout and virtual space's characters. People from the real world such as university staff and other students became part of the game at some stages, making conversation with the players or providing extra assistance.

When the game sessions' period ended, a post-test was taken by the students (see Appendix E). It was then analysed to see whether there had been any differences between the pre-test scores and the post-test scores. The paired t-test was used to compare and analyse each student's pre and post-test. Some students' skills had developed more and others improved less. But on average there was a substantial improvement (see Appendix D).

Considering different skills the mean percentage of 'Electronic Skill' has improved by 53.25%, the 'Word Meaning Skill' by 34.8%, the 'Word Form skill' by 24.69% and the 'Spelling Skill' by 19.23% (see Table 8.4). The two-tailed P value for all skills was 0.000 which was less than 0.05. This difference was considered to be statistically significant.

Table 8.4 Students' score statistics and paired test (t-test) for technical language skills

	Meaning Skill Before Game Play	Meaning Skill After Game Play	Spelling Skill Before Game Play	Spelling Skill After Game Play	Form Skill Before Game Play	Form Skill After Game Play	Electronic Skill Before Game Play	Electronic Skill After Game Play
Mean Percentage	44.10	78.97	45.51	64.66	48.58	73.27	32.54	85.79
Percentage Increase in Mean	34.87		19.23		24.69		53.25	
P Value or Significance Sig.(2-tailed)	0.000		0.000		0.000		0.000	

The detective Game has gradually improved the students' reporting skills from level 1 to 5. It has increased the mean percentage 'Reporting skill' at level 1 by 1.53%, at level 2 by 10.76%, at level 3 by 32.30%, at level 4 by 41.53% and at level 5 by 61.53% (see Table 8.5). The two-tailed P value in level 1 and 2 were 0.337 and 0.068 which were more than 0.05 and not statistically significant. In level 1 and 2 students still lacked the necessary reporting skills. At level 3, 4 and 5 the two-tailed P value was .000 which was less than 0.05. It means there was a statistically significant improvement on reporting skill.

Table 8.5 Students' score statistics and paired test (t-test) for technical reporting (i.e. writing) skill.

	Report 1 Before Game Play	Report 1 After Game Play	Report 2 Before Game Play	Report 2 After Game Play	Report 3 Before Game Play	Report 3 After Game Play
Mean Percentage	23.07	24.61	33.84	44.61	23.06	55.38
Percentage Increase in Mean	1.53		10.76		32.30	
P Value or Significance Sig.(2-tailed)	.337		.068		.000	

	Report 4 Before Game Play	Report 4 After Game Play	Report 5 Before Game Play	Report 5 After Game Play
Mean Percentage	20	61.4	16.92	78.4
Percentage Increase in Mean	41.53		61.53	
P Value or Significance Sig.(2-tailed)	.000		.000	

This game has improved all cognitive processes. It has increased the 'Remembering' cognitive process by 43.58%, the 'Understanding' cognitive process by 21.97%, the 'Applying' cognitive process by 30.76%, the 'Analysis' cognitive process by 20.51% and the 'Evaluation' cognitive process by 56.15% (see Table 8.6). This improvement was especially evident when the students utilized the game for the critical thinking in level 5. The two-tailed P value at all

levels was .000 and less than 0.05 which means a statistically significant improvement has taken place at all levels.

Table 8.6 Students' score statistics and paired test (t-test) for cognitive processes

	Remembering Power Before Game Play	Remembering Power After Game Play	Understanding Power Before Game Play	Understanding Power After Game Play	Applying Power Before Game Play	Applying Power After Game Play
Mean Percentage	46.15	89.66	47.78	69.71	40.64	73.57
Percentage Increase in Mean	43.58		21.97		30.76	
P Value or Significance Sig.(2-tailed)	.000		.000		.000	

	Analysis Power Before Game Play	Analysis Power After Game Play	Evaluation Power Before Game Play	Evaluation Power After Game Play
Mean Percentage	54.39	76.37	29.23	85.38
Percentage Increase in Mean	20.51		56.15	
P Value or Significance Sig.(2-tailed)	.000		.000	

All students (denoted by Sts) experienced an increase in their test results. The rise in the test scores amongst different groups was Group 1 (St 1, 2, 3 and 4) by 32.19%, Group 2 (St 5, 6 and 7) by 37.28% , Group 3 (St 8, 9 and 10) by 22.87% and Group 4 (St 11, 12 and 13) by 32.19%. St10 had withdrawn from playing the game at level 2. Her timetable was different with the

rest of the group and the game sessions had overlapped with her other course unit lectures.

Table 8.7 Students' score statistics and paired samples test (t-test) for each students total test result and game score

Group Numbering	Students	Students' Result Before Game Play Max = 59	Students' Result After Game Play Max = 59	Percentage Increase in Results	Game Score Max = 59
1	St1	28	47	32.20	49
	St2	24	43	32.20	49
	St3	27	47	33.89	49
	St4	27	45	30.50	49
2	St5	26	46	33.89	57
	St6	12	40	44.07	57
	St7	35	55	33.89	57
3	St8	20	34	23.72	37
	St9	22	35	22.03	37
	St10	32	34	3.38	-
4	St11	34	50	27.11	52
	St12	32	48	27.11	52
	St13	30	48	30.50	52
	St14	17	43	44.07	52
Results Analysis N=13	Mean	25.69	44.69	31.93	49.92
	Mean Percentage	43.54	75.74		
	Mean Difference	19.00			
	Percentage Increase in Mean	32.20		Group 1=32.19, Group 2= 37.28, Group 3= 22.87, Group 4= 32.19	
	Standard Deviation	6.67	5.80		
	P Value or Significance Sig.(2-tailed)	.000			

The more advanced students helped students with lower language skills to improve. If the team scored higher in the game as a group, they achieved

higher test results compared to the groups with a lower gaming score. The Pearson correlation test was performed regarding the students' game score with their post test results. The correlation coefficient was 0.731 which was positive and it indicated that there was a direct relationship between the total game score and the test result. The relationship was strong because it was more than 70 % of its possible value (i.e. the coefficient maximum value is 1 or -1). The game scoring that was achieved in the game play appeared to be an important predictor of the students' individual test results. Our sample accurately reflected the relationship between the game scoring and the students' results from which the sample was drawn. The probability value was 0.004 which was well below the conventional threshold of $p < .05$. Thus, our hypothesis of a direct relationship between game scores and students' post-test result was established.

15 students were assumed as a control group from the same class as the game playing students. They were provided with a comprehension test that contained the game's text content. A group of multiple choice questions were used similar to the game puzzles but without the QR codes. A separate paper was supplied that contained the phone numbers of experts and the necessary web links that were supplied to the game playing students. A pre-test and post-test similar to our experimental groups were taken. The paired t-test was used to compare and analyse each student's pre and post-test. The mean value of pre-test was 25.93 (out of 59) and the mean value of post-test was 26.53. The result was only a small improvement with 1% percentage increase in the mean. The two-tailed P value was 0.4202 which was more than 0.05. This difference could therefore not be considered to be statistically significant.

8.10 Discussion Concerning Detective Game's

Assessment

The effectiveness of the detective game seems established. The new pedagogical approach was compared with the conventional method by using quantitative analysis. The learners individually took part in pre and post-tests that required them to give detailed answers to a series of questions about a computer's CPU. The questions had been divided into five sections, each representing a different cognitive process. The learners learned at a higher level in the game based learning compared to the traditional classroom. It produced a deep understanding of electronic concepts and the meaning of vocabularies during the discussions and also applying their previously learned knowledge in new situations. The improvement was lower in level 2, 3 and 4 because these levels had a greater focus on spelling or word forms. This game was more suitable to improving student's electronic skills and word meaning skills by encouraging them to think deeply and collaborate with their peers and teachers. Learners' reporting skill which referred to their '*creating*' skill has improved gradually; this skill has been assessed during the game play (see section 8.11.4). This confirms that writing restructures knowledge (Marzano 1991), improves thinking by making ideas explicit (Applebee 1984) and contributes to critical thinking (Kurfiss and Ashe 1988, Langer and Applebee 1987).

8.11 Observing Students' Learning Processes during the Detective Game Play

Normally during a technical English class, students have been passive and quiet and rarely engaged in discussions. When the game sessions first started students felt reluctant to work collaboratively but gradually they succeeded in integrating the appropriate skills with the aid of game narrative, graphics, QR puzzles, distance experts and their teacher. The Detective game's puzzles promoted thought stimulating questions and these problems stimulated further questions. They often led students to look for the different sources of information and also motivated students to deal with the complexity of the problems with the help of more competent peers and resources available.

8.11.1 Remembering level

Their communication at level 1 was in monologue form where each member spoke their ideas by remembering important vocabularies, recognising and listing embedded facts. They retrieved and searched for further information in the game's virtual space with the help of the on-site teacher. Signs of 'surface level processing' were present in some of the learners where they only focused on guessing the right answers, or asking the teacher for the answer. However the teacher encouraged them to further research the game environment to make them think further by exploring the full capacity of the game. The following dialogues have been extracted from students' conversations at level 1:

8.11.1.1 Recalling and remembering

St1: Ms what does 'manipulate' mean in Farsi? (Asking the on-site teacher)

Teacher: You have already seen this word!

St2: I remember the word 'manipulate' from puzzle one. I am sure A is the wrong answer.

St3: Just by looking at the answers it tells you which one is correct! I go for option C (surface level processing)

St3: Oh it is wrong!

Teacher: Why do you think option C was wrong?

8.11.1.2 Recognising

St3: I know what 'engrave' means, we have seen it in puzzle 2, it means 'to implant'!

St1: Ms what does 'elaborate' mean? (Asking the on-site teacher)

Teacher: Look at the previous puzzle!

St2: We have already seen 'elaborate' so cross that out.

St1: Option B is the answer; this is my gut feeling (surface level processing)

8.11.1.3 Listing

St1: What did the last couple of robots tell us about different kinds of registers?

St2: I think I am kind of confused...

St3: Ok we can skip to the last puzzle, and talk to the robots again.....

St2: Don't waste time looking things up! (Surface level processing)

Teacher: I suggest you to go back to the game and research further!

St3: Look! There are 4 registers: 'address register', 'data register', 'program counter' and 'accumulator'.

8.11.1.4 Describing and retrieving

St1: Ms what is a 'binary system'? I can't find it in the 'Language Academy'!
(Asking the on-site teacher).

Teacher: Try 'Intel Corporation'!

St1: No I can't find it there.

Teacher: Let's see if we can find it by trying this link; you have to go to the camera and take a shot of this QR code.

St3: Oh camera failed!

Teacher: Let me try, don't shake your hands, it needs good exposure to light..., now it is opening the website.

St2: I have never worked with the mobile web...

Teacher: It is not much different; this is how it works.....

St1: Here it says: 'Binary system is'.

St2: Oh I know it is our 'dodoi (in farsi) 0 and 1 system!'

8.11.1.5 Naming

St1: What did that 'star' next to the computer say?

St2: MHz is million frequency waves per second

St3: So the missing word here is 'frequency'.

Teacher: Excellent!

8.11.1.6 Finding

St1: We can find the meaning of manipulate from the Language Academy.

St2: Let's just enter the answer, no need to find anything (surface level processing).

Teacher: I suggest you research further!

8.11.2 Understanding level

In level 2 the on-site teacher has stepped in and acted as a member of the group, and she encouraged students to talk to each other by asking questions. Students practiced the meaning and spelling of the vocabularies (Appendix C, section C.7-C.9). However when they were asked to choose the correct order of operation in the CPU Complex in puzzle 9 (Appendix C, section C.9), most conversations were evoked. They became involved in explaining, interpreting, summarising, paraphrasing and classifying the facts. The following dialogues were extracted from students' conversations in level 2:

8.11.2.1 Explaining ideas or concepts

St1: 'CPU and its caches share the same 64-bit interface',

Teacher: What is this interface?

St2: I think it refers to the data bus between cache and CPU.

Teacher: Would you please explain that again? I don't think I understood this fully.

8.11.2.2 Interpreting

St1: Clock cycle refers to the execution of instructions in CPU.

Teacher: How did you deduce that?

St1: I deduced this from the 'clock speed' definition in the 'Intel Corporation'.

8.11.2.3 Summarising

St2: Puzzle 9 needs us to find the correct order of operation in the CPU Complex.

Teacher: What do you suggest we do St3?

St3: I think we need to go back and make a summary of bus interface unit, branch target buffer, fetch/decode unit, execution unit, dispatch/execute unit, jump execution unit, retirement unit.....

St1: Come on, let's get moving...

8.11.2.4 Paraphrasing

St1: I can't fully understand 'when it finds a μ op ready to process, the unit executes it'.

Teacher: Can you help us with this sentence St2?

St2: In other words the 'dispatch/execute unit' temporarily stores the results of executions.

St3: Execution of the micro-operations....

Teacher: So you are saying that.....

8.11.2.5 Classifying

St1: How can we classify the 'dispatch/execute unit', 'retirement unit', 'jump execution unit' and 'prediction unit'?

St2: Retirement and prediction unit are inspector, they inspect the executions but the other two execute the micro-operation.

Teacher: St3, What is your opinion?

8.11.3 Applying level

In level 3, communication gradually turned into dialogue and students managed to maintain a group conversation. A Bingo like game was incorporated which required deducing the correct vocabularies' synonyms. They also had to choose an option which associated the appropriate processor's components to their

correspondence operations (Appendix C, section C.11.1). At this stage they used the game resources automatically. They shared concepts and opinions by exchanging ideas, asking questions, giving the correct direction, encouraging or supporting each other, elaborating other member's explanations, relating to the previously learned materials and using the tables and diagrams. The following dialogues have been extracted from students' conversations in level 3:

St2: How we have to approach this puzzle?

St1: Let's see what the Dr Athlon has to tell us....

St3: We have to work through this logically; he has provided us with this diagram...The decoder converts instruction to macro-bytes.

St2: And Mr 'Register' explained how the ROB manages the execution and management of macro-bytes,

St3: Well done!

St2: But what about FPU 3D?

St3: I don't know! But let's keep working!

St1: I think it has something to do with multimedia.

St3: Sounds right!

St1: I suggest we hold off making a decision until we have examined all our options. If we look at this link we visited last week we will get a better idea.

St2 – Let's see what we have missed?

8.11.4 Analysing level

In level 4, Students practiced the word forms through a QR board game (Appendix C, section C.14.1). Then they utilized tables from different

processors' specifications to discover the processors' capabilities (Appendix C, section C.15 and C.16). Their dialogue turned into comparing, organising and deconstructing information from different resources to help them analyse different problems. The following dialogues have been extracted from students' conversations in level 4:

8.11.4.1 Comparing, organising and deconstructing

St1: Ms is it possible to tell us a brief history of the microprocessor? (Asking the on-site teacher)

Teacher: You can ask the Intel CPU's expert by making a phone call!

St1: Let's call the 'Intel' expert to give us a brief history of the microprocessors.

St3: What is the actual question here?

St2: We want to know about clock speed and MIPS.

St2: Could you please tell us more about the clock speed and MIPS... (talking)

'Intel' expert: Dr Intel suggests if you look at the table, you can compare 8088, 80386 and 80486 MIPS values...

St1: Let's see what are our facts?

St3: 80286's value is 1.

St2: Why did you make this choice?

St3: 3 and 4 are too big!

8.11.4.2 Interrogating and finding

St1: Dr Athlon and Dr Intel have already told us about those processors. Let's call the expert to find more information about Duron, Opteron and Itanium.

St1: Which one of these processors has the capability to address 1 Terabyte (TB) of memory?

St2: What is one Terabyte?

St3: If you look at the table it is 10^{12} Bytes...

St1: Lets ask the expert how to calculate this...(calling)....(talking)

Expert: You have to look at the each processor's address bus value.

St3: If we use both tables the answer is 'Opteron'. Because...

40 bit address bus: $2^{40} = 1,099,511,627,776$ byte = 1 TB

8.11.5 Evaluating level

Finally in level 5, students made decisions based on in-depth reflection, criticism and assessment about word forms (Appendix C, section 17.1) and complex CPU operations (Appendix C, section 17.2). The communication became dialectic where they started to manage cognitive conflicts by criticising and evaluating each other's ideas, integrating different opinions and participating in debates and enquiries. Students expressed their views, listened to others, asked relevant questions purposefully and judged the understanding of the group. The following dialogues are extracted from the students' conversations in level 5:

St3: Let's get moving! Detective Alavi really needs this clue! Do you know how Quad compares with dual?

St2: Let's call the expert to clarify the advantages and disadvantages of Quad and dual core.

St1: Ringing CPU expert.....talking.....Is it possible for you explain to us how a dual core of 2.8Ghz has lower performance than a quad core with 2.5Ghz?

Expert: 'Professor Speedfast' has told me that you will notice quite an improved performance on a quad, especially if the software is adapted to using it.

St3: But the dual core has the higher clock speed!

Expert: In Dr Athlon's opinion, when Quad core is switching between threads it makes better use of the available resources.

St2: Does she think we will ever see more than 2.8 GHz?

Expert: No, she says the cooling system is an important factor.

St2: Future is multicore, isn't it true?

St3: this is doubtful!

St2: Still I suggest to Professor 'Multicore' if he wants to modernise the CPU complex, it is better to buy Quad core, things change quickly.

Expert: I will pass on your message!

St1: I understand 4 cores means doing 4 things at the same time. 1 core means one thing at a time. If we have a program written for 1 core surely this must execute faster in quad core?

Expert: Professor Multicore thinks it causes massive problem, each core wants to execute part of the problem, they all get kind of confused!(laughing not giving the answer) this is as far as I can help you guys! Mr Inspection is calling me! Bye for now!

St1: We can try the first link, it is about the 'Intel Core 2'.

//St1, St2 and St3: reading the website.

St1: The website has all the technical staff about the dual code, but does not giving anything on the two CPU's comparison.

St2: Here it says: 'Intel's CPUs have varied widely in power consumption according to clock rate, architecture, and semiconductor process'

(http://en.wikipedia.org/wiki/Intel_Core_2#Kentsfield)

St1: It is kind of confusing! We can't compare them on one or two factors.

St2: May be one core does all the jobs and the others just watch. Then quad core will have 0% advantage!

St1: OS is important too, if it is quad core friendly or not. Perhaps 1 core runs the application and the other cores do input and output, still I believe Quad outperforms dual.

St3: No, I still believe if the application is single threaded more cores will not affect performance

St1: I don't agree with you, I have a quad core Intel when I run single threaded games all four cores are active. One core is more active than others, but still the other cores are active.

St2: Is there any other programme running?

St1: No

St3: I don't think OS can split the threads. The thread does the job.

St1: I remember Professor 'Multicore' said in a multicore system, OS distributes the threads.

St2: It distributes different threads to different cores, not splits one thread in pieces!!

St3: We had better go for answer C.

St2: OK

St1: I respect you guys but I don't agree with your approach, I think 'a' is correct.

St3: We had better check this link from Wikipedia to prove it to you.

St3: Here down below it says: 'An out-dated version of an anti-virus application may create a new thread for a scan process, while its GUI thread waits for commands from the user (e.g. cancel the scan). In such cases, a multicore architecture is of little benefit for the application itself due to the single thread doing all heavy lifting and the inability to balance the work evenly across multiple cores.' (Wikipedia http://en.wikipedia.org/wiki/Multi-core_processor)

St1: I rest my case. You have done enough to prove it to me.

8.12 Discussion Concerning Students' Learning Processes during the Detective Game

Two experts at a distance participated during the game play, both Computer Engineering PhD students with good English language skills. They were encouraged to take part in students' dialogues in English whenever called. This was carried out by pointing out the problem, providing interesting examples and posing provocative questions within the story's theme. They encouraged students to learn from each other and did not give the answers directly. At the same time, they kept the conversations short and to the point because the game was still part of the classroom space. Students' conversations were in both Farsi and English.

A deep level of understanding was present in levels 3, 4 and 5 when students worked on the puzzle with more provocative questions that examined the students' applying, analysing and evaluating power. In these challenges, students made plans to solve problems, used diagrams, suggested ideas,

connected ideas logically, used their past experiences and changed or refined their opinion in the process. QR word search and board games seemed to create a more cheerful and relaxed environment. Conversations drifted to more general dialogues which represented the social development processes rather than cognitive ones. It benefited the students' bonding rather than deep processing.

The Detective game has solved the instructional problems of augmented reality games that have been mentioned in the literature (Fotouhi-Ghazvini et al. 2009 b, Klopfer 2008 and Facer 2004). The shortcomings were solved by introducing:

- (1) A hierarchy of learning and use of previously learned knowledge
- (2) Enough attention to each cognitive process
- (3) Added levels and challenges that were detailed and specific
- (4) A game which liberated the learners to access a wide range of different resources.

During the game sessions the learners appeared to be constantly moving in and out of reality and blurring the distinction between real and virtual. The game virtual space and the experts at a distance maintained the fantasy aspect of the game, while the websites and their previous educational or life experiences brought them back to reality. This periodic experience of realism and fantasy helped the game play to maintain the necessary control and the flow of learning in an authentic, meaningful and contextual environment.

8.13 Self-Assessment

In game environments players might develop wrong intuitions by haphazardly diving into the game. They do not know when their hypothesis is correct and when it should be discarded. The presence of some kind of assessment with game rules that examines a wide range of skills and knowledge appears to be necessary (Fotouhi-Ghazvini et al. 2009 b, Klopfer 2008 and Facer 2004). However, direct surveillance of students' work could inhibit their intrinsic motivation and reduce their sense of control. Adding a self-assessment system in game scoring could assist students to evaluate their own actions in a non-controlling environment. On the other hand, teachers need to use continuous assessment to supply them with consistent, accurate and useful information during each game session. In normal classroom assessments, the results are collected too late and they are only used for student's grading. During the teaching sessions teachers have no idea if students have actually learned. The end of term results often is disappointing to teachers and there is a large gap between what is taught with what is learned. Thus the teachers have little or no influence on the learning process and cannot remedy the student's gap in knowledge because they have no real-time information about this.

To design a self-assessment system, the teacher should have clear vision of learning goals and construct challenges appropriate to the academic standards required. Then proper criteria must be allocated to help the fair assessment of the learners' performance for appraisal and scoring purposes. Incorporating multiple choice questions that provoke reasoning not only could lead to deep level learning but also present answers in a concrete format to the

learner and ease the analysis process. In this game, all the puzzles had multiple answers to choose from. This self-evaluating system was seamless and met the particular need of students that used the game.

8.13.1 The Detective game scores' screen

Self-assessment in this game was in the form of scores, skills gained and cognitive progress. Figure 8.1 shows how players could check their progress during the game. They can choose 'Skill-Score-Cognition' option from the game's main menu to access screen in Figure 8.1 (a). From Figure 8.1 (a) all the necessary screens for self-assessment are accessible. These screens are Figure 8.1 (b), 8.1 (c), 8.1 (d) and 8.1 (e) respectively.

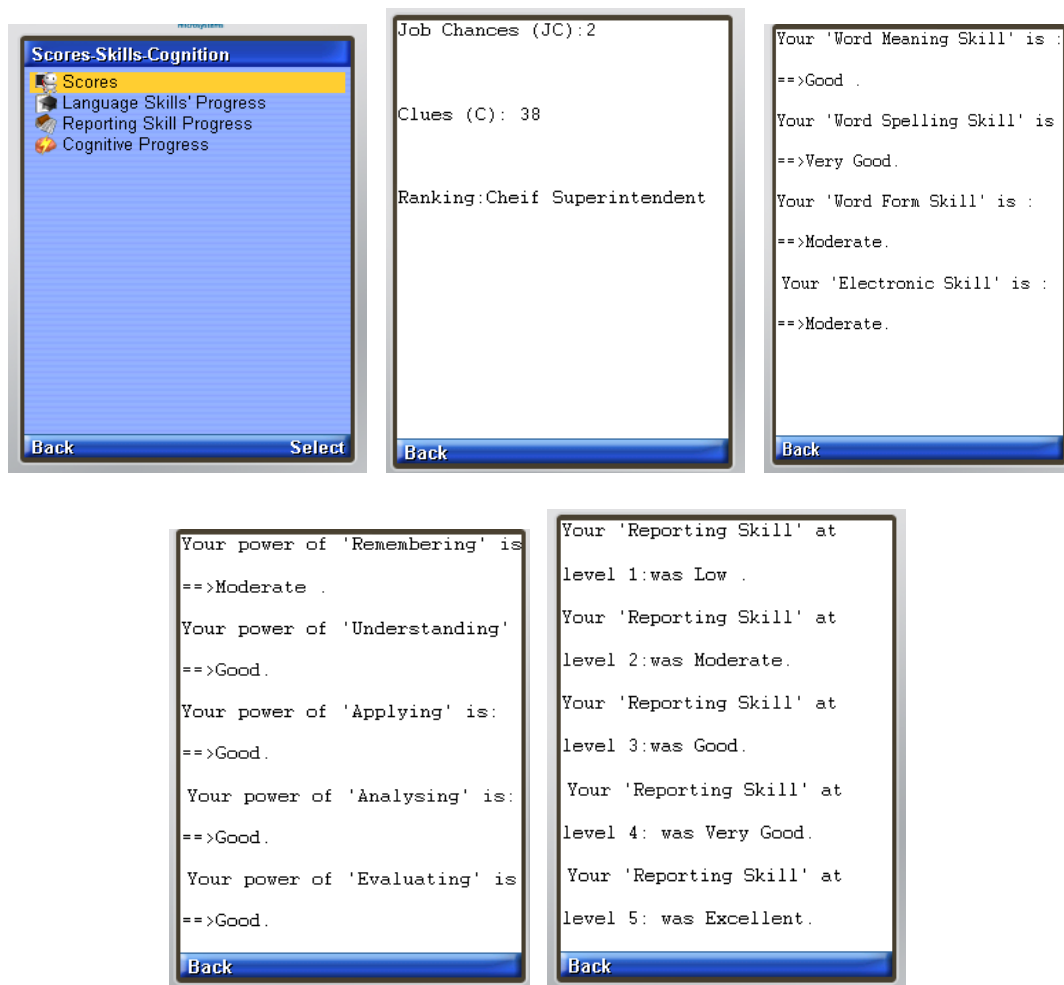


Figure 8.1 (a) scores-skills-cognition screen (b) scores screen (c) skills' progress screen (d) cognitive progress screen (e) reporting progress.

In this game, the player constantly builds on his/her previous scores, so having a high score list is not necessary. However he/she can keep track of the clues, job chances and detective Alavi's job ranking. A player constantly discovers clues by answering different puzzles. A player starts with 3 'JobChances', each time he/she chooses 'Solve Cryptogram' from the main game canvas's option menu to present his/her clues could win the game or loose 1 'JobChance'. The player loses all his/her 'JobChances' after 3 wrong guesses and loses the game. 'Camera' option is available in the game's option menu to capture the right answer which encompasses the clue. 'Camera' refers the player to a QR puzzle which is printed on a sheet of paper. The player collaborates with other players, asks advice from the experts via a phone call or SMS or uses a website to solve the QR puzzle. The camera captures the clue and the number of 'Clues' increase by one after each correct guess.

The total percentage of skill gained and the rank of the player at any instance in the game could be calculated when any of the two conditions were met:

- (1) A certain number of clues were found.
- (2) Certain points were gained for reporting skill.

Table 8.8 Calculation of the percentage of total skill gained so far and current player's rank

Number of discovered clues	Reporting points gained	Percentage of total skill gained so far	Job ranking
0-3	0-5	0-20%	Inspector
4-13	5-10	21-50%	Chief Inspector
14-27	10-14	51-65%	Superintendent
28-41	15-18	66-75%	Chief Superintendent
42-54	19-21	76-85%	Assistant Chief Constable
55-59	22-25	86-100%	Deputy Chief Constable
<i>Guessing the cryptogram correctly and trying all the lower game levels and discovering at least 55 clues and gaining at least 22 in reporting skill</i>			Chief Constable

8.13.2 Language skill's progress menu

There were different kinds of clues that were included in each game level. Clues were categorized according to the type of skill gained: 15 clues for *meaning skill*, 12 clues for *spelling skill*, 19 clues for *form skill* and 13 clues for *electronic skill* (Appendix C, C.19).

Using the table below shows that appropriate feedback was selected for each kind of skill.

Table 8.9 The number of discovered clues and their appropriate feedback to players for each skill.

	Type of Feedback					
	Very low	Low	Moderate	Good	Very good	Excellent
Number of clues discovered from 'Word Meaning' challenges	0-3	4-7	8,9	10,11	12,13	14,15
Number of clues discovered from 'Word Spelling' challenges	0-2	3-6	7	8,9	10	11, 12
Number of clues discovered from 'Word Form' challenges	0-4	5-9	10-12	13,14	15,16	17-19
Number of clues discovered from 'Electronic skill' challenges	0-2	3-6	7,8	9	10,11	12,13

8.13.3 Cognitive progress menu

Each game level targets a separate cognitive level of *remembering, understanding, applying, analysis and evaluating cognitive progress* (Anderson and Krathwohl, 2001). The total number of clues in each level provided the specific level's degree of strength, the table 8.10 shows the process of score allocation and corresponding feedback.

Table 8.10 The number of discovered clues in each level and their corresponding feedback to the player.

	Type of Feedback					
	Very Low	Low	Moderate	Good	Very Good	Excellent
Level 1- Remembering Number of Clues	1	2	3	4	5	6
Level 2 – Understanding Number of Clues	1,2	3-5	6-8	9,10	11,12	13,14
Level 3 – Applying Number of Clues	1,2	3-5	6-8	9,10	11,12	13,14
Level 4- Analysis Number of Clues	1,2	3-5	6-8	9-11	12,13	14,15
Level 5- Evaluating Number of Clues	1	2,3	4,5	6,7	8,9	10

8.13.4 Reporting skill progress

At the end of each game level the ‘Read Report’ item could be selected from the game menu which represented Bloom’s sixth level of cognitive progress i.e. ‘*Creating*’. This option involved students’ in writing a report concerning their game experiences, the game’s learning objectives, and a solution to each of the challenges. A list of ‘learning objectives was presented from the main menu’s ‘Learning Objectives’ item. The actual account of each learning object is narrated by dialogues that are carried out amongst the virtual characters and between teachers and students. When the players select the ‘Read Report’ a phone call is activated to a teacher at distance and a secret code will be provided according to the players’ achievements in understanding the topic. This code provoked any of the six feedbacks: ‘very low’, ‘low’, ‘moderate’, ‘good’, ‘very good’ and ‘excellent’. Each feedback was assigned its specific gain in the ‘Reporting Skill’ screen.

Table 8.11 The secret code in each level and its corresponding feedback to the player.

	Type of Feedback					
	Very Low	Low	Moderate	Good	Very Good	Excellent
Level 1- Remembering Secret code	20	12	18	16	14	10
Level 2 – Understanding Secret code	28	24	26	29	30	21
Level 3 – Applying Secret code	32	37	33	40	39	34
Level 4- Analysis Secret code	41	46	50	44	47	48
Level 5- Evaluating Secret code	51	60	53	59	52	56

8.14 Teacher’s Observation during the Detective Game

The detective Alavi game appeared to be successful from the point of view of the teacher. It met the teacher’s needs by motivating and assessing students continuously. The teacher could use their skills and creativity to guide the discussions according to the specific groups’ requirements. It provided a framework that could be customised by nontechnical procedures. The following observations were mentioned by the on-site teacher about the Detective game:

- **Possessed Customisable Framework:** *The game had an adjustable pace; depending to different groups’ abilities and lecture timetables the duration of play could be changed.*
- **Established Boundaries:** *The game helped to organize the class during the collaborative assignments. Students were encouraged to socialise*

whilst at the same time they were prevented from stepping out too far from the boundaries of the learning objectives.

- ***Improved Behavioural Engagement:*** *Learners' level of attendance, participation and completion of tasks was much higher than in the conventional classroom where they often seemed to be disengaged and uninterested.*
- ***Encouraged Autonomy:*** *Students were no longer passive; they were more participative and started to take responsibility for their own education. The games stimulated the learning and students solved puzzles, argued over a language problem and produced reports at the end of each lesson.*
- ***Division of Tasks:*** *Despite the fact that students were encouraged to share a mobile phone between three, they often desired to have their own mobile phone and divided the tasks between themselves. Games have been installed in most students' mobile phones, but those with older devices that could not install the games borrowed a device from a friend for few hours or from one of their family members for a day.*
- ***Amplified Emotional Engagement:*** *The general atmosphere of the classroom seemed to be enthusiastic, focused and busy. Students gradually learned to work towards joyful discoveries as I was not present in the class. This was contrary to the normal classroom situation where I often feel I have to involve students in work that they are not interested in, presenting them constantly with prizes and punishments.*
- ***Assisted Progress Monitoring:*** *The assessment system facilitated monitoring of the student's progress and it saved time on collecting the*

students' responses and analysing them. I have built an on-going communication loop with students providing them with appropriate feedback. This was due to the fact that I was empowered at all stages of the game to examine:

(a) How students were responding to the learning environment?

(b) How students were doing at initial or intermediate stages?

(c) What were the students' current abilities or gaps in knowledge?

(d) How to help students with early appropriate feedback?

(e) How to improve from the next level of game and provide more information on skills that were yet unsatisfactory?

- **Assisted Self-Assessment:** *The assessment system had also assisted students to discover their weaknesses and strengths continuously during the learning session - anonymously and in a stress free environment. They were encouraged to take the responsibility for working on correcting themselves and focussing themselves on the syllabus standards. I have usually observed the following statements when students checked their progress:*

- *I think our 'spelling' is good!*

- *We seem to be confused about the meaning of technical words.*

- *I think it is necessary to improve our electronic knowledge. It is useful to visit this web site.*

- *We need to learn more about the word 'form'. We have to play that board game again.*

- *I am going to spend more time studying word meanings.*

- *Look! Our analysis power has increased!*

8.15 Discussion Concerning the Learner's

Observation

Engagement is a fundamental requirement for any learning to occur. In this game the behavioural engagement has been increased. Students paid more attention to the tasks with their full capacities over an extended period of time with persistence. They were emotionally involved and showed interest and enthusiasm. They expressed their thoughts, asked questions and offered suggestions. The game framework has provided a wide scope for the learners to speak, read and listen. Learners had plenty of opportunities for action, thought and appropriate use of language which resulted in autonomous learners which were in charge of their learning and felt responsible for outcomes. This autonomy and engagement indicated intrinsically motivated learners and resulted in better learning. Learners also monitored their progress and evaluated their achievement using self-assessment features of the game. The self-assessment increased the metacognition behaviours amongst the learners. Students regularly monitored and evaluated their own progress towards certain educational goals. They also planned specific steps and strategies to improve their weaknesses, correct their cognitive process and enhancing their performance. The use of metacognition strategies by the students has been mentioned by many researchers as an important variable during thinking processes (Swartz 2003, Luckey 2003, Halpern 1998 and Facione 1990). Halpern (1998) has identified the metacognition process as a crucial element during critical thinking.

8.16 Students' Opinions on Changes in their Thinking after Playing Detective Game

When students are faced with obstacles they often experience self-doubt and think of themselves as incapable. The Detective game has helped the students to gradually build their confidence. The complexity of the learning process seemed less threatening and they did not depend on the authority of the teacher as much. When students were asked '**Can you tell me how the game has affected your thinking?**' the following responses were given:

- **Game Learning Effectiveness:** *At the beginning I thought playing the game was a waste of time, so I did not expect much. But now I would like to see more of these games. They will assist me to get a broad view of the subject and lots of practice.*
- **Importance of Authentic Environment:** *Vocabularies need to be learned in the environment that they are applied in order to like this game, not memorising them from a dictionary. I would recommend this mobile game to my other friends; I was impressed with the course.*
- **Mental Support System:** *Our weekly game plays were like an academic- personal support system. My co-players were important elements of the game. I felt my peers wanted me to learn.*
- **Improved Collaborative Skill:** *I will try to listen more to the team members' opinions and understand them, even if I hold opposite points of views; I can always reject their ideas later.*

- **Improved Collaborative Skill:** *Everyone is responsible for the group work; no one should hitchhike on the work of others and get a free ride. Everyone has a special talent and can use it to move the team forward.*
- **Competition:** *Playing against the other team was a valuable experience to prepare us for the pressure of our future professional life.*
- **Improved Autonomy:** *I will try to stay well informed about the computing topics through games, speaking with knowledgeable people and reading specialised websites.*
- **Improved Autonomy:** *I will keep working on the difficult comprehensions, even if they are tough. I will do proper research through the available options for example dictionaries, websites, teacher and different knowledgeable people until I figure it out.*
- **Improved Confidence:** *I feel more confident in my language skills. No matter how difficult the text is, I can comprehend it by working with my friends that are good at English. When we work in a group it is easier to accomplish difficult tasks.*
- **Improved Metacognition:** *Now I know it is important to continuously check my language progress and read different comprehensions and play lots of language games.*
- **Improved Metacognition:** *I am more aware of my language weaknesses. I feel I have to learn the basic vocabularies first - for example their meaning, spelling etc. Through games I will then be able to understand computing textbooks written in English.*

8.17 Discussion Concerning the Effect of Detective Game on Students' Thinking

The game positively affected students' attitude towards game learning and collaborative learning. At the start, students that were not used to playing games needed some assistance to start. Students "*need external incentives to take the first steps in an activity that requires a difficult restructuring of attention. Most enjoyable activities are not natural; they demand an effort that initially one is reluctant to make. But once the interaction starts to provide feedback to the person's skills, it usually begins to be intrinsically rewarding.*" (Csikszentmihalyi 1990 p.68). This feedback was constantly supplied by the game virtual space, the story, the teacher, the mobile expert, QR puzzles and other peers.

The game has assisted students to appreciate the value of group work in solving difficult problems. In the game process their collaborative learning skills such as tolerating opposite views and sharing responsibilities have improved. They seemed more eager to pursue proficiency in the academic subject and were more willing to research for relevant information autonomously. The metacognition was present when students constantly planned for a task, monitored their own actions and evaluated their thoughts. The game stories and narrative has provided a pleasant and flexible structure that encouraged them to learn more. The game steadily built student's confidence in an incremental manner. The gradual increase in game complexity allowed the players to acquire the necessary conceptual foundations to solve the puzzles and gain skills.

8.18 Students' Opinions on Interaction Involved

During the Detective Game Play

Game interactions, feedback and conversations have been easy to access. They were authentic and gradual in the form of story. They aimed towards scaffolding, exploration, research, contribution, competition, monitoring and evaluation, which resulted in improvement of cognition, collaborative skills, autonomy, confidence and metacognition. When students were asked '***In the Detective Alavi's Game, can you explain how you used the feedback, interaction and conversations?***' the following responses were given:

- ***Ease of Communication:*** *QR tags were helpful to initiate a contact with a knowledgeable person via SMS or make a phone call. The experts represented the concepts, hints and comments very well. QR tags were useful in connecting us to the web sites. We could find answers to our problems when searching the web.*
- ***Exploration:*** *I was encouraged to explore the game space to obtain the necessary concepts for the game play. The characters guided me to the specific tasks on QR puzzles. The step- by-step help from QR codes, web sites and experts helped us to be more exposed to educational content and look for answers ourselves.*
- ***Research:*** *We were like a team of researchers. I have learned that we have to collect the information from many different resources.*
- ***Contribution:*** *During the game I constantly documented my findings to prepare for our team report to the chief constable. When I sent back a*

report to chief constable I felt like feeding back all the stuff I have learned.

- **Contribution:** *I had a chance to ask questions. My experiences and knowledge were valued, no one was prevented from making contributions and the teachers really have listened.*
- **Contribution:** *We learned as a group that we ‘sink or swim together’, one member’s achievement is the whole group’s success and one member’s failure is the failure of the group.*
- **Chance of Success:** *You get often labels like ‘unsuccessful’ in a traditional classroom but in this game even so called brighter students sometimes learn from the average ones.*
- **Competition:** *Competing against another team was fun and exciting. It encouraged our group to push forward more quickly.*
- **Competition:** *Competing helped us to compare our progress with others. When we won, it gave us a real sense of achievement.*
- **Scaffolding:** *Feedback from the experts were like learning tools just when we were struggling; although they did not directly give the answers to us.*
- **Monitoring:** *I felt the scoring system was useful. It has helped me to assess my technical language knowledge.*

8.19 Discussion Concerning the Detective Game

Interactions

One of the challenges that faces mixed reality games is that the interactions and dialogues could not be designed in advance and they develop during the game play process (Fotouhi-Ghazvini et al. 2009 b, Klopfer 2008 and Facer 2004). If the students' collaboration is left totally unguided the group work might lead to some general discourses that are not very useful for the learning process. In our game, the virtual game space controlled the collaboration by the virtual characters' order of dialogues. A clear sequence of dialogues was planned (see chapter 7, section 7.8.9) amongst the virtual game characters according to the progress of the cognitive processes which helped the students in their analytic journey. Progressing from one cognitive process to the next and increasing the complexity of the levels benefited the individuals in their intellectual growth and matured and deepened their thought process. The dialogues were accessible only in hierarchy order. This 'linearization' helped the students to stay on the right track while having a free form of conversation.

During the collaboration Laullilard's (2009) conversational framework was used. Students were motivated to access explanations from the virtual world. They asked questions from on-site teachers and mobile experts. They were accompanied with appropriate scaffolding and guidance. They had many opportunities to offer their ideas, ask questions, discuss and debate with their peers and teachers. Each task had a clear goal that was accessible through the game virtual space. The QR puzzles provided repeated practice and

feedback. Students could reflect on their experiences by reporting back to the teachers and solving a difficult cryptogram.

In this process students gradually built trust amongst each other and learned how to communicate effectively. Even the weaker students could express their insights and they had continuously received appropriate feedback from different people both peers and teachers. Socialising with others helped students to internalise the knowledge within the 'zone of proximal development' of Vygotsky (1978). Division of labour amongst the game's virtual characters, students, on-site teacher and teachers at a distance assisted them in understanding language that contained structure a step beyond their current level of competence. Engestrom (1978) pointed out that this distribution of roles and functions is an important factor in communities to achieve shared goals. Competition on the other hand, produced an external pressure and a sense of drama. It changed the group dynamics, students worked more efficiently with higher speed to win. In this game winning did not produce any valuable awards such as grades or materialistic prizes. The teacher had periodically pointed to the 'total point' of the groups and it removed the anxiety of winning or fear of failure from the process. Each session ended with a winner but winning did not have a long term effect. All learners had a reasonable chance to win. Consequently students paid full attention to the process of learning and were not preoccupied with winning. The Detective game had achieved a balance between collaboration and competition. This combination has increased students' enjoyment and motivation.

8.20 Student's experiences Concerning the Usability of the Detective Game

The usability of a game “*is the capability in human functional terms to be used easily and effectively by the specified range of users, given specified training and user support, to fulfil the specified range of tasks, within the specified range of environmental scenarios*” (Shackel 1991, p.24). When the students were asked ‘**What was your experience in using the games?**’ the following responses were given:

- **Undisturbed Normal Function of the Phone:** *I could operate the game with one hand and move around during the game. I could easily handle incoming calls and SMS during the game. After a pause, you just continued from where you have left off.*
- **Ease of Navigation:** *It was easy to navigate and move between hierarchical menus and screens. I remembered how to do different tasks quickly, like checking my progress or capturing a clue. The command names guided me to perform different tasks.*
- **Appropriate Text and Graphics:** *The text on the screen was easy to read and the characters and background on the screen were appealing. Dialogues exchanged between Mr Alavi and the room's staff helped me on language learning.*
- **Smooth Bluetooth Function:** *It was relatively easy to connect to Bluetooth when running the game. The game helped me to find other players nearby easily. I could compete with other players. I could see if*

there were any changes to other team's game data. If they moved away there was a message telling me that I knew when my competing players were out of reach.

- **Slow Database:** *It took too long to load and save the game.*
- **Unexpected Shutdowns:** *Our device had a faulty battery. It unexpectedly shut down a few times during the games and we did not have a chance to save our data. However our teacher used the teacher setting to enter our scores.*
- **Error Prone QR Decoding:** *QR code readings were error prone; I should have kept my elbow pressed on the body when capturing an image. However if we missed it more than few times we used the Kaywa reader (<http://reader.kaywa.com/>) to find the clue and we just entered the clue manually in a text box.*
- **Battery Life:** *Capturing images decreased the battery life. The number of pictures that were taken, and the amount of time each image was viewed before the shots determined the phone's battery consumption. I should have remembered to charge my mobile phones or bring its chargers in case the phone runs out of power. Normally when we played for four consecutive hours, we experienced a low battery. Our classroom had four sockets; I could easily plug in my charger when needed.*
- **Browsing Difficulties:** *When we used GPRS the web searching speed was slow. Browsing experiences for each device were different, some of them were not able to open or view certain file types integrated in the web page. It is better to use a customised website for fast quick access.*

8.21 Discussing the Usability of the Detective Game

The game features such as:

- (1) Consistent and simple design of game graphics, text and the sequence of actions
 - (2) Shortcuts for different actions
 - (3) Appropriate responses and feedbacks
 - (4) Logical grouping of tasks
 - (5) Error prevention and error handling
 - (6) High tolerance and opportunity for reversal of actions
 - (7) Preserving internal locus of control for learners in game interface design
- have contributed to a usable game (see Fotouhi-Ghazvini et al. 2011c).

However extracting contextual data and using mobile communication could be error prone and slow. The capability of mobile phone in saving data at run-time is very low and is often a sluggish process.

8.22 Students' Experiences when Extending the Detective Game to Outside the Classroom

The following responses have been obtained when we asked students '***What was your experience in using the game outside the classroom?***':

- ***Increased Realism:*** *I felt like a real detective, examining things closely myself and searching around. We looked so serious about finding the*

clues that people wanted to know where Detective Alavi is and how they can help.

- ***Interested Surrounding People:*** *The people passing by looked at us and wondered what we were doing. They were confused on what we are so excited about. They asked many questions. Some of our friends even joined us and insisted that we install the game for them.*
- ***Curiosity of Surrounding People:*** *People in the computer room were curious why we need to access certain PCs and then take a photograph of a mysterious code with our mobile phones! After we finished with the PC they started to try with their own mobile phone camera! But it just left them more confused ...giggling... QR codes are cool.*
- ***Harmony of the Real World with Virtual World:*** *At times we were approached by people who knew something about the CPU complex and the game's characters. It really astonished us and left us amazed.*
- ***Familiarity with the Location:*** *It was easy to find the rooms, we already had many lab sessions in those rooms and we were pretty familiar with the building.*
- ***Conflict between Real and Virtual Worlds:*** *Sometimes the room that we were supposed to find the clue had a different configuration with the one in the game. In that case we really needed to look around and at times we tried a couple of PCs to find the right one with the specific puzzles and clues.*
- ***Limitation of Real World:*** *Occasionally the room with the clue had been booked for a lecture, we either had to wait until the end of class or move in very quietly.*

- **Real World Rules and Norms:** Staff were informed about the game and they were helpful. However we were asked to move in small numbers, quietly, and keep the noise down.

8.23 Discussing Students' Experience outside the Classroom

“Mobile devices demolish the need to tie particular activities to particular places or particular times” (Traxler 2010). When the game play was extended to outside the classroom, students' motivation has increased. The surprise, disappointments and excitement became more meaningful. The realism of the game was amplified; the learners took the role of a detective more seriously, they acted as an apprentice and examined their surroundings while seeking help from their mobile experts, real people and real objects. *“Mobility and connectedness strengthen and complicate the previously discrete concepts of digital identity. Learners have multiple and overlapping digital identities but their mobile devices add new dimensions to these”* (Traxler 2011 p.100). The QR codes novelty was apparent and the game play was contagious, attracting other people nearby. However students had to deal with the limitations of the real world and conflicts of rules and norms. *“Mobile devices are reconfiguring the relationships between different public spaces and private ones, and by the types of behaviour that are acceptable in each. Furthermore, these are penetrated by mobile virtual spaces”* (Traxler 2011 p.97).

8.24 Students' Experiences with the Detective

Game Characters, Story and puzzles

The Storytelling can be a powerful approach in language learning (Tsou et al. 2006). It motivates students and assists them in organising the concepts better in their minds and internalises much easier (Schank 1990 and Mello 2001). Stories in educational games consist of a plot, narratives, characters and puzzles. The following responses have been obtained when students were asked '**What was your experiences with the game characters, narrative and puzzles?**':

- **Lack of Variety in Graphics:** *When I played with the Detective game for the first couple of sessions, small PC, laptops, room arrangements, small characters looked really interesting. Later on I became too familiar with the environment. I would like to see more PC like games with lots of animation and graphics.*
- **Gradual Challenges:** *The material we learned at lower level puzzles helped us greatly on higher levels. We seemed to be constantly reusing what we learned before! The difficulty seems to be gradually increasing.*
- **Novelty:** *We were really drawn into QR puzzles. We were so curious we just continued to play the game. My friends that had not played with them really liked to try the QR puzzles.*
- **Character's Capabilities:** *Character's names, backgrounds and graphics were interesting! I liked Detective Alavi's character the most; he was able to do lots of things.*

- **Character's Guidance:** *The game characters prevented us moving to the next stage too soon and this helped us to finish what we were supposed to do at the time. When we finished a puzzle, all characters helping us with that puzzle disappeared and this helped us to see all the tasks for that puzzles were finished and we could move to the next puzzle.*
- **Limited Characters' Abilities:** *I wanted to see the game characters doing more than just talking to Detective Alavi. I'd liked to see the Detective Alavi's capabilities increased as his rank increased. He should be able to fight with the bad guys.*
- **Insufficient Character Building:** *I liked to see each characters in real life not just read it in text format. I think if there were more scenes like the one we have seen in the game's introduction, this would have made the game more interesting.*
- **Story Element used by Experts:** *Sometimes the experts mentioned and described what the game characters thought. I found that quite pleasant.*
- **Insufficient Appraisal:** *We had to wait a long time to win the game or receive proper praise from the game. It was like 'OK you finished level one now move to the next level!'*
- **Lack of Danger and Vulnerability:** *I would like to see real enemies and threats facing the Detective Alavi in the game. We kind of had to wait until the end of game to see the bad guy!*

- **Lack of Educational Audio:** *I would like the Detective game to have a voice-over for dialogue, so we become familiar with vocabularies' pronunciations.*

8.25 Discussion Concerning Students'

Experiences with the Game Characters Story and Puzzles

Puzzles acted as mental challenges targeting different language learning skills. Each time they revealed more detail of the overall concept and gradually developed students' abilities. Puzzles that had a game-like nature, for example QR word search, board games and snake and ladder received most attention, because they were novel and evoked the curiosity of the players. However other puzzles needed to be more playful and fun. One way to achieve this is to distribute pieces of story and game graphics to these puzzles and build a stronger tie between the real and virtual spaces. Distance experts tried to add this element by mentioning game characters in their feedback but more work is obviously required. MEMRG games have to be shaped by a complex narrative that takes place cumulatively over different spaces. Different pieces of story, character building information (for example their background, occupation and career), game events and educational content must be distributed equally amongst the game virtual space, QR puzzles, websites, teacher, surrounding people and experts conversations. This distribution of resources will avoid burden on device memory and processing power, and at the same time helps to engage students.

Despite the fact that the feeling of danger or vulnerability seem irrelevant to educational games, students that have experience with playing games will ask to see normal game attributes like enemies and conflicts in their physical form. Both genders believe this makes the game more interesting. Additionally, incorporating dramatic use of images and sounds for praising students' achievements appear to be very popular as they expect these visually appealing approvals periodically during the game play. It provides real-time encouragement and reinforcement.

8.26 Students' Degree of Engagement while

Playing the Detective Game

A game player's expectation of an educational gaming environment is for it to not only possess the appropriate functions but also to engage the player. Engagement is the aspect of the students' experience where they use their sensory and spatiotemporal elements and are emotionally and physically involved in the game play. The following responses have been obtained when students were asked '***Did you feel the game made you feel involved?***':

- ***Timeliness:*** *During the game the time just passed by and we seemed to be working hard! In most sessions we nearly missed our next lecture without noticing it!*
- ***Enduring:*** *Playing this game was worthwhile and I would recommend this game to my friends.*
- ***Extended Intermittent Attention:*** *When we played with MOBO city it was easy to block out things around us, you just sit there for an hour,*

absorbed in the game, noticing nothing. The Detective game is different; you start to feel in union with your surroundings and kind of extend yourself. You talk to the people, constantly discuss with other team members, ask questions from teacher, call experts, search websites and capture QR codes. It is real and you are in charge of it. It becomes your entire world. The whole experience is deeply enjoyable and you feel more 'together' after the play. Everybody seemed to be cheerful and happy.

8.27 Discussing Students' Degree of Engagement

In this game, players were not aware of the time passing; however they were aware of events happening outside the game environment. At times they were distracted, had lost focus and concentration or needed to do couple of actions in parallel. This was due to the nature of mobile media and unexpected real-world events. This resulted in '*intermittent attention*'. However this interrupted attention did not prevent an overall flow experience in the game play. After the play, students were happy and likely to recommend it to others and they planned to play it again. The flow state in this unpredictable and demanding environment was due to the following factors:

(1) Students were accustomed to incorporate the mobile phones in their life.

"One can be interrupted or interrupt friends and colleagues at any time. Individuals live in the phone space – they can never let it go, because it is their primary link to the temporally, spatially fragmented network of friends and colleagues they have constructed for themselves. It has

become their new umbilical cord, pulling the information society's digital infrastructure into their very bodies" (Traxler 2011 p.98).

(2) *"People raised with the computer think differently from the rest of us. They develop hypertext minds. They leap around. It's as though their cognitive structures were parallel, not sequential."* (Prensky 2001 p.02-8).

The new digital generation play more video games than their previous generation. *"Playing video games enhance players' skills at "divided attention" tasks, such as monitoring multiple locations simultaneously, by helping them appropriately adjust their "strategies of attentional deployment. Players get faster at responding to both expected and unexpected stimuli."* (Prensky 2001 p. 02-10) *"They often feel much more comfortable than their predecessors when doing more than one thing at the same time."* (Prensky 2001 p. 02-16). They are able to organise their consciousness and work toward their goals in this unpredictable environment. They *"are in control of their psychic energy, and everything they do adds order to their consciousness."* (Csikszentmihalyi 1990 p.40). In the process of the game play they are able to select a limited range of information into their awareness which is necessary to achieve their goals.

This feeling of flow leads to a sense of accomplishment that students did not experience before. *"Enjoyable events occur when a person has not only met some prior expectation or satisfied a need or a desire but also gone beyond what he or she has been programmed to do and achieved something unexpected, perhaps something even unimagined before"* (Csikszentmihalyi 1990 P.46). Thus mixed reality games will expand the person's boundaries through different spaces and result in more complex experiences which are

enduring. Players return to play the game again and also recommend it to others.

However some level of immersion needs to be achieved first for the players to tolerate the incoherence of modalities (Cheng and Cairns 2005). In general, mobile games provide lower visual and audio stimuli than desktop games. In PC games large screens are often incorporated with head phones that make high quality graphic input and high audio volume available to the players. The small screen and auditory ineffectiveness of the device automatically reduce the players' attention. This is the reason why most of the commercial mobile games are only played for a few minutes. Nevertheless to achieve the initial immersion a variety of game graphics need to be added while considering the balance between the multimedia features and the mobile phone's capabilities. This helps to gain the learner attention and sense of curiosity (Gagne et al. 1992, Keller 1987, Malone and Lepper 1987). The possibility of error in using the interface also needs to be reduced and the learners' sense of control increased (Malone and Lepper 1987). This has been achieved in the Detective game by following the generally accepted design interface guidelines (Nielsen 1994, Shneiderman 2004, Stone et al. 2005 and Fotouhi-Ghazvini et al. 2011 c).

The continuous immersion during the games could be stimulated by introducing a number of stories that wrap around the knowledge. Each story must be designed according to the learners' cognitive level (Quinn 2005) with academic content tightly coupled with the story (Malone and Lepper 1987, Quinn 2005 and Gunter et al. 2008) which is integrated into different game levels each with different thematic puzzles (Bates 2004). These stories must

stimulate emotions in environments that normally arouse none (Carroll 2004). This emotional charging must periodically produce feelings of amusement, satisfaction and accomplishment with accompanying feeling of wonder, mystery, challenge, danger, vulnerability or even confusion. These positive and negative emotions will keep the dynamics of the story alive. Additionally, the stories need an interesting and robust plotline that constantly stimulates the learners' curiosity, as well as being flexible enough for the teacher to add variations to the story and also the access to learning resources. The variations could come from the on-site teacher and mobile experts' different versions of the story, changes in QR puzzles, different cut-scenes, and incorporating genuine or fake informational websites and blogs. The story must evolve and unfold over time in a playful spirit. However it is important to keep various scenarios manageable and easy to internalise for the teachers, and to avoid complex narratives that overwhelm both teachers and experts.

8.28 Conclusion

Quiz games were fun but the engagement with the game was not educational in nature. The game story and the learning challenges were not related and they resulted in no cognitive change. The MOBO city has a clear goal, an educational story theme and the right level of challenges which engaged the players to understand the electronic concepts and practice a large repertoire of vocabularies. Compared to traditional methods such as using a dictionary and reading comprehension, there was a significant improvement in understanding vocabularies and their meaning. However, students repeated certain vocabularies' spellings no matter how many times they played the games. It

seemed as if a certain amount of explicit instruction focusing on language form may be necessary as well. The Butterfly game was used for this purpose in order to produce the right kind of stimulus. Pedagogy theorists (e.g. Skinner 1974) believe this mode of learning can be employed when a specific target behaviour or skill has to be achieved. In Butterfly, the game learners became sensitized towards vocabularies shapes and spellings at each encounter and increased their registration with the human sensory organs. With repeated play, the vocabularies were rehearsed and encoded and had a better chance of being passed to long term memory.

In this game, players acted as collaborating apprentices who immersed themselves in the electronic world of the CPU and experienced a narrative in which they could see the world 'through the eyes' of the components responsible for CPU functions. The objective of this was to encourage a process of '*enculturation*' as described by Brown et al. (1989). As a result of 'practice in situ' the students learned the norms of 'electronic culture'. This culture was mixed with the traditional school environment that students were familiar with. Authentic activities in the detective game were defined as the ordinary practices of the learner's central character within the CPU environment. The detective game used Brown et al.'s (1989) '*cognitive apprenticeship*' to help students to see the world through the eye of the practitioner and, more importantly, understand its significance through the interrelationship of the component parts. In the process of enculturation, the game assisted the learners to focus and also externalise their ideas. Giving expression to ideas and making reasoning explicit, helped ideas to become tangible, sharable and negotiable. This guided the learners to further

improvement, actualisation and abstraction of key principles. Consequently in the detective game, learners' development occurred in the two stages of '*intermental*' (i.e. between people) and '*intramental*' (i.e. within people). The cognitive development in this game occurred through social interactions within the learner's 'zone of proximal development' Vygotsky (1978). Vygotsky believed that a learner cannot gain new cognitive abilities by performing tasks that they could already perform independently. In this game tasks were designed which required a higher cognitive ability which could not be solved independently by learners and needed collaborative work with peers and teachers. Students needed to analyse, compare and make choices from studying and discussing different resources, and collaborate with each other and the teacher. To begin with, students were unable to fully implement the constructivist philosophy of collaborative learning. Students focused on the content of the virtual character's dialogue and approached puzzles as a memory task. They depended on teacher's authority and required explicit approval to move to the next task. However, as the game sessions continued, students started sharing the authority with the teacher and mediating their own learning. This new authority transformed into a shared responsibility, fully exploring the potentials of the game, paying attention to the material and having an active role in their learning. A continuous interaction between students, teachers, context and the learning material was developed. This interaction was in conversational format and in its most productive nature led to shared points of view over the curriculum objectives that were embedded in the game story. The mobile game environment provided the flexible and functional framework that was necessary to support the user, and it was also able to

provide the degree of immersion necessary to involve the user in the game play that is required in order to achieve the learning goals. The game fully implemented the hierarchy of learning objectives in the game structure. This structure motivated students to master the basic level first and take part in assessment and evaluation. The game challenges stimulated the recall of prior knowledge by the new challenges referring back to things learned in previous levels. By this enhanced retention and transfer of knowledge, challenges were gradually increased and could be handled individually, through to the final performance level needing collaborative work. Students learned about the complex relationships between different concepts. For students, the essence of meta-cognition (i.e. self- monitoring and evaluation), which was the objective of this process, has been achieved.

The following results were inferred from the game play:

- Teachers' roles are very important, especially in the beginning of the game. His/her roles fluctuate as an observer to a member of group to a guide and to a story narrator. She/he must explain the game environment, customise the learning material, provide the right feedback, encourage further research and place an emphasis on the collaboration skills.
- The game helps the teachers to engage students in the game play both emotionally and physically with a higher sense of responsibility, persistence and confidence.
- There must be a balance between fun games like QR word search and the more provocative questions. This will achieve both excitement and promote debate.

- A self-assessment system must be present by means of a detailed a scoring system that contains game rules which assess a wide range of skills implicitly in the game context. This will promote metacognition and critical learning amongst students through monitoring. It also evaluates their strengths and weaknesses and facilitates planning for future improvements. This is also helpful for the teachers in monitoring the students' current abilities during the game.
- Students who never played games before might show some unwillingness at the beginning. The reasons behind this are that often they think they are incapable of playing a game, or they think it is going to be a waste of time. However during the first few sessions they start to enjoy educational games and realise its usefulness.
- Students that consider themselves advanced players expect more multimedia and animation features in the game interface (like PC games). However the game story, real world experiences, collaboration, competition and QR codes keep them engaged.
- Using a conversational framework in the game space will result in:
 - Higher contribution and possibility of accomplishment from students through asking questions, discussion, debates, reflection and distribution of their work.
 - Better group work, scaffolding and monitoring of the student's work.
- Competition must be present to help students compare their work with others and add external drama, fun and excitement.

- The games must be usable and designed especially for mobile phones. They must follow the user interface design guidelines to provide for efficient use of the game and allow for any unexpected errors from contextual data and unpredictable events from mobile space.
- Incorporating the games outside the classroom adds to the excitement and realism of the game, however the limitation, rules and norms of the real world must be considered.
- The initial immersion in the game play occurs by incorporating a variety of graphics which must be designed according to the phone capabilities and user interface guidelines.
- Storytelling is a very important element for creating a continuous immersion in the game play, which could be achieved by:
 - Graphics that tell part of story and are meaningful on their own
 - Introducing a variety of virtual characters with different capabilities and backgrounds in graphical format
 - Incorporating thematic, game like, novel and graded puzzles
 - Distributing the narrative amongst teachers, experts and surrounding people
 - Adding enough drama, surprises, danger and appraisals
- Storytelling must be simple and robust to help teachers manage the narrative.
- Mixed reality games often produce '*intermittent attention*' however they achieve the overall flow experience because students are accustomed to the mobile life, parallel processing of tasks, divided attention, unexpected stimuli and unpredictable environments.

Chapter 9

Conclusions and Future Work

9.1 Discussion and Conclusions

It appears clear that mobile learning using games has the potential to be very useful and influential in developing countries. Because of its ubiquitous nature and comparatively low cost, the mobile phone system appears to be the most practical way of delivering m-learning for the foreseeable future. The creation of appropriately tailored content thus becomes the highest priority, taking full account of human factors and behavioural patterns in order to maximise acceptance. Even though this research has focused on a developing economy, some implications for the developed world can still be speculatively drawn. For example, the marginalised poorer sectors of society in all countries may well benefit from similar strategies to those appearing to be propitious in the developing world. Many governments are realising that further and higher education can provide recipients with the intellectual capital to contribute more effectively to their country's knowledge economy, which in turn can increase

national and international trade, which can distribute wealth more equitably around the globe.

In the MOBO city package (Fotouhi-Ghazvini et al. 2009 a and d) and Detective Alavi (Fotouhi-Ghazvini et al. a and d) virtual environments were designed according to the recipients' target academic courses by integrating the theoretical knowledge in the game's belief system. Fotouhi-Ghazvini et al. (2009 a and d and 2011 a and d) believed these environments promoted the students to act as apprentices in authentic situations and activities, and adapt to the academic culture and norms. These environments presented the knowledge in a natural manner where inadequate or false theories could be experimented with and mistakes could be made without individuals feeling threatened about exposing their weaknesses.

MEMRG games use these virtual spaces as well as simultaneously incorporating mobile hardware such as Bluetooth, Infrared, GPS, camera and sensors into the game structure and environment (Fotouhi-Ghazvini et al. 2011 a, b and d). These games could have an effective and efficient user interface design for a wide range of users (Fotouhi-Ghazvini et al. 2011 c). They can access mobile and wireless technologies such as WiFi, GPRS, 3G or 4G during the game. They use mobile communication modes such as mobile phone calls, SMS and MMS to form ad hock learning groups where there are no physical or temporal boundaries. These games are aware of their surrounding context and provide relevant information to the players. Moreover by utilizing communication facilities players are encouraged to converse and enter dialogue with other players to share ideas (Fotouhi-Ghazvini et al. 2011b). MEMRG

could have significant academic, social and psychological benefits for the players by forming enjoyable, authentic and vibrant learning environments (Fotouhi-Ghazvini et al. 2011 a and d). Mental images and thoughts are built up as the different sources of information are translated and accessed - leading to a sense of union. This convergence helps individual players to create their own reality depending on how emotionally they get involved in the changing realities of the spaces.

These games help the learner create living experiences while still being immersed in a virtual synthetic world. According to Fotouhi-Ghazvini et al. (2011 d) these kinds of interactions could result in a conceptual change and have the power to modify the mental model of the learner.

These games are able to enhance the basic senses to produce a more complete learning experience by acting as a mediator which encourages and stimulates social interaction amongst the participants. Fotouhi-Ghazvini et al. (2011 d) believed these interactions within the zone of proximal development are essential contributors to building higher mental functions within people. According to Fotouhi-Ghazvini et al. (2011 a and d) these kinds of encounter help to externalise ideas in more intellectual and a less dominant fashion. These learning spaces help students to ask questions, offer their ideas, participate in debates, and produce and present the results of their work. Fotouhi-Ghazvini et al. (2011 a and d) suggested that these features could contribute to a deeper learning experience.

MEMRG provides flexible, portable and seamless learning. It could be used in the classroom, on location,, in the laboratory and at home with no need

for maintenance or service support. According to Fotouhi-Ghazvini et al. (2011 a and d) it could help with the following:

- (1) Teachers to present and provide information in appropriate fashion,
- (2) Teachers to organise and facilitate collaborative learning
- (3) Learning by offering motivating and engaging environments to students where it provides for, and supports, deep critical learning
- (4) Self-assessment by extracting and classifying evaluation data to drive the evaluation of students' progress which leads to metacognition.

9.2 Cultural Considerations

One key question to consider is the extent to which the results of the assessments and evaluations are generalizable to different cultural contexts. For example, would the answers of students in other countries have been the same as the students in our specific context? And if not, where would possible differences arise? It may therefore be difficult to generalise the results of this work to other cultures. However, it is clear that within our experiment the approach to learning using mixed reality games has accomplished positive outcomes. Teachers in developing countries often dominate the classroom and rely on this to transmit information. Students' participation in language learning classroom activities is low (Sarani and Kafipour 2008) and (Hamzah et al. 2009). Female students are either too shy to speak or not interested in the subject. Mobile games encouraged female students to enjoy the freedom of learning by themselves in non-threatening environment. MEMRG helped students to engage in the learning process and communicate by its

collaborative features and the opportunity to explore different spaces. The parity between the number of male and female game characters, and that it was not necessary to press the mobile phone keys in a rapid sequence helped the female students to feel less intimidated and increased their confidence to explore and express their views. Mobile games designed for a technical context if introduced in developing world high schools could encourage more girls to participate in engineering courses, as it builds their confidence, and involves realistic experiences in authentic environments that incorporate rich social interactions.

9.3 Enhancements and Future Work

9.3.1 Improving QR code image capturing and processing

9.3.1.1. Increasing the camera control

In the future, as the number of devices with Advanced Multimedia Supplements (AMS) increases amongst the mobile phone users, it could be incorporated into the game to extend MMAPi. AMS provides more control over the phone's camera by:

- (1) Exposure control of light in the aperture and shutter
- (2) Flash control according to the lighting condition
- (3) Focus control with manual and autofocus
- (4) Zoom control and accessing camera's digital or optical zoom values.

When a QR decoder utilizes AMS then camera zooming capabilities become another important factor for better QR images.

9.3.1.2 Improving the bad light condition and the non-uniform background

Images taken by mobile phones are often exposed to bad light conditions and non-uniform backgrounds (see Figure 9.1 (a)). Chang et al (2007) has proposed a QR extraction algorithm that *”uses light balancing to eliminate uneven light noise in the image”* and uses page segmentation to extract a QR code from a non-uniform background. The scheme was shown to be highly accurate.

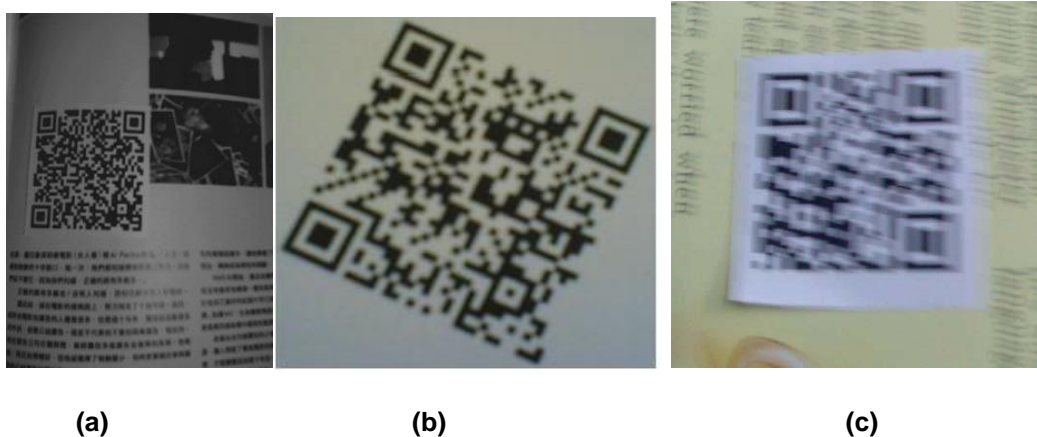


Figure 9.1 (a) An image in bad lighting condition and non-uniform background (from Chang et al 2007) (b) a twisted image (from Sun et al 2007) (c) a shaken image (from Chu et al. 2007).

9.3.1.3 Improving the twisted Image

Sun et al. (2007) proposed a new algorithm to re-build a QR image from a distorted one (see Figure 9.1 (b)) with contour finding.

9.3.1.4 Improving the shaken image

Camera phones often do not have auto-focus, they are lightweight and have small size, and these factors are most likely to contribute to shake when the user takes a close-up shot or the user might hold the phone unsteadily (see Figure 9.1 (c)). Consequently images captured by mobile phones are often exposed to shake which leads to distorted images. In the Chu et al (2007) algorithm, the image is taken to the frequency domain “*to estimate the shaken length and angle*” and to restore the original image.

9.3.2 Adding touch capabilities

Touch capabilities could improve the user experience, increase engagement and the fun element of the games. Infants, pre-school children, autistic children and slow learners could benefit most from the touch-enabled educational games. They could easily use their fingers to move objects on the screen. By utilizing the familiar context of everyday life they could solve puzzles. They could play these games simply by moving different shapes, colours, numbers, alphabets, animals and connecting them, or moving them apart.

There are a number of touch actions available to a touch user interface: “*‘Touch’ (touch down), ‘Release’ (touch release), ‘Tap’ (touch down + touch release), ‘Long tap’ (touch down and hold), ‘Drag’ (touch down + drag), ‘Drag and drop’ (touch down + drag + touch down (“stop”) + touch release), ‘Flick’ (touch down + drag + touch release while dragging)*” (Forum Nokia 2011). These actions could be used for selecting certain objects or moving them on the game canvas (Forum Nokia 2011).

There are 4 different paths that could be taken to implement a touch User Interface action (Forum Nokia 2011):

- (1) Using universal basic touch events that are available on all Java enabled phones which recognize touch events as pointer events, there are only three simple methods available (a) to identify when the pointer is pressed (b) when the pointer is dragged and (c) when the pointer is released
- (2) Using ready-made Gesture API classes and methods that implement all of the mentioned actions and handle gesture recognition complexities at constant or a given speed in the case of 'drag and drop' or 'flick' actions; this API is only available to series 40 Nokia phones (low-end Nokia devices).
- (3) Using an embedded Standard Widget Toolkit (eSWT) that acts in a similar way to the desktop version and handles all the touch actions as mouse events. This toolkit is only available on phones with the Symbian operating system (from S60 3rd Edition FP2 onwards).

Using a small stylus to point at objects on a small mobile phone screen, is more accurate and precise than selecting small details on the screen. However they should not be provided to infants or pre-school children as they could swallow it by accident. There is therefore a health and safety issue for small children – they should only be allowed to use their fingers. In this case, touch enabled objects must be at least as big as the width of a finger, index or thumb depending the size of the game targets, for example 1 cm × 1 cm square character could be sensed by fingers. Two touch objects must be a few millimeters apart to become distinguishable by fingers (Forum Nokia 2011).

9.3.3 Considering the vision-impaired students

A real haptic user interface and an audio layer could help blind or vision-impaired students greatly and strengthen emotional connections for students with no vision problems. Audio-haptic information through the touch interface could allow the player feel and hear the characters, game environment and their actions. Again the use of greater sensory information could enhance the learner experience.

9.3.3.1 Adding haptic capabilities

Touch feedback in the mobile phone is not still truly haptic, and touch screens are not still much better than a mouse pointer. In a haptic touch screen, when fingers touch the screen they send touch input and receive the touch output at the exact location. These touch outputs could be in the form of temperature change, stretching the skin, pressure or texture, thus making the user feel what is actually happening in the game environment. Fingers have many somatic sensors and they can act as the most precise tool for receiving a sense of touch. It must be noted that today's touch feedback in mobile phones is nonspecific to the entire device. If the player cannot feel the reaction at a touched location then very soon the player will lose interest in too many generic vibrations.

9.3.3.2 Adding an audio layer

The ear can sense an immense range of sounds. The mind can associate these sounds with objects or theoretical ideas. An audio layer such as musical

patterns with varying volume and rhythm could provide enough information about the game environment to make it understandable without looking at the interface. The following designs could be used to notify the player:

- A voice-over for menu option
- Audible control of every single menu
- Audio output for any changes in contextual information such as location
- Audio assistance for navigation
- Different audio signs for places, obstacles, objects and characters
- An audio notification when an action or goal is accomplished.

9.3.4 Considering the future larger screens

Although mobile devices such as iPad with a 9.7 inch display and Galaxy Tab with 7-inch screen are not widespread in developing countries, but because they could be used in mobile learning we offer some design considerations. In larger displays everything could happen in one screen. There is no need for the long option menus and many hierarchical screens, which greatly increases the accessibility of the mixed reality games. Graphical elements such as background and characters could be larger, more visible and more detailed. The screen could be split into two, with one player at the top of the screen and the other at the bottom playing against each other using the multi-touch support of the device. The new mobile devices with wide screens provide new types of multiplayer experiences which are beneficial in collaborative classroom projects.

9.3.5 Considering the device sensor

The game's canvas could use the data collected from the mobile phone's sensor such as the accelerometer to help with the movement of objects in the game. It could be used for fast actions that do not have to be accurate or focused. However, the 'Mobile Sensor API' must be available otherwise the implementation is impossible. For example, in the Nokia N95 the sensor's hardware is present but because the actual Java API 'i.e. Mobile Sensor API' is not available, the sensor's data is not accessible during the game. In more sophisticated Symbian phones (S60 3rd Edition FP 2 onwards) this API exists.

9.3.6 Considering the future increase in bandwidth and speed

The two factors of high 'network latency' and low 'network bandwidth' in GPRS networks, cause complications in online multiplayer games. High network latency means lag and this affects the game responsiveness. Low network bandwidth corresponds to low network throughput and affects the game scalability. As the mobile internet bandwidth and speed increases, multiplayer online games will reach a satisfactory level of quality in mobile devices. In multiplayer games having human opponents, and being involved in a virtual collaborative team work, could produce richer experience than single player versions.

9.3.7 Considering the future video calls

Real time video calling completely changes the way students connect to their distance teachers and produces a much richer experience. However, both the caller and the recipient must be located in a high speed area with a high bandwidth network such as 3G.

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Appendix A

Measuring the Degree of Mobility, Context and Communication in Games

**Table A.1 A questionnaire to measure the degree of mobility, context and communication
in MOBO city, Detective Alavi, Live Long and Prosper, Environmental Detective,
Outbreak@MIT and Savannah games**

	MOBO city	Detective Alavi	Live Long and Prosper	Environmental Detective	Outbreak@MIT	Savannah
DM 1- Is the learner able to take your game and play it in the gaps between work?	✓	✓	✓	x	x	x
DM 2- Is your game free of bounding to certain location?	✓	✓	✓	x	x	x
DM 3- Does your game utilise Bluetooth or Infrared?	x	✓	✓	x	x	x
DM 4- Does your game utilise WiFi, GPRS or 3G?	x	✓	x	✓	✓	✓
DM 5- Does your game utilise GPS?	x	x	x	✓	x	✓
DM 6- Does your game utilise mobile camera?	x	✓	x	x	x	x
DM 7- Does your game utilise SMS or MMS?	x	✓	x	x	x	x
DM 8- Does your game utilise phone calls?	x	✓	x	x	x	x
DM 9- Does you game allow the learner to move from topic to topic?	x	✓	x	x	x	x
DM 10- Does your game allow forming different groups?	x	x	x	✓	✓	✓
DM 11- Does your game allows learning that is accumulated at different points in time?	✓	✓	✓	x	x	x
ST 1- Is your game aware of time?	x	x	x	x	x	x
ST 2- Does your game provide temporal information to the learner?	x	x	x	x	x	x
ST 3- Does your game utilise absolute position of the mobile device?	x	x	x	✓	x	✓
ST 4- Does your game utilise relative position of the mobile device?	x	✓	✓	x	✓	x
ST 5- Does your game utilise relative position and orientation of a physical object?	x	✓	x	x	x	x
ST 6- Does your game utilise orientation of the mobile device?	x	x	x	x	x	x
DC 1- Is your game	✓	✓	✓	✓	✓	✓

designed considering information about device screen size and resolution?						
DC 2- Is your game designed considering information about available device memory?	✓	✓	✓	✓	✓	✓
DC 3- Is your game designed considering information about device processing power?	✓	✓	✓	✓	✓	✓
DC 4- Is your game designed considering information about mobile internet bandwidth?	x	✓	x	x	x	x
DC 5- Is your game designed considering information about device's operating system and software capabilities?	✓	✓	✓	✓	✓	✓
VW 1- Does your game assign learning goals?	✓	✓	✓	✓	✓	✓
VW 2- Does your game assign the learning modules or topics?	✓	✓	✓	✓	✓	✓
VW 3- Does your game calculate current state of learner interactivity?	x	x	x	x	✓	x
VW 4- Does your game calculate learner's progress?	x	✓	x	x	x	x
VW 5- Does your game calculate learner's score?	✓	✓	✓	✓	✓	✓
VW 6- Does your game calculate current state of teaching?	x	✓	x	x	x	x
VW 7- Does your game calculate other team's progress?	x	✓	x	x	✓	x
PC 1- Is your game designed considering physiological aspects of learner?	✓	✓	✓	✓	✓	✓
PC 2- Is your game designed considering mental conditions of learner?	✓	✓	✓	✓	✓	✓
PC 3- Is your game designed considering biographical information of the learner?	✓	✓	✓	✓	✓	✓
RC 1- Does your	✓	✓	✓	✓	✓	✓

game help the learner to have a social role according to other learners?						
RC 2- Does your game help the learner to have a social role according to virtual characters?	✓	✓	x	✓	✓	x
RC 3- Does your game help the learner to be acknowledged about social roles of other learners?	x	✓	x	x	✓	x
RC 4- Does your game help the learner to be acknowledged about social roles of virtual characters?	x	✓	x	✓	✓	x
RC 5- Does your game help the teacher to have a social role according to learners?	x	✓	x	x	x	x
DCom 1- Does your game encourage learners to converse and collaborate with other learners?	✓	✓	✓	✓	✓	✓
DCom 2- Does your game encourage learners to share information?	x	✓	x	x	✓	x
DCom 3- Does your game encourage learners to offer their own ideas and understanding?	x	✓	x	✓	✓	✓
DCom 4- Does your game encourage the learners to participate in discussion and debate?	x	✓	x	x	x	x
DCom 5- Does your game encourage learners to compete with other learners?	x	✓	x	x	✓	x
DCom 6- Does your game encourage learners to ask questions from the teacher?	x	✓	x	x	x	x
DCom 7- Does your game encourage learners to present ideas to the teacher?	x	✓	x	x	x	x
DCom 8- Does your game provide a method for teachers to send feedback to learners?	x	✓	x	x	x	✓

Table A.2 Quantifying responses from MOBO city, Detective Alavi, Live Long and Prosper, Environmental Detective, Outbreak@MIT and Savannah games according to the MEMRG scale

	MOBO city	Detective Alavi	Live Long and Prosper	Environmental Detective	Outbreak@MIT	Savannah games
Degree of Mobility/11	3 (poor)	9 (very good)	4 (poor)	3 (poor)	2 (very poor)	3 (poor)
Spatio/temporal Context/6	0	2	1	1	1	1
Device Context/5	4	5	4	4	4	4
Virtual World Context / 7	3	6	3	3	5	3
Personal Context/3	3	3	3	3	3	3
Role Context/4	2	5	1	3	4	1
Total Degree of Context	12 (moderate)	21 (good)	12 (moderate)	14 (moderate)	17 (good)	12 (moderate)
Degree of Communication/ 8	1 (very poor)	8 (very good)	1 (very poor)	2 (poor)	3 (moderate)	2 (poor)

Appendix B

MOBO City Concept Maps, characters and Dialogues

B.1 CPU Concept Map and Characters

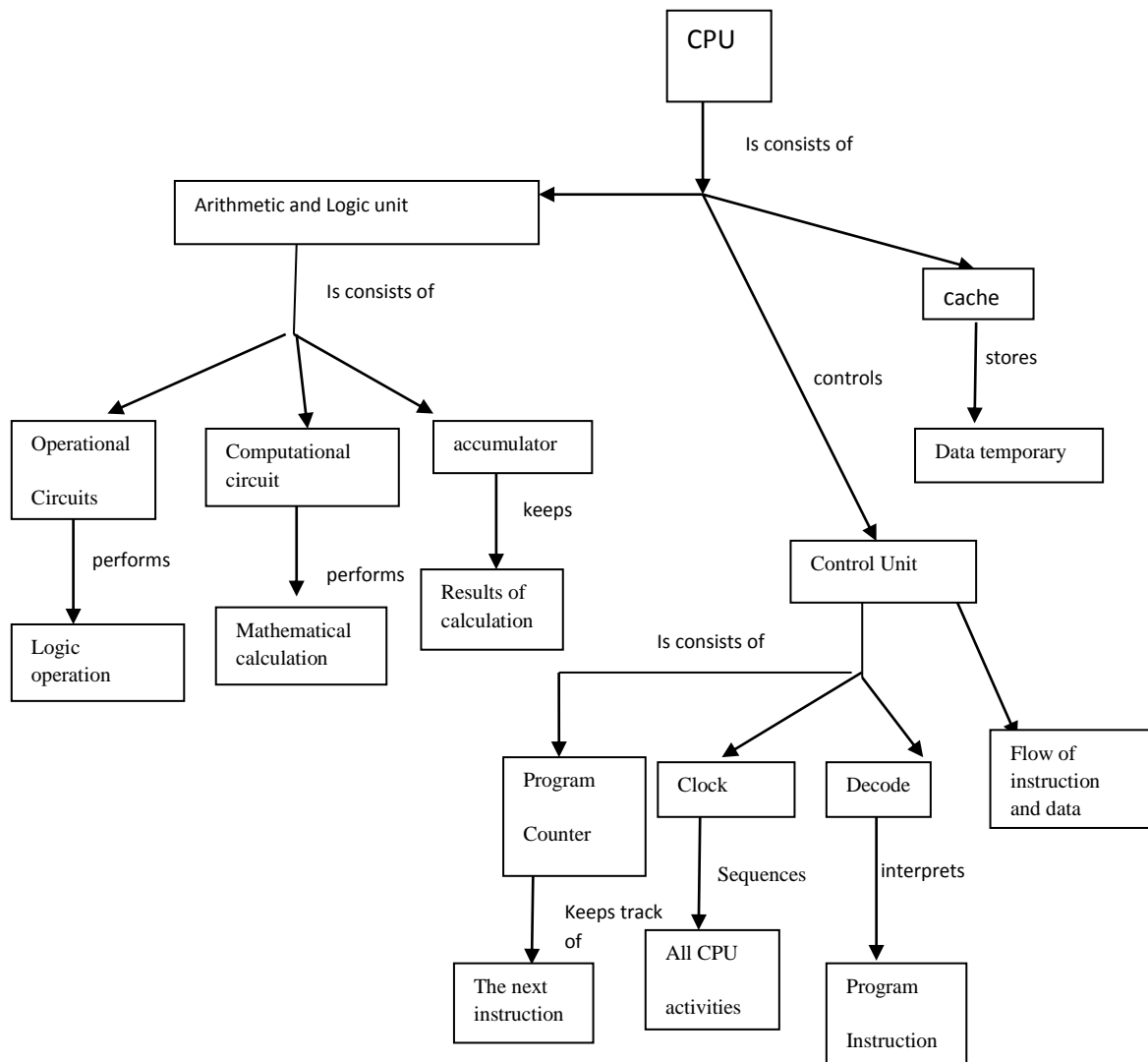


Figure B.1 Representation of a concept map illustrating the functions of a CPU



Clock: I will try to sequence all activities in this station.



Hi! I am the 'program counter'. You brought the right instruction for us



This is 'cache' waiting room. We respect our customers by increasing the rate at which their work is done! We believe, we can increase the system 'throughput'.



Hello my name is 'accumulator'. I keep the results of your calculations



Hi! I do your logic operation



Hi! I do your mathematical operations



Hello, my name is 'decoder'. I will interpret then program instruction you brought, so my colleagues know what task they should do for you!

Table B.1 Different CPU characters and their corresponding dialogues.

Smiley faces images have been extracted and modified from Emofaces Site (2008)

B.2 Graphic Card Concept Map and Characters

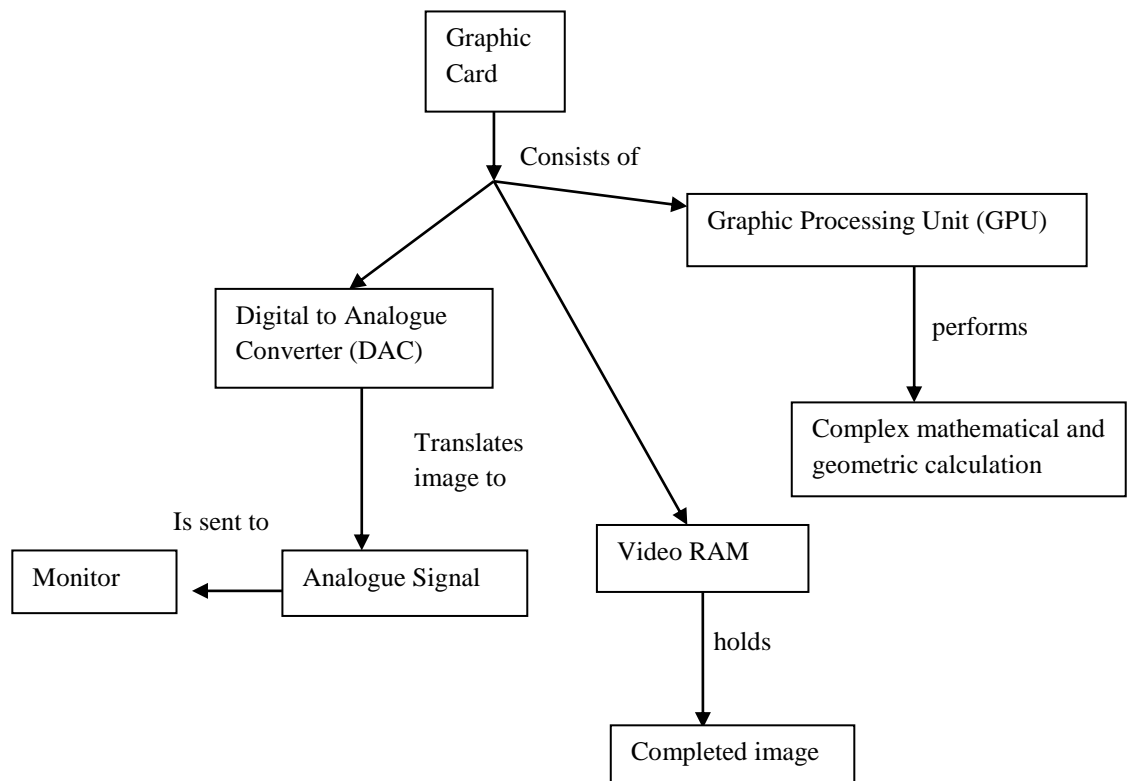


Figure B.2 Representation of a concept map illustrating the functions of Graphic card.



Hi! I will do all geometric calculation for you.



Welcome to video RAM area! We can keep results of your calculations for a while!



Welcome to Digital to analogue Centre

Table B.2 Different Graphic card's characters and their corresponding dialogues.

Smiley faces images have been extracted and modified from Emofaces Site (2008)

B.3 Sound Card Concept Map and Characters

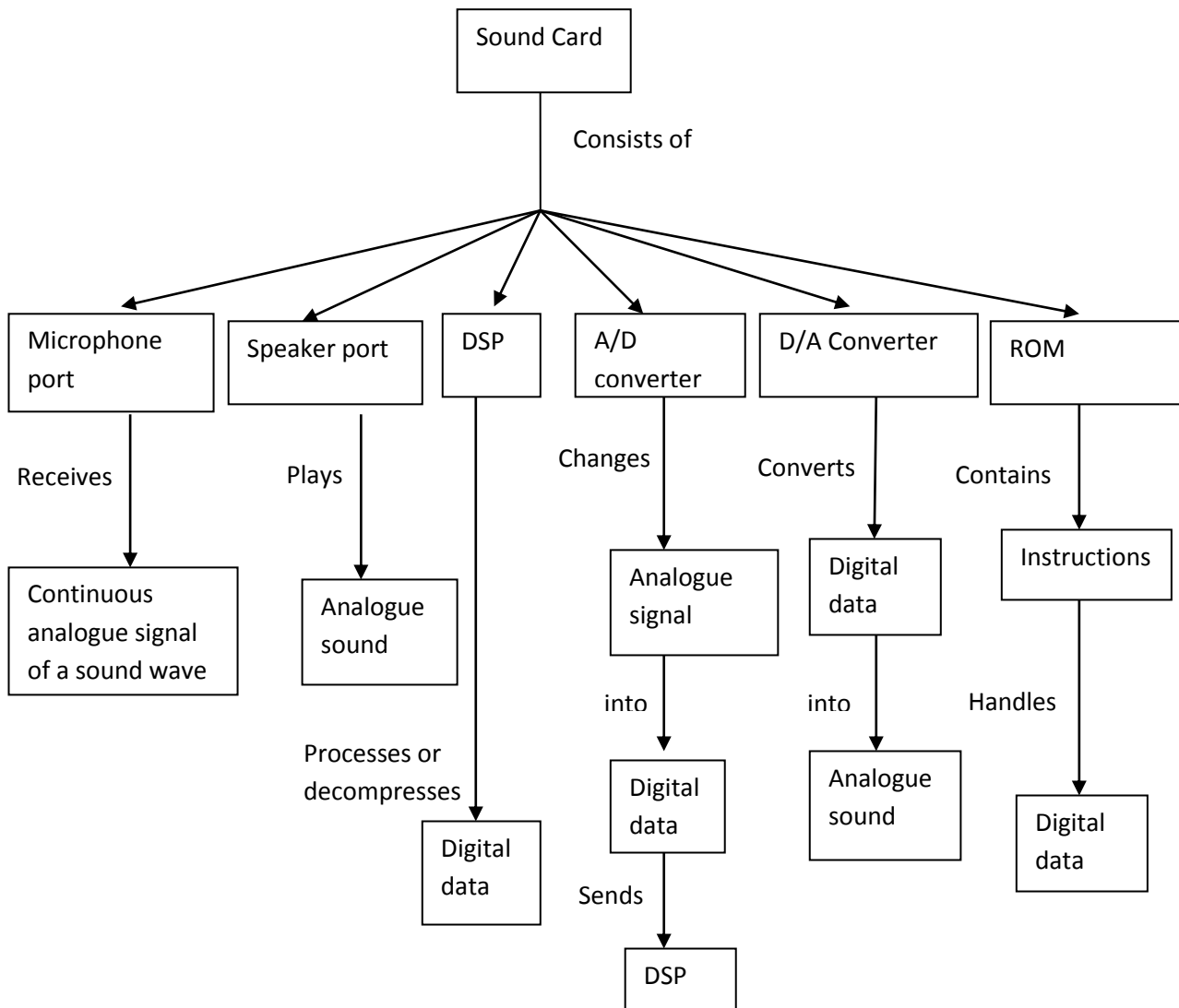


Figure B.3 Representation of a concept map, describing what a sound card consists of and what it does.



Microphone port: This is microphone port! We receive continuous analogue sound.
Speaker port: This is speaker port! We play the continuous analogue sound.



A/D converter: We are analogue to digital converters. We change analogue signal into 0 and 1 digital data.



DSP: We are digital signal processors. We process digital data and send it to CPU. We also decompress sounds from CPU.



D/A converter: We are digital to analogue converters. We convert digital data to analogue data.



ROM: This is ROM. We contain instructions that tell us to hold digital data.

Table B.3 Different sound card's characters and their corresponding dialogues.

Smiley faces images have been extracted and modified from Emofaces Site (2008)

B.4 Modem Card Concept Map and Characters

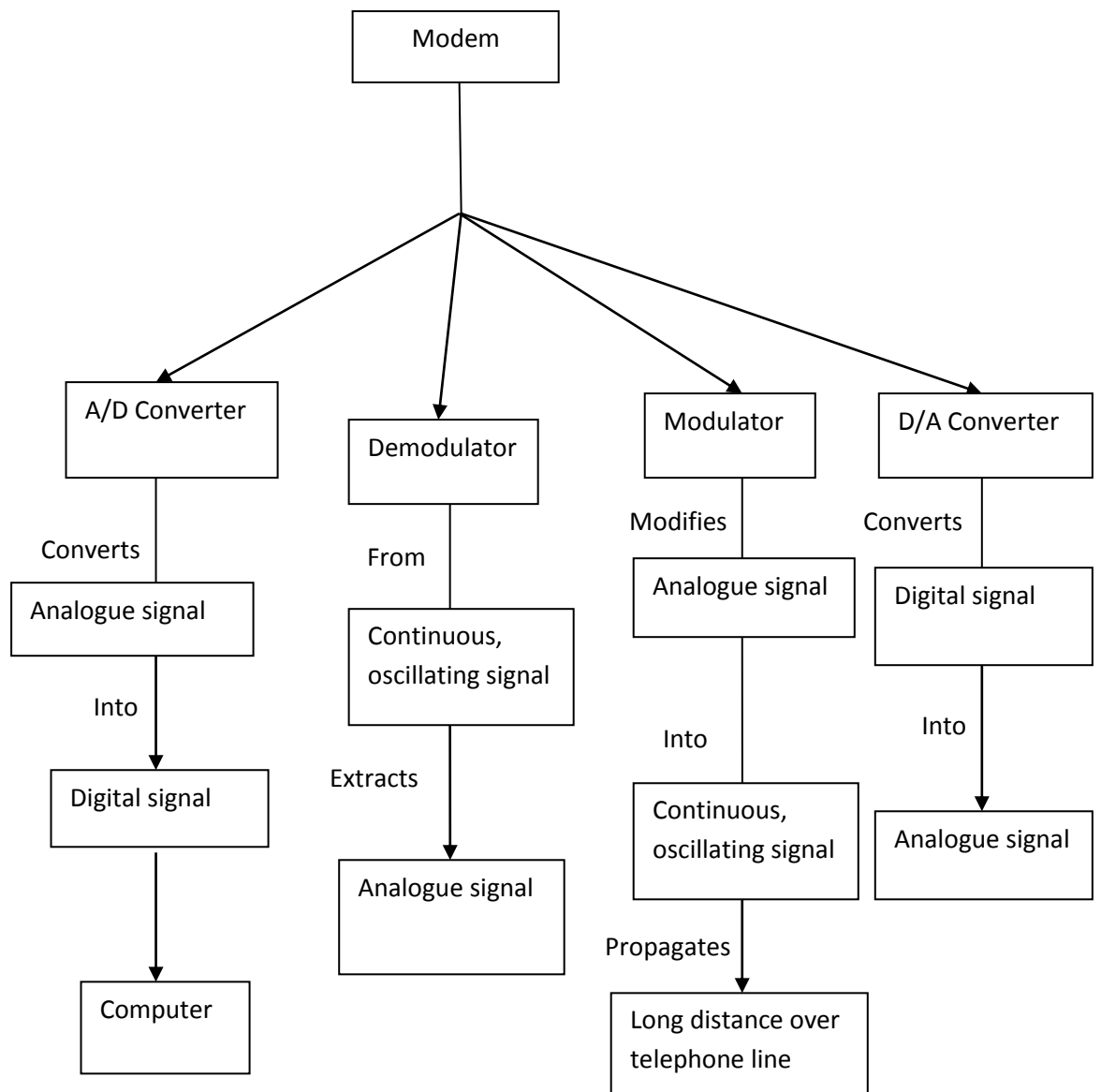


Figure B.4 A concept map, describing what Modem consists of and what it does.



Demodulator: We demodulate and extract analogue signal from continuous, oscillating signal. *A/D converter:* We are analogue to digital converters. We convert analogue signal into 0 and 1 digital data, then we send it to MOBO city.



D/A converter: We are digital to analogue converters. We convert digital data to analogue data.



Modulator: We modulate and modify analogue signal to continuous, oscillating signal to be able to propagate long distance over the telephone line.

Table B.4 Modem card's characters and their corresponding dialogues.

Smiley faces images have been extracted and modified from Emofaces Site (2008)

B.5 Hard Drive Concept Map and Characters

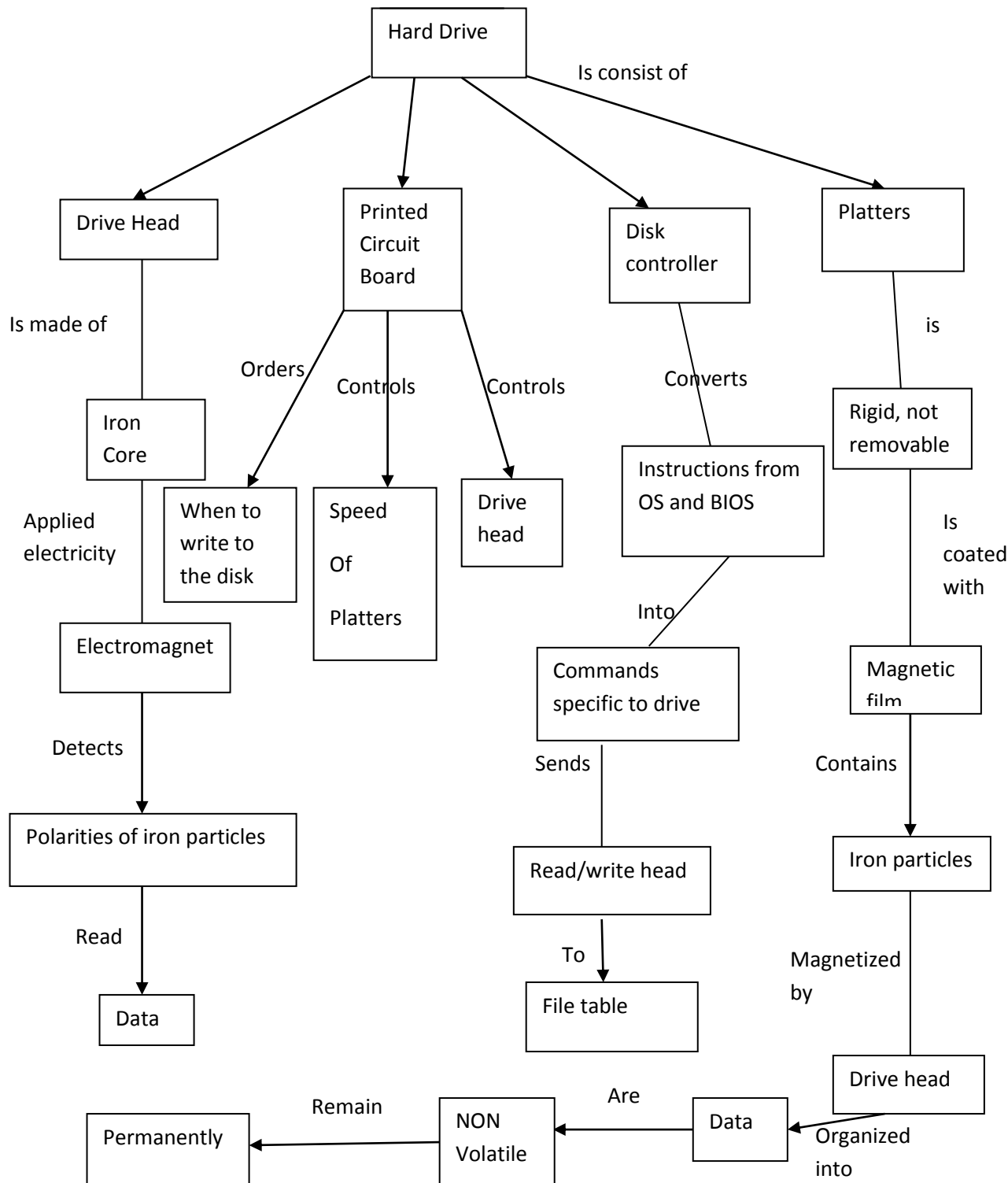


Figure B.5 A concept map, describing what a Hard disk consists of and what it does.



Printed Circuit Board: This is printed circuit board! We control drive head. We give the order to read and write from platters.



Drive Head: I am drive head! I have iron core. The electricity you brought has turned me into magnet.



Platters: We are platters! We are rigid. We contain iron particles, when magnetized represent the data you brought to us. We can keep it here permanently!



Disk Controller: I am disk controller. I convert instruction you brought to command for read and write data from platters, to file table.

Table B.5 Hard disk's characters and their corresponding dialogues.

Smiley faces images have been extracted and modified from Emofaces Site (2008)

Appendix C

QR Puzzles used for the Detective Alavi Game

QR codes are two dimensional bar codes that can be decoded using a mobile phone camera. The data embedded in the QR is in the form of a URL link, text message, phone number or some textual information. Their development is rapid and maintenance-free. To decode it players use a mobile camera to capture the QR tag and a QR code decoder algorithm integrated into the game to access the content. This algorithm frees the QR tags from any centralised image recognition techniques that are server based and contain a limited number of images.

QR codes in this research have been generated using the Kaywa barcode generator (<http://qrcode.kaywa.com/>) free of charge. The size and quality of QR codes in this appendix have been considerably reduced to fit within the margin requirements of the thesis. The original QR codes were at least twice as large as the QR codes presented here. They have often been printed on A3 sized paper. QR codes are vulnerable to dirt, blurred edges, tilting, rotation, damage, extreme light, uneven light, low resolution camera, low contrast and distance.

In each puzzle all tags must have the same size. If the shapes of all the wrong answers are the same then the correct answer will stand out. Consequently a different tag must be used for each incorrect answer, so each QR code looks unique, for example incorrect1, incorrect2, incorrect3.

C.1 Puzzle 1 (Level 1- Remembering)

C.1.1 Find meaning of vocabulary 'Manipulate'

1- Handle



Tag says: Handle.
to handle or manage, esp.
with skill

3- Represent



Tag says: Incorrect.
Represent: symbolize, stand for

2- Plan



Tag says: Incorrect.
Plan: make a scheme, plot

4- Withhold:



Tag says: Incorrect.
Withhold: hold back; restrain

Clue: Handle.

C.2 Puzzle 2 (Level 1- Remembering)

C.2.1 Find meaning of vocabulary 'Etch'

1- Determine



Tag says: Incorrect.

Determine: decide, settle, conclude.

2- Fetch



Tag says: Incorrect.

Fetch: go after and bring back.

3- elaborate



Tag says: Incorrect.

elaborate: detailed, complicated

Clue: Engrave

4- engrave:



Tag says: engrave.

to engrave with, to implant firmly

C.3 Puzzle 3 (Level 1- Remembering)

C.3.1 Find meaning of vocabulary 'Operate'

Note: Here we are practicing vocabularies "elaborate" and "manipulate" again.

1-Function



Tag says: Function. act, function; manage, use

3- elaborate



Tag says: Incorrect. elaborate: detailed, complicated

2- improve



Tag says: Incorrect. Improve: make better, enhance;

4-Manipulate



Tag says: Incorrect. Manipulate: to handle, esp. with skill

Clue: Function

C.4 Puzzle 4 (Level 1- Remembering)

C.4.1 Fill in the blank. 100 MHz is 100 million.....waves per second.

1- Chip



Tag says: Incorrect. A semiconductor ship containing a group of robots

2-Transistor



Tag says: Incorrect. CPU robots help to process data

3-Generation



Tag says: Incorrect. group of transistors made around the same time

4-Frequency



Tag says: Frequency. rate at which a signal cycles

Clue: Frequency

C.5 Puzzle 5 (Level 1- Remembering)

C.5.1 Find meaning of vocabulary 'execute'

Note: Here we are practicing vocabularies "fetch", "withhold" and "determine" again.

Perform



Tag Says: Perform. perform, carry out, put into practice

Withhold



Tag says: Incorrect. hold back; restrain

Fetch



Tag says: Incorrect. Fetch: go after and bring back

Determine



Tag says: Incorrect. Determine: decide, settle; conclude

Clue: Perform

C.6 Puzzle 6 (Level 1- Remembering)

C.6.1 What are the accumulator register robots, responsible for?

1-Collecting RAM
Addresses



Tag says: Incorrect.
Address register collects
RAM addresses

2-Collecting RAM Content



Tag says: Incorrect. Memory
data register collects RAM
content

3-Holds the result of
executing an operation.

-



Tag says: Accumulation.
Accumulator register holds
the result of execution

Clue: Accumulation

C.7 Puzzle 7 (Level 2- Understanding)

C.7.1 Find meaning of vocabulary 'alleviate'

Note: Here we are practicing vocabularies "manipulate", "handle" and "fetch" again.

relieve



Tag says: relieve. Lessen, diminish

Transact



Tag says: Incorrect.
Transact: carry out, perform

Alleviate



Tag says: Incorrect. Alleviate: lessen, diminish

Manipulate



Tag says: Incorrect.
Manipulate: handle or control with care

Clue: Relieve

C.8 Puzzle 8 (Level 2- Understanding)

C.8.1 Find the starting point (row, column) and the end point (row, column) of requested word and capture it from the tag table.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	F	T	N	O	F	R	Y	U	S	H	J	Z	A	Y	Z
2	B	K	C	H	N	E	L	X	I	N	V	O	L	V	E
3	E	I	E	T	X	D	U	T	A	T	W	S	L	U	H
4	V	F	Q	X	G	R	V	Z	C	C	U	V	E	N	V
5	Z	C	B	K	E	O	G	I	B	O	W	J	V	V	D
6	W	Q	R	V	D	C	D	W	E	U	Z	D	I	X	V
7	E	N	M	J	E	E	U	N	K	F	F	A	A	U	A
8	B	V	E	A	R	R	A	T	N	Z	I	F	T	Y	Z
9	R	K	E	P	X	T	L	E	I	S	U	R	E	L	Y
10	A	R	R	I	L	T	P	S	P	O	A	J	B	R	M
11	N	O	R	U	R	V	G	H	P	N	N	C	W	N	X
12	C	E	M	H	C	T	A	P	S	I	D	A	L	H	V
13	H	I	T	F	H	H	E	A	E	W	S	A	I	Q	C
14	S	D	L	C	P	X	C	R	I	A	E	K	G	C	T
15	S	R	D	V	Z	T	P	O	L	C	Y	V	A	J	H

Figure C.1 Word search puzzle

C.8.2 QR codes to help finding the vocabularies in Figure C.1

11,12,4,12



13,8,6,15



10,10,3,2



2,6,2,10



13,1,13,9



1,8,1,13



4,9,10,3



1,8,1,13



6,9,10,11



8,14,1,7



7,9,10,11



9,5,14,10



6,8,6,1



5,6,2,3



1,14,14,1



3,3,11,11



2,3,14,1



7,9,15,9



7,8,15,8



9,2,15,2



6,2,14,2



8,2,10,3



C.8.3 Puzzle 8 Solution

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	F	T	N	O	F	R	Y	U	S	H	J	Z	A	Y	Z
2	B	K	C	H	N	E	L	X	I	N	V	O	L	V	E
3	E	I	E	T	X	D	U	T	A	T	W	S	L	U	H
4	V	F	Q	X	G	R	V	Z	C	C	U	V	E	N	V
5	Z	C	B	K	E	O	G	I	B	O	W	J	V	V	D
6	W	Q	R	V	D	C	D	W	E	U	Z	D	I	X	V
7	E	N	M	J	E	E	U	N	K	F	F	A	A	U	A
8	B	V	E	A	R	R	A	T	N	Z	I	F	T	Y	Z
9	R	K	E	P	X	T	L	E	I	S	U	R	E	L	Y
10	A	R	R	I	L	T	P	S	P	O	A	J	B	R	M
11	N	O	R	U	R	V	G	H	P	N	N	C	W	N	X
12	C	E	M	H	C	T	A	P	S	I	D	A	L	H	V
13	H	I	T	F	H	H	E	A	E	W	S	A	I	Q	C
14	S	D	L	C	P	X	C	R	I	A	E	K	G	C	T
15	S	R	D	V	Z	T	P	O	L	C	Y	V	A	J	H

Figure C.2 Solution of Figure C.1.

C.8.4 Puzzle 8 Solution

(Column, Row (Starting point), Column, row (End point))

Clue: Alleviate (13, 1, 13, 9)

Clue: Branch (1, 8, 1, 13)

Clue: Buffer (9, 5, 14, 10)

Clue: Dispatch (11, 12, 4, 12)

Clue: Execution (3, 3, 11, 11)

Clue: Involve (9, 2, 15, 2)

Clue: Leisurely (7, 9, 15, 9)

Clue: Predict (4, 9, 10, 3)

Clue: Recorder (6, 8, 6, 1)

Clue: Retrieve (8, 14, 1, 7)

Clue: Simultaneously (1, 14, 14, 1)

Clue: Transact (13, 8, 6, 15)

C.9 Puzzle 9 (Level 2- Understanding)

C.9.1 Choose the correct order of operation in CPU Complex

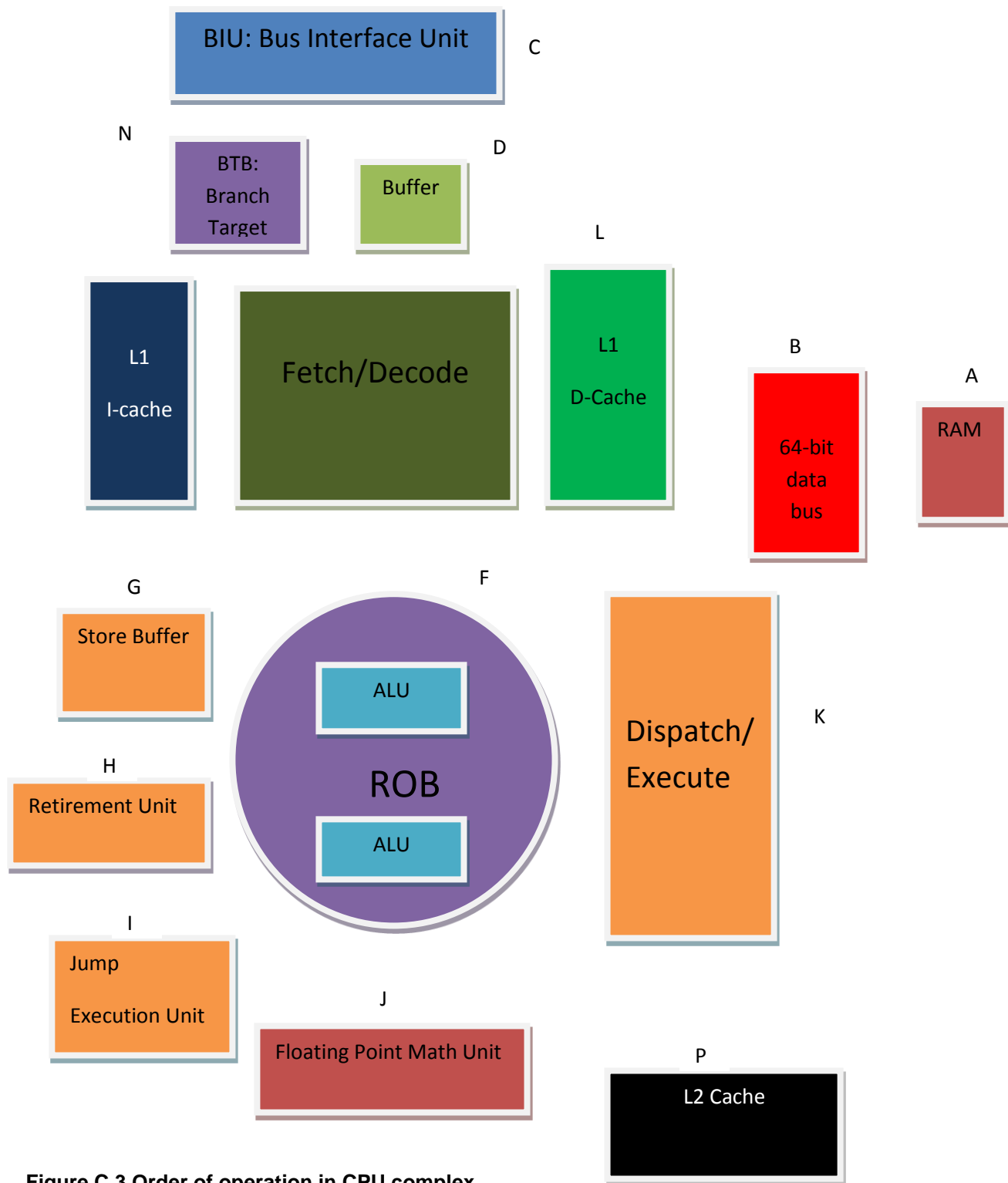


Figure C.3 Order of operation in CPU complex

1- A-B-C-D-E-F-K-H-G-C-B-A

2- A-B-C-D-E-F-I-J-P



Tag says: Inorrect1



Tag says: Incorrect2

3- A-B-C-L-E-F-K-J-G-C-B-P

4- A-B-C-M-N-E-F-K-H-G-C-B-A



Tag says: Incorrect3



Tag says: operation

Clue: Operation

C.10 Puzzle 10- (Level 3-Applying)

C.10.1 Choose an option which associates the components to their correspondence operations.

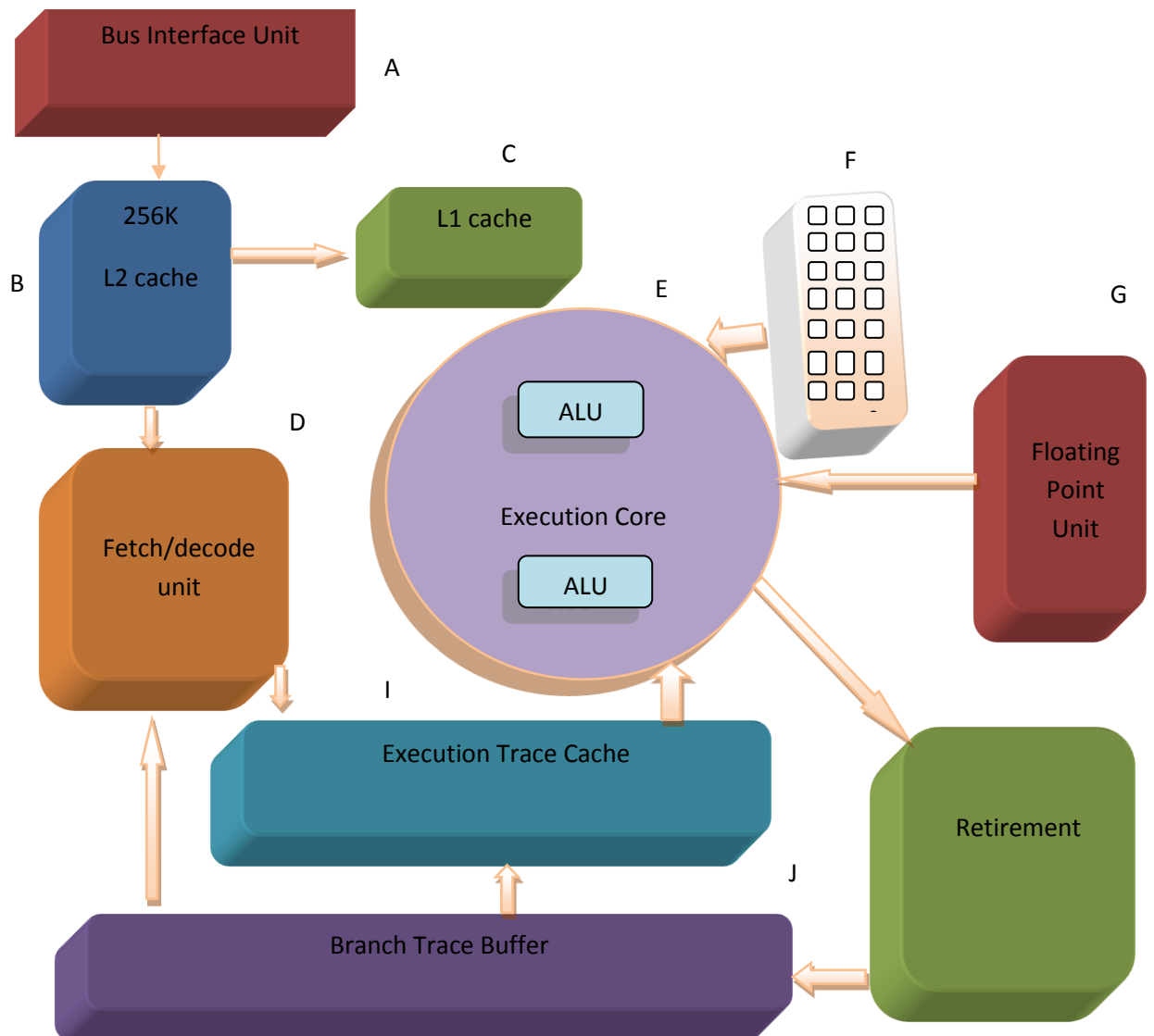


Figure C.4 Order of operation in Intel Pentium

Operations:

- 1- Stores 12KB of the most used microops
- 2- Predicts which path the program will take.

3- Uses simple instruction/multiple data

Options:

1-C,2-B,3-G

1-A, 2-I, 3-D



Tag says: incorrect 1

Tag says: incorrect 2

1-I, 2-J, 3-F

1-B, 2-F, 3-J



Tag says: Microop

Tag says: incorrect3

Clue: Microop

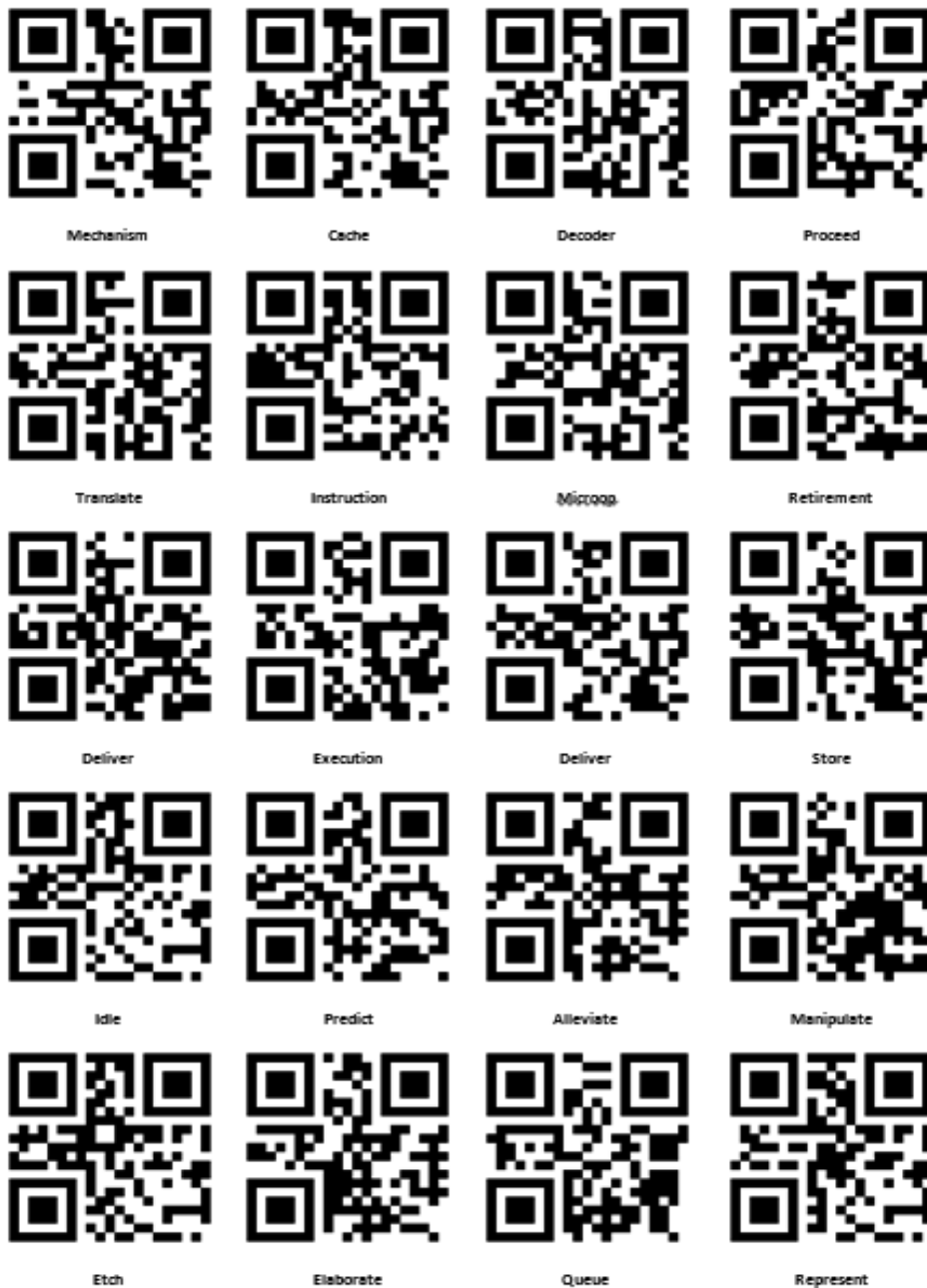
Tag says:
<http://www.hardwaresecrets.com/article/235>
An article about Pentium-4 architecture.



C.11 Puzzle 11 (Level 3- Applying)

C.11.1 Puzzle 11 comes in 3 sheets; each sheet of puzzle belongs to one of the team members. Clues are distributed among all three members of students have to work together to find all of the clues from the definition given. Each sheet contains 20 vocabulary spaces and their equivalent QR code, hiding 4 clues.

□





Deliver



Retirement



Microop



Translate



Decoder



Cache



Pipeline



Mechanism



Alleviate



Predict



Idle



Dispatch



Store



Perform



Execution



Represent



Elaborate



Etch



Micropp



Manipulate



Elaborate



Etch



Synchronous



Manipulate



Alleviate



Retrieve



Predict



Translate



Decoder



Cache



Mechanism



Transact



Temporality



Execution



Store



Idle



Microop



Retirement



Deliver



Represent

C.11.2 Puzzle 11 solutions

Clues

Instruction (in sheet 1, row 2 , column 2)

Deliver (in sheet 1, row 3, column 3)

Pipeline (in sheet 2, row 2, column 3)

Dispatch2 (in sheet 2, row 3, column 4)

Retrieve2 (in sheet 3, row 2, column 2)

Transact (in sheet 3, row 3, column 4)

Proceed (in sheet 1, row 1 , column 4)

Queue (in sheet 1, row 5 , column 3)

Perform2 (in sheet 2, row 4, column 2)

Macroop (in sheet 2, row 5, column 3)

Temporarily (in sheet 3, row 4, column 1)

Synchronous (in sheet 3, row 1, column 3)

Definitions

A single operation of processor

Convey, give, express

Different stages which the CPU processes instruction

send off quickly

recover, regain, fetch

interaction between two parties

continue, carry on

stand in line

do, carry out, execute

Results from Athlon decoders' translating instructions

Briefly

occurring at the same time, simultaneous

C.12 Puzzle 12: (Level 3 Applying)

C.12.1 Choose an option which associates the components to their true correspondence operations.

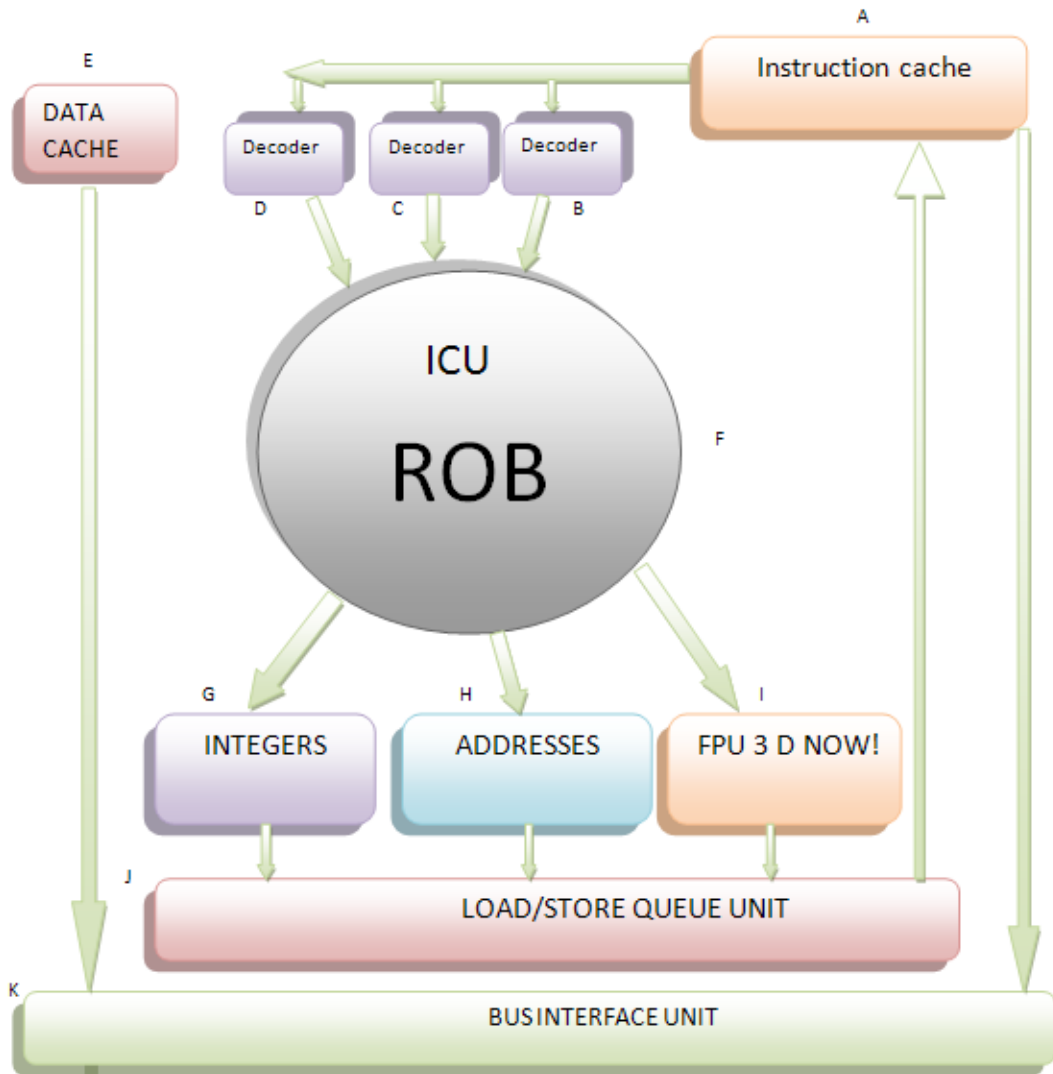


Figure C.5 Order of operation in AMD Athlon

Operations:

- 1- Converts instruction to macrobytes
- 2- Manages the execution and management of macrobytes
- 3- Enhances the performance of CPU for games and multimedia

Options:

1-A, 2-F, 3-G



Tag says: incorrect1

1-E, 2-D, 3-K



Tag says: incorrect2

1-B, 2-F, 3-I



Tag says: multimedia

1-B, 2-J, 3-K



Tag says: incorrect3

Clue: Multimedia



This Tag sends an SMS to an Athlon CPU expert's mobile number (00989127506309).


C.13 Puzzle 13- (Level 4 Analysing)

C.13.1 From this table you can see that, in general, there is a relationship between clock speed and MIPS, there also exist a relationship between the number of transistors and MIPS.

Which option is best estimate for A, B, C, D.

Table C.1 relationship between clock speed and MIPS and the number of transistors

Name	Transistors	Clock speed	Data width	MIPS
8080	6,000	2 MHz	8 bits	0.64
8088	29,000	5 MHz	16 bits 8-bit bus	0.33
80286	134,000	6 MHz	16 bits	A
80386	275,000	16 MHz	32 bits	5
80486	1,200,000	25 MHz	32 bits	20
Pentium	3,100,000	60 MHz	32 bits 64-bit bus	100
Pentium II	7,500,000	233 MHz	32 bits 64-bit bus	~300
Pentium III	9,500,000	C	32 bits 64-bit bus	~510
Pentium 4	42,000,000	1.5 GHz	32 bits 64-bit bus	B
Pentium 4 "Prescott"	125,000,000	D	32 bits 64-bit bus	~7,000



Expert's phone number

A-1, B-1700, C-450 MHz, D-3.6 GHz



Tag says: Intel

A-4, B-3000, C-1GHz, D-5GHz



Tag says: Incorrect1

A-3, B-5000, C-322 MHz, D-1.7 GHz



















Tag says: Incorrect2

Clue: Intel

C.14 Puzzle 14- (Level 4 Analysing)

C.14.1 Find a compound word from the vocabularies and suffixes given in table like QR codes. This puzzle comes in 3 sheets; each sheet of puzzle belongs to one of the team members. Clues are distributed among all three members, consequently they have to work together to find all of the clues. Each sheet contains 4 hidden clues.

ment	ance	ion	al	
				manipulate
				calculate
				operate
				function

ment

ance

ion

al



improve



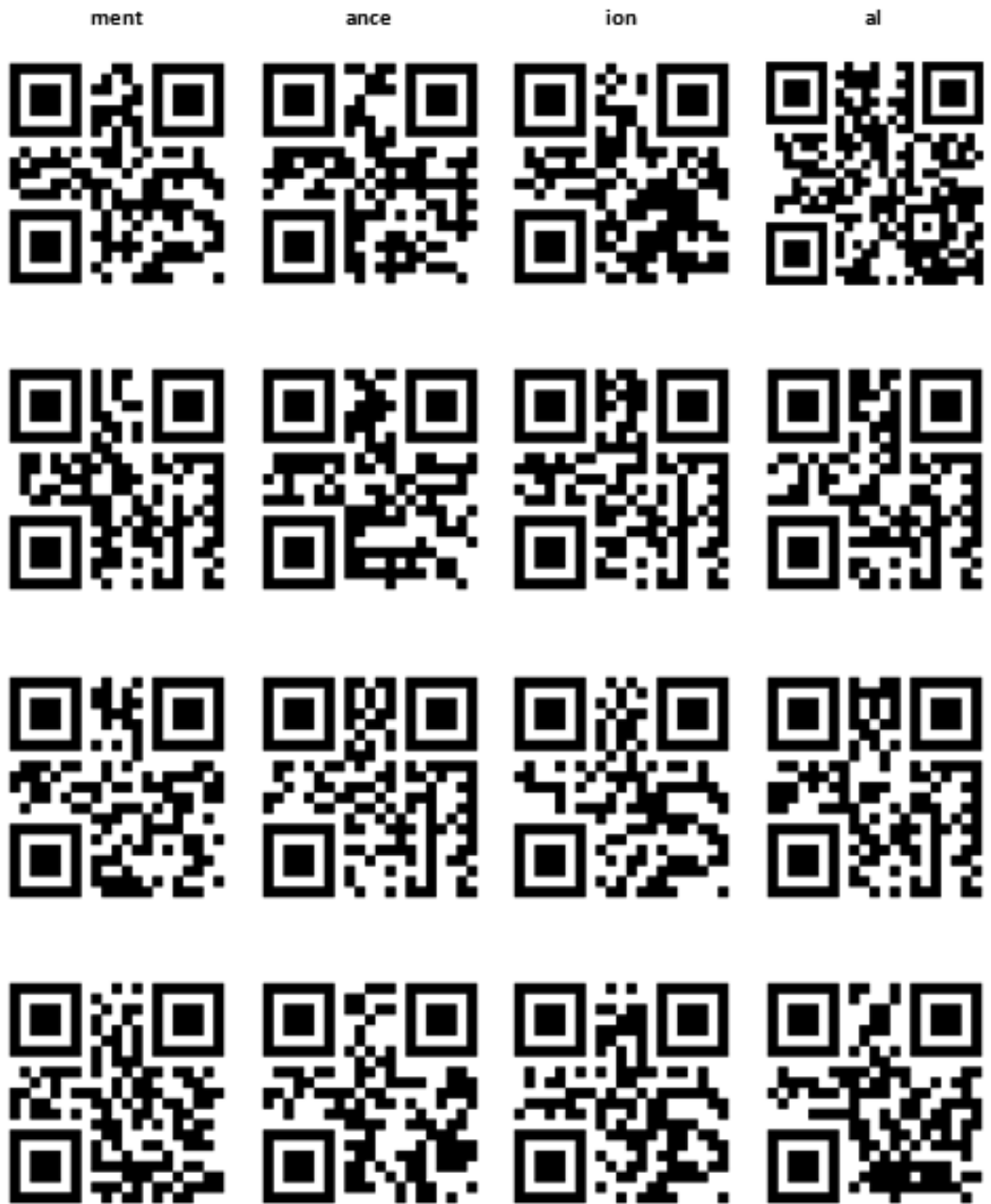
perform



involve



transact



C.14.2 Solutions to puzzle 14

Clues: Manipulation

Clues: Calculation

Clues: Operation2

Clues: Functional

Clues: Improvement

Clue: Performance

Clue: Involvement

Clue: Transaction

Clue: Instructional

Clue: Avoidance

Clue: Retirement

Clue: Measurement

C.15 Puzzle 15- (Level 4 Analysing)

C.15.1 Fill in the blank:

.....is a 64-bit processor.

Table C.2 Intel processor specification (from Mueller 2004, p. 42)

Processor	CPU Clock	Voltage	Internal Register Size	Data Bus Width	Max. Memory	Level 1 Cache	L1 Cache Type
8088	1x	5v	16-bit	8-bit	1MB	—	—
8086	1x	5v	16-bit	16-bit	1MB	—	—
286	1x	5v	16-bit	16-bit	16MB	—	—
386SX	1x	5v	32-bit	16-bit	16MB	—	—
386SL	1x	3.3v	32-bit	16-bit	16MB	0KB'	WT
386DX	1x	5v	32-bit	32-bit	4GB	—	—
486SX	1x	5v	32-bit	32-bit	4GB	8KB	WT
486SX ²	2x	5v	32-bit	32-bit	4GB	8KB	WT
487SX	1x	5v	32-bit	32-bit	4GB	8KB	WT
486DX	1x	5v	32-bit	32-bit	4GB	8KB	WT
486SL ²	1x	3.3v	32-bit	32-bit	4GB	8KB	WT
486DX ²	2x	5v	32-bit	32-bit	4GB	8KB	WT
486DX ⁴	2x-3x	3.3v	32-bit	32-bit	4GB	16KB	WT
486 Pentium OD	2.5x	5v	32-bit	32-bit	4GB	2x16KB	WB
Pentium 60/66	1x	5v	32-bit	64-bit	4GB	2x8KB	WB
Pentium 75-200	1.5x-3x	3.3v-3.5v	32-bit	64-bit	4GB	2x8KB	WB
Pentium MMX	1.5x-4.5x	1.8v-2.8v	32-bit	64-bit	4GB	2x16KB	WB
Pentium Pro	2x-3x	3.3v	32-bit	64-bit	64GB	2x8KB	WB
Pentium II	3.5x-4.5x	1.8v-2.8v	32-bit	64-bit	64GB	2x16KB	WB
Pentium II PE	3.5x-6x	1.6v	32-bit	64-bit	64GB	2x16KB	WB
Celeron	3.5x-4.5x	1.8v-2.8v	32-bit	64-bit	64GB	2x16KB	WB
Celeron A	3.5x-8x	1.5v-2v	32-bit	64-bit	64GB	2x16KB	WB
Celeron III	4.5x-11.5x	1.5v-2v	32-bit	64-bit	64GB	2x16KB	WB
Celeron IIIB	9x-14x	1.5v	32-bit	64-bit	64GB	2x16KB	WB
Pentium III	4x-6x	1.8v-2v	32-bit	64-bit	64GB	2x16KB	WB
Pentium IIIE	4x-9x	1.3v-1.7v	32-bit	64-bit	64GB	2x16KB	WB
Pentium IIIB	8.5x-10.5x	1.45v	32-bit	64-bit	64GB	2x16KB	WB
Pentium II Xeon	4x-4.5x	1.8v-2.8v	32-bit	64-bit	64GB	2x16KB	WB
Pentium III Xeon	5x-6x	1.8v-2.8v	32-bit	64-bit	64GB	2x16KB	WB
Pentium IIIE Xeon	4.5x-6.5x	1.65v	32-bit	64-bit	64GB	2x16KB	WB
Celeron 4	4.25x	1.6v	32-bit	64-bit	64GB	2x16KB	WB
Pentium 4	3-5x	1.7v	32-bit	64-bit	64GB	12+8KB	WB
Pentium 4A	4x-6x	1.3v	32-bit	64-bit	64GB	12+8KB	WB
Pentium 4 Xeon	3x-5x	1.7v	32-bit	64-bit	64GB	12+8KB	WB
Itanium	3x-5x	1.6v	64-bit	64-bit	16TB	2x16KB	WB
Itanium 2	3x-5x	1.6v	64-bit	128-bit	16TB	2x16KB	WB

Options:

Expert's phone number

1- Pentium Pro

2- Celeron





Tag says:
Incorrect
Pentium Pro has 32-bit internal register size.



Tag says:
Incorrect
Celeron has 32-bit internal register size.

3- Pentium 4



Tag says:
Incorrect
Pentium 4 has 32-bit internal register size.

4- Itanium



Tag says:
Itanium.
Itanium has 64-bit internal register size.

Clue: Itanium

C.16 Puzzle 16- (Level 4 Analysing)

C.16.1 Which one of these processors has the capability to address 1 Terabyte (TB) of memory?

Table C.3 The memory-addressing capabilities of processors (Mueller 2004, p. 47):

Processor Family	Address Bus	Unit	Equivalent
8088/8086	20-bit		
286/386SX	24-bit		
386DX/486/ Pentium/K6	32-bit		
Pentium Pro, Pentium II, Pentium III, Celeron, Pentium 4, Athlon, Duron, Athlon 64	36-bit	1 kilobyte (KB)	1,024 bytes
		1 megabyte (MB)	1,048,576 bytes
		1 gigabyte (GB)	1,073,741,824 bytes
		1 terabyte (TB)	1,099,511,627,776 bytes
Opteron	40-bit	1 petabyte (PB)	1,125,899,906,842,624 bytes
Itanium	44-bit		



Expert's phone number

Options:

1- Opteron



Tag says:
Opteron.
40 bit address bus: $2^{40} =$
1,099,511,627,776 byte = 1 TB

2- 8088



Tag says:
Incorrect
20 bit address bus: $2^{20} =$
1,048,576 byte

3- Athlon 64



Tag says:
Incorrect
36 bit address bus: $2^{36} =$
68,719,476,736 byte

4- Itanium



Tag says:
Incorrect
44 bit address bus: $2^{44} =$
17,592,186,044,416 byte = 16 TB

Clue: Opteron

C.17 Puzzle 17- (Level 5 Evaluating)

C.17.1 In the following sentences indicate if vocabularies A, B, C, D, E, F, G have been used in their correct form. Puzzle 17 is a snake and ladder game; see how lucky you are in capturing clues. Correct answers contain the clue, by choosing the wrong answer you miss the clue and there are some empty squares that you only can skip.

Sources: http://en.wikipedia.org/wiki/Instruction_pipeline

<http://en.wikipedia.org/wiki/Overclocking>

http://www.thaiio.com/Hardware-cgi/0025_pc.htm

<http://www.informit.com/articles/article.aspx?p=482324&seqNum=19>

Puzzle 17 Sentences

1- Overclocking is the **processor (A)** of running a computer component at a higher clock rate.

2- Pipelining allows the computer's control circuitry to issue instructions at the **processing (B)** rate of the slowest step, which is much faster than the time needed to perform all steps at once.

3- The bus interface unit is the part of the **processing (C)** that interfaces with the rest of the PC.

4- The Central **Processing (D)** Unit or the processor is the most important portion of a computer system.

5- A block diagram can show if a **process (E)** has to be repeated or if there are alternative routes to be taken.

6- The **process (F)** status is a collection of 'indicators' that give some indication of the current state of the central processing unit at any moment.

7- During processing, instructions and data are passed between the various types of internal memories, the **processor's (G)** control unit, the ALU, and the peripheral devices over the common electrical bus.

C.17.2 QR Snake and Ladder Puzzle

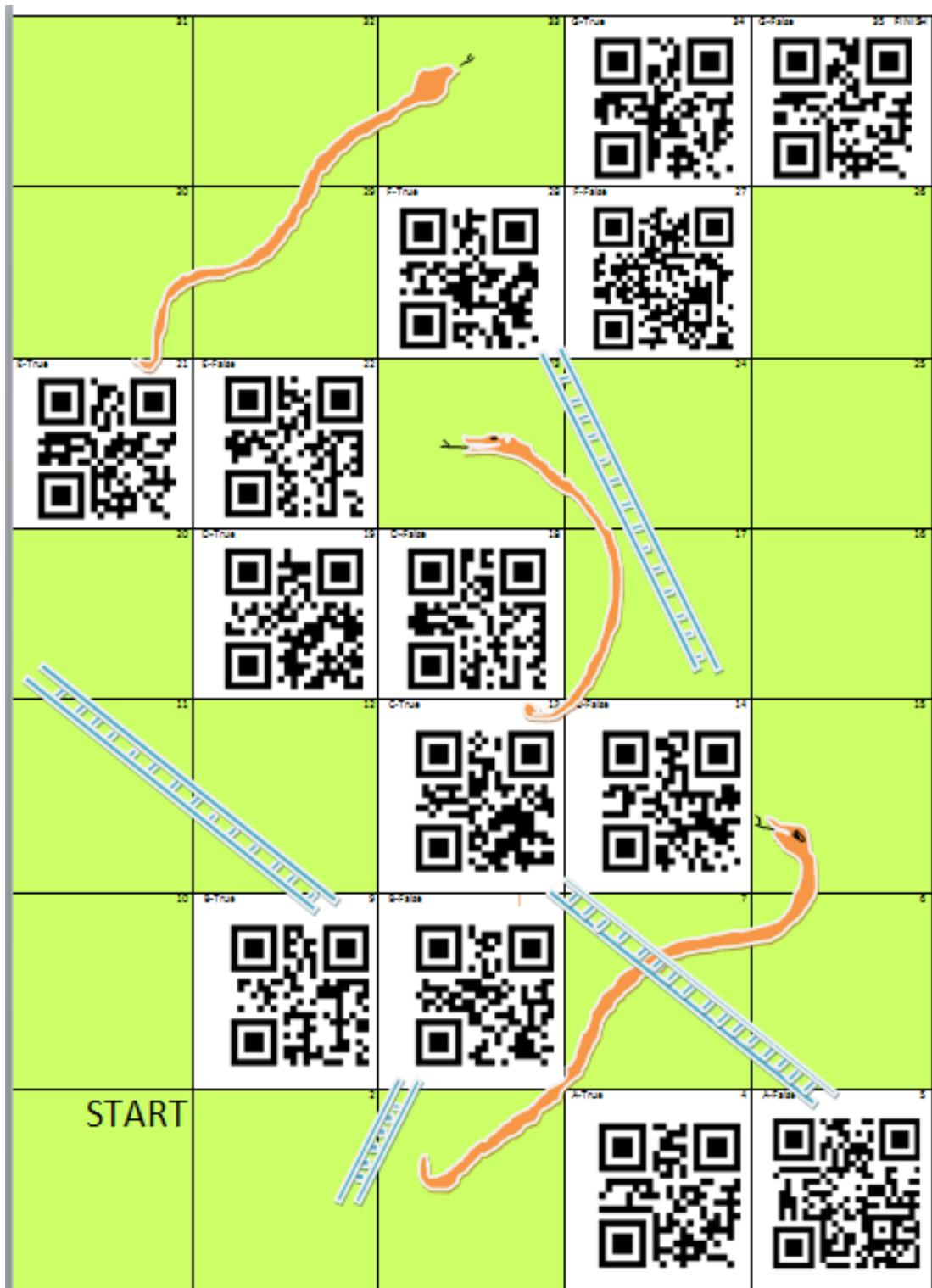


Figure C.6 QR Snake and Ladder

C.17.3 Puzzle 17 Clues

A- False Clue: Overclocking

B-True Clue: Processing

C-False Clue: Processor

D-True Clue: CPU

E- True Clue: Process

F- False Clue: Indicator

G-True Clue: ALU

C.17.4 Puzzle 17 Solutions

Overclocking is the **process (A)** of running a computer component at a higher clock rate. Pipelining allows the computer's control circuitry to issue instructions at the **processing (B)** rate of the slowest step, which is much faster than the time needed to perform all steps at once. The bus interface unit is the part of the **processor (C)** that interfaces with the rest of the PC. The Central **Processing (D)** Unit or the processor is the most important portion of a computer system. A block diagram can show if a **process (E)** has to be repeated or if there are alternative routes to be taken. The **processing (F)** status is a collection of 'indicators' that give some indication of the current state of the central processing unit at any moment. During processing, instructions and data are passed between the various types of internal memories, the **processor's (G)** control unit, the ALU, and the peripheral devices over the common electrical bus.

C.18 Puzzle 18- (Level 5 Evaluating)

C.18.1 MULTICORE PROCESSORS

From: <http://www.csa.com/discoveryguides/multicore/review3.php>

And <http://www.csa.com/discoveryguides/multicore/review5.php>

Due to advances in circuit technology and performance limitation in wide-issue, super-speculative processors, Chip-Multiprocessors (CMP) or multi-core technology has become the mainstream in CPU designs. Speeding up processor frequency had run its course in the earlier part of this decade; computer architects needed a new approach to improve performance. Power consumption increases by 60% with every 400MHz rise in clock speed. But the dual-core approach means you can get a significant boost in performance without the need to run at ruinous clock rates.

If we set two cores side-by-side, one can see that a method of communication between the cores, and to main memory, is necessary. This is usually accomplished either using a single communication bus or an interconnection network. The bus approach is used with a shared memory model, whereas the interconnection network approach is used with a distributed memory model. The shared and distributed memory models are depicted in Figure 1. After approximately 32 cores the bus is overloaded with the amount of processing, communication, and competition, which leads to diminished performance; therefore, a communication bus has a limited scalability.

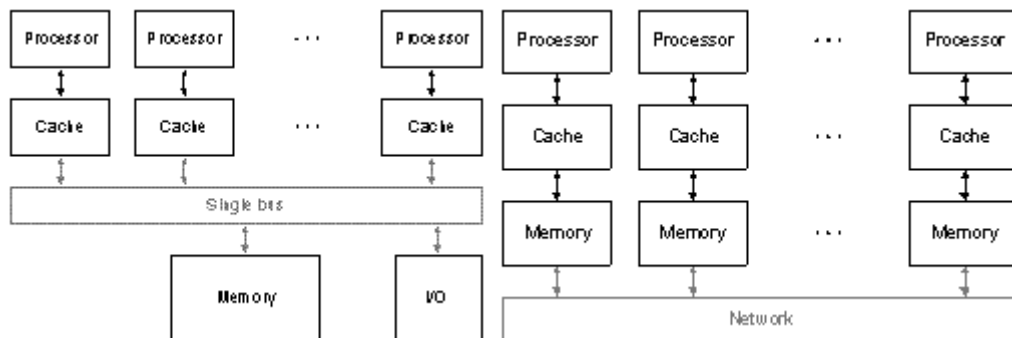


Figure C.7 (a) Shared Memory Model (b) Distributed Memory Model

Table C.4 Single Core vs. Multicore Power and Temperature

	Single core processor (45nm)	Multi-core processor (45nm)
Vdd	1.0V	1.0V
I/O pins(total)	1280 (ITRS)	3000 (Estimated)
Operating frequency	7.8GHz	4GHz
Chip-package data rate	7.8 Gb/s	4Gb/s
Bandwidth	125GByte/s	1 TeraByte/s
Power	429.78W	107.39W
Total number of pins on chip	3840	9000(Estimated)
Number of pins on the package	2480	4500(Estimated)

Multicore processors seem to answer the deficiencies of single core processors, by increasing bandwidth while decreasing power consumption. Table 1, shows a comparison of a single and multicore (8 cores in this case) processor used by the Packaging Research Center at Georgia Tech.

If two cores were placed on a single chip without any modification, the chip would, in theory, consume twice as much power and generate a large amount of heat. In the extreme case, if a processor overheats your computer may even combust. To account for this the multiple cores run at a lower frequency to reduce power consumption. To combat unnecessary power consumption many designs also incorporate a power control unit that has the authority to shut down unused cores or limit the amount of power. By powering off unused cores and using clock gating the amount of leakage in the chip is reduced. To lessen the heat generated by multiple cores on a single chip, the chip is architected so that the number of hot spots doesn't grow too large and the heat is spread out across the chip.

Cache Coherence

Cache coherence is a concern in a multicore environment because of distributed L1 and L2 cache. Since each core has its own cache, the copy of the data in that cache may not always be the most up-to-date version. For example, imagine a dual-core processor where each core brought a block of memory into its private cache. One core writes a value to a specific location; when the

second core attempts to read that value from its cache it won't have the updated copy unless its cache entry is invalidated and a cache miss occurs. This cache miss forces the second core's cache entry to be updated. If this coherence policy wasn't in place garbage data would be read and invalid results would be produced, possibly crashing the program or the entire computer.

In general there are two schemes for cache coherence, a snooping protocol and a directory-based protocol. The snooping protocol only works with a bus-based system, and uses a number of states to determine whether or not it needs to update cache entries and if it has control over writing to the block. The directory-based protocol can be used on an arbitrary network and is, therefore, scalable to many processors or cores, in contrast to snooping which isn't scalable. In this scheme a directory is used that holds information about which memory locations are being shared in multiple caches and which are used exclusively by one core's cache. The directory knows when a block needs to be updated or invalidated.

Multithreading

The last, and most important, issue is using multithreading or other parallel processing techniques to get the most performance out of the multicore processor. Programmers have to write applications with subroutines able to be run in different cores, meaning that data dependencies will have to be resolved or accounted for (e.g. latency in communication or using a shared cache). Applications should be balanced. If one core is being used much more than another, the programmer is not taking full advantage of the multicore system.

Intel Core 2

http://en.wikipedia.org/wiki/Intel_Core_2#Kentsfield



Multi-core processor

http://en.wikipedia.org/wiki/Multi-core_processor



C.18.2 Find the true sentences:

A- A single threaded application performs much better in Quad core system.



False

B- A single threaded application cannot run in Quad core system.



False2

C- A single threaded little benefit from Quad Core system.



True

C.18.3 From Table C.4 it can be inferred.....

A- With the same source voltage and single core running at a higher frequency in single core, we see an almost tenfold increase in bandwidth while the total power consumption is reduced by a factor of four.

B- With the same source voltage and multiple cores running at a lower frequency in multicore, we see an almost tenfold increase in bandwidth while the total power consumption is reduced by a factor of four.

C- With the same source voltage and single core running at a higher frequency we see an equal increase in bandwidth and the total power consumption in both single and multicore.



False3



True2



False4

C.18.4 Which option best fills the blanks?

Having multiple cores on a single chip gives rise to some problems and challenges. Power and temperature management are two concerns that can.....A.... exponentially with the addition of multiple cores. Memory/cache coherence is another challenge, distributed L1 and in some cases L2 caches must be...B.... And finally, using a multicore processor to its full potential is another issue. If programmers don't write applications that take advantage of multiple cores there is no gain, and in some cases there is a loss of performance. Application need to be written so that different parts can be runC....(without any ties to another part of the application that is being run simultaneously). Options:

A-increased, B-coordinate, C-
concurrently



Correct

A-decreased, B-coordinate, C-
concurrently



Incorrect2

A-increased, B-coordinate, C-
at the different times



Incorrect3

A-increased, B-uncoordinated,
C- at the different times



Incorrect4

Clues: True, True2, Correct

C.19 Clues in each game level

Table C.5 List of clues in each game level and their corresponding target skill

Levels	No. of clues	Clues	Skills
Level 1 - remembering	6	Handle Engrave Function Frequency Perform Accumulation	Meaning Meaning Meaning Electronic Meaning Electronic
Level 2 - understanding	14	Relieve Alleviate Branch Buffer Dispatch Execution Involve Leisurely Predict Recorder Retrieve Simultaneously Transact Operation	Meaning Spelling Spelling Spelling Spelling Spelling Spelling Spelling Spelling Spelling Spelling Spelling Spelling Spelling Electronic
Level 3 - applying	14	Microop Instruction Deliver Pipeline Dispatch2 Retrieve2 Transact Proceed Queue Perform2 Macroop Temporarily Synchronous Multimedia	Electronic Meaning Meaning Electronic Meaning Meaning Meaning Meaning Meaning Meaning Meaning Electronic Meaning Meaning Electronic
Level 4 - analysis	15	Intel Manipulation Calculation Operation2 Functional Improvement Performance	Electronic Form Form Form Form Form Form

		Involvement Transaction Instructional Avoidance Retirement Measurement Itanium Opteron	Form Form Form Form Form Form Electronic Electronic
Level 5 - Evaluation	10	Overclocking Processing Processor CPU Process Indicator ALU True True2 Correct	Form Form Form Form Form Form Form Electronic Electronic Electronic

C.20 Cryptogram

C.20.1 Cryptogram presented to students

JEWMOU, UWKHENU, YSWXGBLW, YHUVSUWXC, RUHYLHT,
EXXSTSOEGBLW, HUOBUNU, EOOUNBEGU ,QHEWXJ, QSYYUH,
MBDREGXJ, UAUXSGBLW, BWNLONU, OUBDSHUOC, RHUMBXG,
HUXLHMUH, HUGHBUNU ,DBTSOGEWULSDOC, GHEWDEXG,
LRUHEGBLW, TBXHLLR, BWDGHSXGBLW , MUOBNUH, RBRUOBWU,
MBDREGXJ2 ,HUGHBUNU2 , GHEWDEXG, RHLXUUM, VSUSU,
RUHYLHT2, TEXHLLR, GUTRLHEHBOC, DCWXJHLWLSD ,
TSOGBTUMBE, BWGUO, TEWBRSOEGBLW, XEOXSOEGBLW,
LRUHEGBLW2, YSWXGBLWEO, BTRHLNUTUWG ,RUHYLHTEWXU,
BWNLONUTUWG, GHEWDEXGBLW, BWDGHSXGBLWEO, ENLBMEWXU,
HUGBHUTUWG, TUEDSHUTUWG, BGEWBST, LRGUHLW,
LNUHXOLXFBWK, RHLXUDDBWK, RHLXUDDLH, XRS, RHLXUDD,
BWMBXEGLH, EOS , GHSU, GHSU2, XLHHUXG

Call this number
and read your clues
to win the game!



C.20.2 Cryptogram solutions

Handle, Engrave, Function, Frequency, Perform, Accumulation, Relieve,
Alleviate ,Branch, Buffer, Dispatch, Execution, Involve, Leisurely, Predict,
Recorder, Retrieve ,Simultaneously, Transact, Operation, Microop, Instruction ,
Deliver, Pipeline, Dispatch2 ,Retrieve2 , Transact, Proceed, Queue, Perform2,
Macroop, Temporarily, Synchronous , Multimedia, Intel, Manipulation,
Calculation, Operation2, Functional, Improvement ,Performance, Involvement,
Transaction, Instructional, Avoidance, Retirement, Measurement, Itanium,
Opteron, Overclocking, Processing, Processor, CPU, Process, Indicator, ALU ,
True, True2, Correct

Appendix D

Students' Test Results Before and After Detective Alavi Game Play

Table D.1 Paired samples statistics and paired samples test (t-test) for Meaning Skill

Group Numbering	Students	Meaning Skill Before Game Play Max = 15	Meaning Skill After Game Play Max = 15
1	St1	6	10
	St2	4	11
	St3	10	12
	St4	7	11
2	St5	4	12
	St6	3	11
	St7	11	15
3	St8	5	11
	St9	7	11
	St10	6	5
4	St11	10	15
	St12	8	10
	St13	7	14
	St14	4	11
Results Analysis N=13	Mean	6.6154	11.8462
	Mean Percentage	44.10	78.97
	Mean Difference	-5.23077	
	Percentage Increase in Mean	34.8718	
	Standard Deviation	2.59931	1.72463
	t	-9.033	
	df	12	
	P Value or Significance Sig.(2-tailed)	0.000	
95% Confidence Interval of the Difference	Lower	-6.49242	
	Upper	-3.96911	

Table D.2 Paired samples statistics and paired samples test (t-test) for Spelling Skill

Group Numbering	Students	Spelling Skill Before Game Play Max = 12	Spelling Skill After Game Play Max = 12
1	St1	7	8
	St2	5	7
	St3	6	8
	St4	8	9
2	St5	4	6
	St6	2	5
	St7	6	11
3	St8	4	6
	St9	5	7
	St10	5	7
4	St11	6	8
	St12	9	10
	St13	6	8
	St14	3	8
Results Analysis N=13	Mean	5.4615	7.76
	Mean Percentage	45.51	64.66
	Mean Difference	2.30769	
	Percentage Increase in Mean	19.23075	
	Standard Deviation	1.94145	1.64083
	t	-6.325	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
95% Confidence Interval of the Difference	Lower	-3.10269	
	Upper	-1.51269	

Table D.3 Paired samples statistics and paired samples test (t-test) for Form Skill

Group Numbering	Students	Form Skill Before Game Play Max = 19	Form Skill After Game Play Max = 19
1	St1	14	17
	St2	9	14
	St3	10	16
	St4	7	12
2	St5	10	17
	St6	5	13
	St7	13	17
3	St8	7	10
	St9	7	7
	St10	12	12
4	St11	9	15
	St12	10	14
	St13	12	17
	St14	7	12
Results Analysis N=13	Mean	9.2308	13.9231
	Mean Percentage	48.58	73.27
	Mean Difference	4.69231	
	Percentage Increase in Mean	24.696	
	Standard Deviation	2.65059	3.09466
	t	-8.392	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
95% Confidence Interval of the Difference	Lower	-5.91054	
	Upper	-3.47407	

Table D.4 Paired samples statistics and paired samples test (t-test) for Electronic Skill

Group Numbering	Students	Electronic Skill Before Game Play Max = 13	Electronic Skill After Game Play Max = 13
1	St1	1	12
	St2	4	11
	St3	1	11
	St4	5	13
2	St5	8	11
	St6	2	11
	St7	5	12
3	St8	4	7
	St9	3	10
	St10	9	10
4	St11	9	12
	St12	5	14
	St13	5	9
	St14	3	12
Results Analysis N=13	Mean	4.2308	11.1538
	Mean Percentage	32.54	85.79
	Mean Difference	6.92308	
	Percentage Increase in Mean	53.25	
	Standard Deviation	2.38586	1.77229
	t	-8.875	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
	95% Confidence Interval of the Difference	Lower	-8.62266
Upper		-5.22349	

Table D.5 Paired samples statistics and paired samples test (t-test) for Report 1

Group Numbering	Students	Report 1 Before Game Play Max = 5	Report 1 After Game Play Max = 5
1	St1	1	1
	St2	1	1
	St3	1	1
	St4	1	1
2	St5	2	2
	St6	1	2
	St7	2	2
3	St8	1	1
	St9	1	1
	St10	1	1
4	St11	1	1
	St12	1	1
	St13	1	1
	St14	1	1
Results Analysis N=13	Mean	1.1538	1.2308
	Mean Percentage	23.076	24.616
	Mean Difference	-.07692	
	Percentage Increase in Mean	1.5384	
	Standard Deviation	.37553	.43853
	t	-1.000	
	df	12	
	P Value or Significance Sig.(2-tailed)	.337	
95% Confidence Interval of the Difference	Lower	-.24452	
	Upper	.09068	

Table D.6 Paired samples statistics and paired samples test (t-test) for Report 2

Group Numbering	Students	Report 2 Before Game Play Max = 5	Report 2 After Game Play Max = 5
1	St1	2	2
	St2	2	2
	St3	2	2
	St4	2	2
2	St5	2	3
	St6	0	3
	St7	2	3
3	St8	2	2
	St9	2	2
	St10	2	2
4	St11	2	2
	St12	2	2
	St13	2	2
	St14	0	2
Results Analysis N=13	Mean	1.6923	2.2308
	Mean Percentage	33.846	44.616
	Mean Difference	.53846	
	Percentage Increase in Mean	10.7692	
	Standard Deviation	.75107	.43853
	t	-2.007	
	df	12	
	P Value or Significance Sig.(2-tailed)	.068	
95% Confidence Interval of the Difference	Lower	-1.12307	
	Upper	.04614	

Table D.7 Paired samples statistics and paired samples test (t-test) for Report 3

Group Numbering	Students	Report 3 Before Game Play Max = 5	Report 3 After Game Play Max = 5
1	St1	0	2
	St2	0	2
	St3	2	2
	St4	1	2
2	St5	1	4
	St6	0	4
	St7	3	4
3	St8	1	2
	St9	0	2
	St10	2	-
4	St11	2	3
	St12	3	3
	St13	2	3
	St14	0	3
Results Analysis N=13	Mean	1.1538	2.7692
	Mean Percentage	23.06	55.384
	Mean Difference	1.61538	
	Percentage Increase in Mean	32.3076	
	Standard Deviation	1.14354	.83205
	t	-4.882	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
95% Confidence Interval of the Difference	Lower	-2.33626	
	Upper	-.89451	

Table D.8 Paired samples statistics and paired samples test (t-test) for Report 4

Group Numbering	Students	Report 4 Before Game Play Max = 5	Report 4 After Game Play Max = 5
1	St1	0	3
	St2	2	3
	St3	2	3
	St4	0	3
2	St5	0	4
	St6	0	4
	St7	3	4
3	St8	1	2
	St9	0	2
	St10	2	-
4	St11	3	3
	St12	2	3
	St13	0	3
	St14	0	3
Results Analysis N=13	Mean	1.0000	3.0769
	Mean Percentage	20	61.4
	Mean Difference	-2.07692	
	Percentage Increase in Mean	41.5384	
	Standard Deviation	1.22474	.64051
	t	-5.671	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
95% Confidence Interval of the Difference	Lower	-2.87486	
	Upper	-1.27898	

Table D.9 Paired samples statistics and paired samples test (t-test) for Report 5

Group Numbering	Students	Report 5 Before Game Play Max = 5	Report 5 After Game Play Max = 5
1	St1	1	3
	St2	1	3
	St3	2	3
	St4	0	3
2	St5	0	5
	St6	0	5
	St7	2	5
3	St8	0	2
	St9	0	2
	St10	1	-
4	St11	3	5
	St12	2	5
	St13	0	5
	St14	0	5
Results Analysis N=13	Mean	.8462	3.9231
	Mean Percentage	16.924	78.4
	Mean Difference	-3.07692	
	Percentage Increase in Mean	61.5384	
	Standard Deviation	1.06819	1.25576
	t	-7.698	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
95% Confidence Interval of the Difference	Lower	-3.94780	
	Upper	-2.20604	

Table D.10 Paired samples statistics and paired samples test (t-test) for Remembering Power

Group Numbering	Students	Remembering Power Before Game Play Max = 6	Remembering Power After Game Play Max = 6
1	St1	2	5
	St2	4	6
	St3	4	6
	St4	4	6
2	St5	3	5
	St6	2	4
	St7	2	6
3	St8	2	5
	St9	2	5
	St10	3	5
4	St11	2	6
	St12	3	5
	St13	4	6
	St14	2	5
Results Analysis N=13	Mean	2.7692	5.3846
	Mean Percentage	46.15	89.66
	Mean Difference	-2.61538	
	Percentage Increase in Mean	43.58	
	Standard Deviation	.92681	.65044
	t	-12.279	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
	95% Confidence Interval of the Difference	Lower	-3.07945
Upper		-2.15132	

Table D.11 Paired samples statistics and paired samples test (t-test) for Understanding Power

Group Numbering	Students	Understanding Power Before Game Play Max = 14	Understanding Power After Game Play Max = 14
1	St1	7	10
	St2	6	9
	St3	7	10
	St4	9	11
2	St5	5	8
	St6	3	7
	St7	8	13
3	St8	5	8
	St9	6	9
	St10	7	9
4	St11	8	10
	St12	11	12
	St13	8	10
	St14	4	10
Results Analysis N=13	Mean	6.6923	9.7692
	Mean Percentage	47.78	69.71
	Mean Difference	-3.07692	
	Percentage Increase in Mean	21.978	
	Standard Deviation	2.17503	1.64083
	t	-8.402	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
95% Confidence Interval of the Difference	Lower	-3.87486	
	Upper	-2.27898	

Table D.12 Paired samples statistics and paired samples test (t-test) for Applying Power

Group Numbering	Students	Applying Power Before Game Play Max = 14	Applying Power After Game Play Max = 14
1	St1	5	10
	St2	5	10
	St3	6	11
	St4	5	10
2	St5	4	11
	St6	2	8
	St7	11	13
3	St8	5	8
	St9	6	8
	St10	6	4
4	St11	11	13
	St12	7	10
	St13	5	12
	St14	2	10
Results Analysis N=13	Mean	5.6923	10.3077
	Mean Percentage	40.64	73.57
	Mean Difference	-4.61538	
	Percentage Increase in Mean	-30.7692	
	Standard Deviation	2.75029	1.70219
	t	-8.066	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
95% Confidence Interval of the Difference	Lower	-5.86211	
	Upper	-3.36866	

Table D.13 Paired samples statistics and paired samples test (t-test) for Analysis Power

Group Numbering	Students	Analysis Power Before Game Play Max = 14	Analysis Power After Game Play Max = 14
1	St1	10	13
	St2	7	10
	St3	7	11
	St4	7	10
2	St5	11	12
	St6	3	11
	St7	9	13
3	St8	6	7
	St9	5	7
	St10	10	10
4	St11	9	12
	St12	9	12
	St13	9	11
	St14	7	10
Results Analysis N=13	Mean	7.6154	10.6923
	Mean Percentage	54.39	76.37
	Mean Difference	-3.07692	
	Percentage Increase in Mean	-20.5128	
	Standard Deviation	2.18092	1.93152
	t	-6.325	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
95% Confidence Interval of the Difference	Lower	-4.13692	
	Upper	-2.01692	

Table D.14 Paired samples statistics and paired samples test (t-test) for Evaluation Power

Group Numbering	Students	Evaluation Power Before Game Play Max = 10	Evaluation Power After Game Play Max = 10
1	St1	4	9
	St2	2	8
	St3	3	9
	St4	2	8
2	St5	3	10
	St6	2	10
	St7	5	10
3	St8	2	6
	St9	3	6
	St10	6	6
4	St11	4	9
	St12	2	9
	St13	4	9
	St14	2	8
Results Analysis N=13	Mean	2.9231	8.5385
	Mean Percentage	29.231	85.38
	Mean Difference	-5.61538	
	Percentage Increase in Mean	56.1538	
	Standard Deviation	1.03775	1.33012
	t	-15.277	
	df	12	
	P Value or Significance Sig.(2-tailed)	.000	
95% Confidence Interval of the Difference	Lower	-6.41625	
	Upper	-4.81452	

Appendix E

Students' Test Before and After Detective Alavi Game Play

Level 1- Remembering

1- State the meaning of vocabulary 'represent'. (*Meaning Skill*)

2- State the meaning of vocabulary 'engrave'. (*Meaning Skill*)

3- State the meaning of vocabulary 'manipulate'. (*Meaning Skill*)

4- Fill in the blank. (*Electronic Skill*)

5000K.....is 5 million frequency waves per seconds.

5- State the meaning of vocabulary 'operate'. (*Meaning Skill*)

6- Fill in the blank. (*Electronic Skill*)

A/An.....is a register in which arithmetic and logic results are stored.

1- Accumulator 2- Address register

3- Floating point register 4- Program counter

Level 2 - Understanding

7- Explain the meaning of vocabulary 'execute'. (*Meaning Skill*)

8- State the spelling of vocabularies that you hear. (*Spelling Skill*)

Vocabularies: Alleviate, Branch, Buffer, Dispatch, Execution, Involve, Leisurely, Predict, Recorder, Retrieve, Simultaneously, transact)

9- Explain the correct order of operation from 'Bus Interface Unit' to 'Store Buffer' in computer CPU. (*Electronic Skill*)

Level 3 – Applying

10- Explain the order of operation in Intel Pentium. (*Electronic Skill*)

11- State the meaning of the following vocabularies: (*Electronic +Meaning Skill*)

Queue, Synchronous, Deliver, Transact, Perform, Macroop, Temporarily, Instruction, Dispatch, Pipeline, Retrieve, Proceed.

12- Explain the order of operation in AMD Athlon. (*Electronic Skill*)

Level 4 – Analysis

13- From this table you can see that, in general, there is a relationship between clock speed and MIPS, there also exist a relationship between the number of transistors and MIPS. Which option is best estimate for A, B, C, D. (*Electronic Skill*)

Name	Transistors	Clock speed	Data width	MIPS
8080	6,000	2 MHz	8 bits	0.64
8088	29,000	5 MHz	16 bits 8-bit bus	0.33
80286	134,000	6 MHz	16 bits	1
80386	275,000	16 MHz	32 bits	5
80486	1,200,000	25 MHz	32 bits	20
Pentium	3,100,000	60 MHz	32 bits 64-bit bus	A
Pentium II	7,500,000	C	32 bits 64-bit bus	~300
Pentium III	9,500,000	450MHz	32 bits 64-bit bus	B
Pentium 4	42,000,000	D	32 bits 64-bit bus	1700
Pentium 4 "Prescott"	125,000,000	3.6GHz	32 bits 64-bit bus	~7,000

A) 100, 510, 233MHz, 1.5GHz

B) 80, 1000, 233MHz, 1.5GHz

C) 150, 510, 80MHz, 1.5 GHz

14- Make compound words from the following vocabularies: (*Form Skill*)

Perform, Transact, Function, Calculate, Manipulate, Operate, Improve, Involve, Instruction, Measure, Retrieve, Avoid.

15- According to the table below (from Mueller 2004, p. 42) fill in the blank.
(*Electronic Skill*)

Pentium Pro is abit processor

Processor	CPU Clock	Voltage	Internal Register Size	Data Bus Width	Max. Memory	Level 1 Cache	L1 Cache Type
8088	1x	5v	16-bit	8-bit	1MB	—	—
8086	1x	5v	16-bit	16-bit	1MB	—	—
286	1x	5v	16-bit	16-bit	16MB	—	—
386SX	1x	5v	32-bit	16-bit	16MB	—	—
386SL	1x	3.3v	32-bit	16-bit	16MB	0KB	WT
386DX	1x	5v	32-bit	32-bit	4GB	—	—
486SX	1x	5v	32-bit	32-bit	4GB	8KB	WT
486SX ²	2x	5v	32-bit	32-bit	4GB	8KB	WT
487SX	1x	5v	32-bit	32-bit	4GB	8KB	WT
486DX	1x	5v	32-bit	32-bit	4GB	8KB	WT
486SL ²	1x	3.3v	32-bit	32-bit	4GB	8KB	WT
486DX ²	2x	5v	32-bit	32-bit	4GB	8KB	WT
486DX ⁴	2x-3x	3.3v	32-bit	32-bit	4GB	16KB	WT
486 Pentium OD	2.5x	5v	32-bit	32-bit	4GB	2x16KB	WB
Pentium 60/66	1x	5v	32-bit	64-bit	4GB	2x8KB	WB
Pentium 75-200	1.5x-3x	3.3v-3.5v	32-bit	64-bit	4GB	2x8KB	WB
Pentium MMX	1.5x-4.5x	1.8v-2.8v	32-bit	64-bit	4GB	2x16KB	WB
Pentium Pro	2x-3x	3.3v	32-bit	64-bit	64GB	2x8KB	WB
Pentium II	3.5x-4.5x	1.8v-2.8v	32-bit	64-bit	64GB	2x16KB	WB
Pentium II PE	3.5x-6x	1.6v	32-bit	64-bit	64GB	2x16KB	WB
Celeron	3.5x-4.5x	1.8v-2.8v	32-bit	64-bit	64GB	2x16KB	WB
Celeron A	3.5x-8x	1.5v-2v	32-bit	64-bit	64GB	2x16KB	WB
Celeron III	4.5x-11.5x	1.5v-2v	32-bit	64-bit	64GB	2x16KB	WB
Celeron IIIB	9x-14x	1.5v	32-bit	64-bit	64GB	2x16KB	WB
Pentium III	4x-6x	1.8v-2v	32-bit	64-bit	64GB	2x16KB	WB
Pentium IIIE	4x-9x	1.3v-1.7v	32-bit	64-bit	64GB	2x16KB	WB
Pentium IIIB	8.5x-10.5x	1.45v	32-bit	64-bit	64GB	2x16KB	WB
Pentium II Xeon	4x-4.5x	1.8v-2.8v	32-bit	64-bit	64GB	2x16KB	WB
Pentium III Xeon	5x-6x	1.8v-2.8v	32-bit	64-bit	64GB	2x16KB	WB
Pentium IIIE Xeon	4.5x-6.5x	1.65v	32-bit	64-bit	64GB	2x16KB	WB
Celeron 4	4.25x	1.6v	32-bit	64-bit	64GB	2x16KB	WB
Pentium 4	3-5x	1.7v	32-bit	64-bit	64GB	12+8KB	WB
Pentium 4A	4x-6x	1.3v	32-bit	64-bit	64GB	12+8KB	WB
Pentium 4 Xeon	3x-5x	1.7v	32-bit	64-bit	64GB	12+8KB	WB
Itanium	3x-5x	1.6v	64-bit	64-bit	16TB	2x16KB	WB
Itanium 2	3x-5x	1.6v	64-bit	128-bit	16TB	2x16KB	WB

16- According to table (Mueller 2004, p. 47) below how much of the memory, an Itanium processor has the capability to address? (*Electronic Skill*)

Processor Family	Address Bus
8088/8086	20-bit
286/386SX	24-bit
386DX/486/ Pentium/K6	32-bit
Pentium Pro, Pentium II, Pentium III, Celeron, Pentium 4, Athlon, Duron, Athlon 64	36-bit
Opteron	40-bit
Itanium	44-bit

Level 5 – Evaluating

17- In the following sentences indicate if vocabularies A, B, C, D, E, F and G have been used in their correct form. (*Word Form Skill*)

Sentences:

- 1- Overclocking is the **processed (A)** of running a computer component at a higher clock rate.
- 2- Pipelining allows the computer's control circuitry to issue instructions at the **process (B)** rate of the slowest step, which is much faster than the time needed to perform all steps at once.
- 3- The bus interface unit is the part of the **processor (C)** that interfaces with the rest of the PC.
- 4- The Central **Processor (D)** Unit or the processor is the most important portion of a computer system.
- 5- A block diagram can show if a **processing (E)** has to be repeated or if there are alternative routes to be taken.
- 6- The **processing (F)** status is a collection of 'indicators' that give some indication of the current state of the central processing unit at any moment.

7- During processing, instructions and data are passed between the various types of internal memories, the **processor's (G)** control unit, the ALU, and the peripheral devices over the common electrical bus.

A..... B..... C..... D..... E.....

F..... G.....

18- Clarify the advantage and disadvantage of Quad and Dual core? Explain how a dual core of 2.8 GHz has lower performance than a Quad core with 2.5 GHz? (*Electronic Skill*)