Comprehensive study of an integrated camera as a tool for collaboration in multiplayer mobile serious games

Ekaterina Kuts

May 15, 2008

Department of Computer Science and Statistics

University of Joensuu

Master's thesis

Comprehensive study of an integrated camera as a tool for collaboration in multiplayer mobile serious games

Ekaterina Kuts

Department of Computer Science and Statistics

University of Joensuu

P.O. Box 111, FI-80101 Joensuu, FINLAND

ekuts@cs.joensuu.fi

Master's thesis

Abstract

Currently mobile games for educational purposes is a rapidly developing area. In this work we focus on multiplayer mobile games and specific aspects such as communication and collaboration between players and learners. This knowledge is valuable not only for further game development with an educational purpose but in any type of mobile games. However, during our research we have observed that there is not enough analysis done on this topic.

The first step, a literature overview of several authors' implementations of different communication types between players in educational mobile games. We analyzed these papers in the view of collaboration support. This overview showed that some types of media are almost not used or not used for this purpose. Based on the outcomes of this literature overview, we decided to implement an educational mobile game which promotes collaboration at its core. In choosing the technology for the development we put special attention on types of communication that can support collaboration in a specific game design.

This paper presents an approach to a multiplayer mobile game. As a technology for the player's communication and collaboration we selected technology which is often used by mobile users but rarely supported in mobile games - photo exchange. Game testing enables us to collect feedbacks from users and analyze obtained data according to the main research questions. Thus, evaluation of the PiX game was done and preliminary conclusions were produced.

ACM Computing Classification System, 1998 version :

I.3.6 [Methodology and Techniques], H.4.3 [Communications Applications], H.5.1 [Multimedia Information Systems], H.5.2. [User Interfaces], H5.m. [Miscellaneous]

Keywords : education mobile games, collaboration, communication, integrated camera interaction

Preface

Last year was not the easiest period of my life and I would like to thank several people who helped me to make this work done.

I was lucky to get two supervisors guided my work at once. A big "thank you" goes to my supervisor Carolina Islas Sedano from the University of Joensuu for her patience, encouragement and long hours of dealing with my thesis. Thank you for trusting in me and your optimism, without your inspiration and guidance, none of this would have been possible. Also I would like to thank my supervisor Dr. Jarkko Suhonen from the University of Joensuu for his advices and valuable comments. I am grateful to Professor Jan Pawlowski from University of Jyväskylä for reviewing my thesis.

I would like to thank all current and former members of the Department of Computer Science and Statistics. I would like to thank Professor Jussi Parkkinen, Dean of the Faculty of Science at the University of Joensuu, who gave me the opportunity to participate IMPIT program and get Master's degree in Finland. I am grateful to Professor Erkki Sutinen, Head of Educational Technology Department, for providing me the opportunity to conduct research in the EdTech laboratory and his help in writing and proceeding with conference' papers. I am thankful to our coordinators Wilhelmiina Hämäläinen and Roman Bednarik and our secretaries Merja Hyttinen and Tarja Karhu for their help related to many questions. I also would like to thank Antony Harfield and Briana Egan for revising the language of this work. Besides, I wish to thank all people who helped me to run usability tests of the game, without these tests a big part of this research would have not been possible.

Special thanks go to Matti Tedre even if he will never read this. His course "Philosophy of Computer science" which I attended at the University of Joensuu in April 2007 became an initial point of my research activities. I identified my interests and started to form my ideas in readable shape :). Thank you, Matti, for your ideas and comments.

I also want to thank my friends who have stood with me during my study, especially Andrei Oprisan who helped me a lot in different ways. I am grateful to Ivan Fedorenko for his firm belief in my abilities to make this research done, thank you for your criticism of my writings and inexhaustible cheerfulness. Special thanks go to Evgeny Gornov for

his striking patience and support during my life in Joensuu, you was (and hopefully will be) the first and best reader and critic of my papers.

And finally, I want to express my deepest gratitude to my parents and sister. Without your help, love and support I would have never finished this work. You have always encouraged me in my choices in education and career, thank you for everything.

. . . to be continued :)

- *Ekaterina Kuts, May 2008*

Table of Contents

List of Figures

List of Tables

List of Abbreviations

GSM	Global System for Mobile communications
GPS	Global Positioning System
HTTP	Hypertext Transfer Protocol
PDA	Personal Digital Assistant
WLAN	Wireless Local Area Network
CHI	Human-Computer Interaction
ACM	Association for Computing Machinery

Chapter 1

Introduction

> An inexpensive instrument, not bigger than a watch, will enable its bearer to hear anywhere, on sea or land, music or song, the speech of a political leader, the address of an eminent man of science, or the sermon of an eloquent clergyman, delivered in some other place, however distant. In the same manner any picture, character, drawing,or print can be transferred from one to another place.
>
> Nikola Tesla, 1908

During the last few years mobile devices such as mobile phones, smart phones or PDAs have become an integral part of daily life. Continuous development of the technologies has made mobile devices smaller and more complex. A mobile device is used not only for voice communication; modern mobile devices have implemented various types of multimedia functionality from digital camera, graphical editors, MP3-players and voice recorders to several communication channels such as Internet connection via wireless network, or information exchange by using Bluetooth technology. Wireless technology facilitates interaction between people independent from location. Many providers allow upload of multimedia files (audio, video, images) to public sites for common use directly from the mobile device.

At the same time mobile technologies are a new field of research which offers the opportunity to embed learning in a natural environment. A mobile device has a number of unique advantages, such as mass availability, territory envelopment, a wide spectrum of

carried out tasks and constantly growing capacities. These functions in particular make it possible to use a mobile device in the educational sphere. Learning levels can be increased with use of mobile games with mobility and agility of participants.

Statistics demonstrate that mobile games are the most popular applications for mobile devices [Wagner, 2005]. Mobile games provide opportunities for study without the limitations of time and place. Games tend to consider the educational process as a form of entertainment. The focus on using a game for educational purposes (or in other words serious games) has been growing over time. This research is ample but with technologies rapid development new perspectives develop all the time.

Some researchers assert the necessity to improve the quality and impact of the studies in education and technologies fields [Reeves, 2006]. One of the possible solutions is to improve the research design based on development goals. The activity should be focused on the following main objectives: creative approaches to solve problems and at the same time construct reusable design principles. The development of games with educational purposes clearly falls within this categorization. As a consequence both objectives are present in games. On the other hand mobile technology is a new field of research. If we combine game development with the use of mobile technologies it offers us a wide set of possibilities.

1.1 Research questions

The dynamic development of mobile technologies as well as the wide-ranging possibilities for use provides a set of difficulties for users and developers. Many researches consider the problem of communication between players in educational mobile games as one of the most important; furthermore, for multiplayer mobile games collaboration problem enhanced for the last years. McGrenere [McGrenere, 1996] appeals to designers and developers and highlights to pay special attention to understanding of social dynamics in order to support them properly for successful collaboration. By using Grudin's "paradox of collaboration" he defined that

"we interact with other people continually and usually rather effortlessly, but designing computer support for collaboration is very difficult because we

> *have to actually understand how groups and organizations function. Collaborative activities fail because designers don't understand the fundamentals of group behaviour"*

In 2004 Mitchell [Mitchell and Savill-Smith, 2004] mentioned that the market of mobile games is the growing market for the all game industry: recent devices have higher screen definition, extended memory, functionalities while expenses of development are lower for mobile games than for games on more traditional platforms. Nowadays applications have become less constrained by the limitations of the technical parameters of mobile devices. But there are still some challenges in player's communication and collaboration. In spite of advantages, educational multiplayer mobile games have a set of problems. We cannot avoid the fact that mobile devices development is improving rapidly; however, devices with strong limitations are still in use. Hardware problems include slow CPU speed, limited storage space, low precision on screen and the requirement of a large battery capacity for gaming. Besides hardware challenges, mobile games also reveal problems in game play, personal understanding and software implementation. Most of the games have a set of restrictions such as age, sex, language, background, nationality and/or political orientation.

This thesis has a several purposes. First of all it introduces the readers to mobile technologies, their practical use an applications. The core of the thesis is in multiplayer mobile gaming and the problems of collaboration and communication between people. The importance and relevance of the educational multiplayer mobile games and its challenges is described. Besides, this thesis is considered the specific feature of mobile devices (integrated camera) and opportunity to improved collaboration through its use. We emphasized the main research questions as following:

- How does communication and collaboration between people through mobile games take place?
- What are the advantages and challenges of multiplayer mobile games for educational purposes?
- How is an integrated camera used to support communication and collaboration in multiplayer mobile games?

- What criteria should be used in evaluation of collaboration and communication in multiplayer mobile game?

1.2 Research methods

The research questions enable us to specify the research boundaries and conduct a literature overview according to the specific purposes. The literature overview represents the selection of the relevant information and summarizes approaches of different authors. This search is oriented on the electronic document search in academic databases (ACM Digital Library and IEEE Xplore) and the Internet using Scholar Google. Analysis enables us to make conclusions and identify further research. Through this analysis we find answers for the research questions; some theoretical findings need to be proved with practical use. Development of the new application which is based on research findings helps to find benefits or weaknesses in theory. Thus, the second method was design and implementation of the multiplayer mobile application. Experiments and evaluation of the multiplayer mobile game were performed as a last research method. Game test with a number of volunteers was executed for these purposes. These methods enable us to find answers on formulated research questions of this work.

Figure 1.1 illustrates connection between different research methods and work flow.

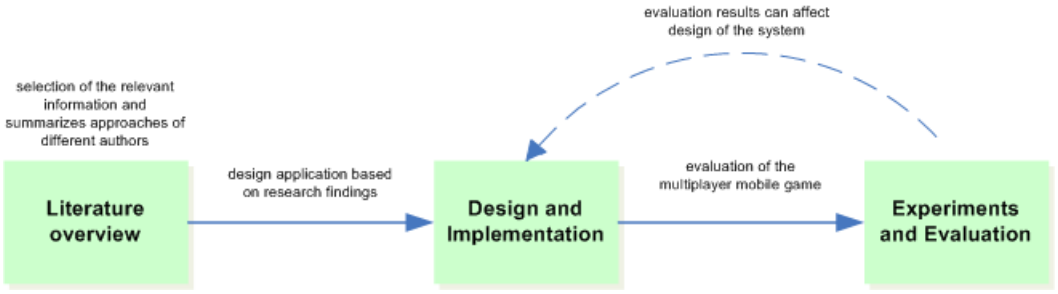

Figure 1.1: Research methods and work flow

1.3 Definition of main terms

Communication: *"the exchange of meanings between individuals through a common system of symbols"* [Britannica, 2008] . From the other source *"Communication is defined as a process by which we assign and convey meaning in an attempt to create*

shared understanding. This process requires a vast repertoire of skills in intrapersonal and interpersonal processing, listening, observing, speaking, questioning, analyzing, and evaluating. Use of these processes is developmental and transfers to all areas of life: home, school, community, work, and beyond. It is through communication that collaboration and cooperation occur" [Bergeson, 2008].

Collaboration: cooperation and join of intellectual facilities between several participants Mobile device is a portable device used for communication or for running applications, such as a PDA, a cell phone, or a Smartphone.

Mobile device: a portable device used for communication or for running applications, such as a PDA, a cell phone, or a Smartphone.

Game: *"a set of activities involving one or more players. It has goals, constraints, payoffs and consequences. A game is rule-guided and artificial in some respects. Finally, a game involves some aspect of competition, even if that competition is with oneself."* [Dempsey et al., 2002]

Mobile game: a game played on a portable device.

Serious games: games used to non-entertainment purposes. These games are used to develop education, management or other skills [Serious Games, 2008]

Location-based game (pervasive game): a game which involves players' location in a game play.

1.4 Structure of thesis

This thesis consists of six chapters. In the Introduction we identify the relevance of the topic, research questions, methods and main terms. In the second chapter we observe technology and communication trends that are present in educational multiplayer mobile games and attended challenges. The main outcome of this chapter is the analysis of the technology usage an identification of the most and least popular. The results of these actions enable us to find that photos are rarely used to achieve communication between players. This is the subject for the next chapter because statistics demonstrate opposite data - the users are interested in camera use and picture exchange. The third

chapter describes the specific of interaction with integrated mobile cameras and highlights the main characteristics of the successful camera-based application. We apply research findings for Chapter 2 and Chapter 3 and introduce in Chapter 4 the concept of the new collaborative multiplayer mobile application - the PiX game based on image exchange. Chapter 5 describes the analysis of the application tests and proposals for the future work. This chapter is followed by Conclusion and Future work.

Figure 1.2 represents graphically the thesis structure and expended time.

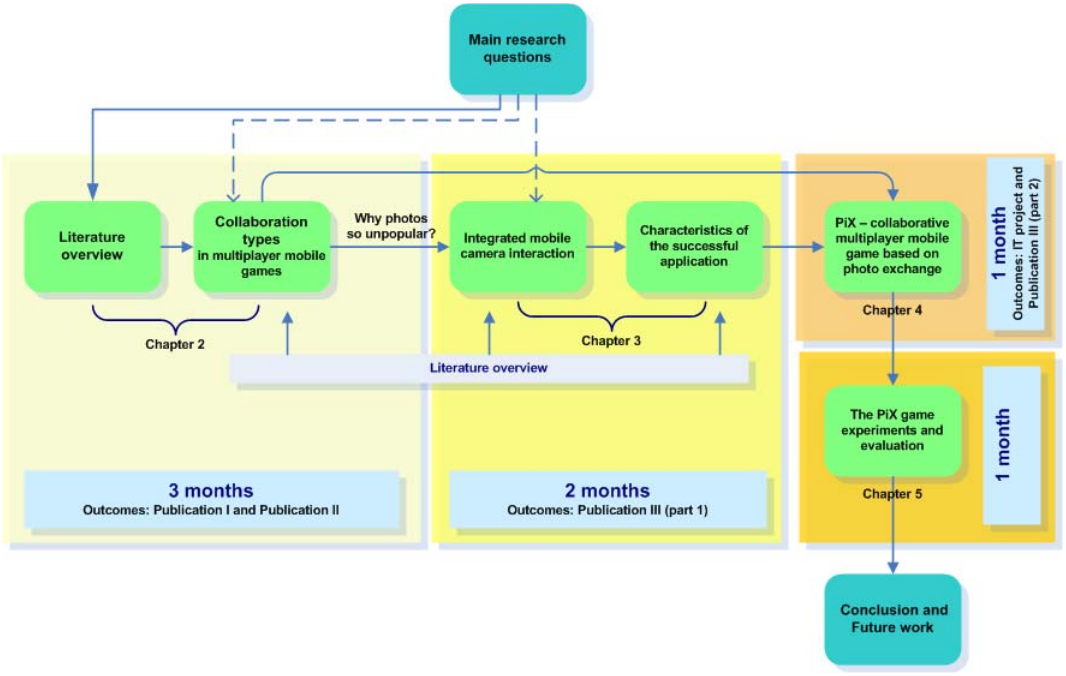

Figure 1.2: Visual representation of the thesis structure

1.5 Contribution

Based on the work contributed with the thesis, three papers have been published. The list of publications and contribution of the author in each of the papers is as follows:

Publication I Islas-Sedano, C., Kuts, E., Sutinen, E. (2008): Computer Science students can help to solve problems of multiplayer mobile games. Forthcoming proceeding of Koli Calling 2008. November 15-18, 2007, Koli National Park, Finland. [Islas-Sedano et al., 2008]

Contribution: Kuts contributed in development of the presented analysis of study curricula, and shared responsibilities of writing the paper.

Publication II Kuts, E., Islas-Sedano, C., Botha, A., Sutinen, E. (2007): Communication and collaboration in educational mobile games. Proceeding of IADIS International Conference on Cognition and Exploratory Learning in Digital Age, December 7-9, 2007, Algarve, Portugal [Kuts et al., 2007]

Contribution: Kuts conducted the presented analysis and responsible for writing. Kuts and Islas-Sedano were co-creators of the main concept of the paper. Islas-Sedano and Botha acted as experts and supervisors for the paper.

Publication III Kuts, E., Islas Sedano, C, Sutinen, E. (2008): Let's Play Together with the Camera of Your Mobile Device. Forthcoming proceeding of the Nordic Serious Games conference. February 28-29, 2008. Jyväskylä, Finland. [Kuts et al., 2008]

Contribution: The presented project was done at the University of Joensuu by Ekaterina Kuts under supervision of Carolina Islas-Sedano. Islas-Sedano acted as expert and supervisor of the paper. Kuts was responsible for writing.

Chapter 2

Literature overview: types of communication in multiplayer mobile games

> The single biggest problem in communication is the illusion that it has taken place.
>
> George Bernard Shaw,
> Irish literary Critic, Playwright and Essayist.
> 1856-1950

For the last years interest in the multiplayer mobile gaming and its influence on the different aspects of the human life has increased rapidly. This thesis deals with two related problems: communication and collaboration between people through multiplayer mobile games. We emphasized two questions concerning this problem. First of all, we are interested to find how these processes take place in multiplayer mobile games and what are the advantages and challenges? In order to develop an answer we conducted a literature overview. This thesis literature overview attempts to summarize approaches of different authors a challenge of communication and collaboration between players in different multiplayer mobile games. The aim of this chapter is focused on the communication types supporting collaboration in multiplayer mobile games and its main challenges. In addition this chapter gives clear research findings about the current situation in the multiplayer mobile games development market in view of the technology used for communication.

2.1 Literature overview: fundamentals

Multiplayer mobile gaming is a relatively new and rapidly expanding field of study. Different studies have been done in this area but few of them touch upon the communication and collaboration problem. In the beginning of this chapter we identified the research questions which will give us fundamentals for the further analysis. Following the aim of this thesis, we conducted the scientific search of the existing publications. It enables us to understand the current situation on mobile game development market, and find technologies which are more popular between developers during the last years. The search was oriented on the electronic document search in academic databases (ACM Digital Library and IEEE Xplore) and the Internet using Scholar Google. The search was performed during June - July 2007 and based on the keywords mobile games, multiplayer mobile game, mobile educational game, collaboration through mobile games, communication through mobile games. We use the following criteria to select articles for this overview:

- article is written in English;
- article opens a questions of educational multiplayer mobile games development;
- article is published by reliable source (i.e. established in scientific community);
- overviewed articles did not overlap with another overview's articles.

Moreover,

- the number of articles for the review is no less than 15;
- papers which consist of experiments, research or reports about multiplayer mobile gaming in view of communication problems were selected.

The abstracts and conclusions were reviewed for each paper, and a decision about further use of this article was given. If the article validated its claims and the data was useful for this review, then it was selected. As a result of this procedure, a total of 26 articles were selected. Most of them were published by ACM (Association for Computing Machinery), CHI (International Journal of Human-Computer Interaction),

MLEARN (International Conference on Mobile Learning) and NETGAMES (Workshop on Network and Systems Support for Games).

The information of resultant set of articles was extracted and embedded in a table. This was done for the purpose to visualize clearly the main information concerning communication and collaboration in the mobile games. The table consists of the following columns:

1. Reference information: article title, author(s) publisher and year of publication, and source,
2. type of tests,
3. target group,
4. benefits,
5. challenges,
6. authors recommendation divided by human and technical,
7. comments in Human Computer Interaction,
8. authors' open questions.

Thereby, this table became the starting point of the further research analysis.

2.2 Literature overview: outcomes

The first outcome of this literature overview is the association of two main streams of reporting multiplayer mobile games: theoretical and practical. Theoretical papers are the articles with strong theoretical research that include literature reviews, analysis of existing games, new game concepts and recommendations for the future developing. The experimental (or practical) set is consisting of the articles reporting empirical research and game prototypes with an educational component.

As it was mentioned above, we selected 26 papers, amongst which we identify nine theoretical and seventeen practical ones. Year of publication of these papers varies between

2001 and middle of 2007, only one of them was published before 2001. Figure 2.1 presents the distribution of selected articles by the year of publication. According to Figure 2.1, interest in multiplayer mobile gaming has increased last years.

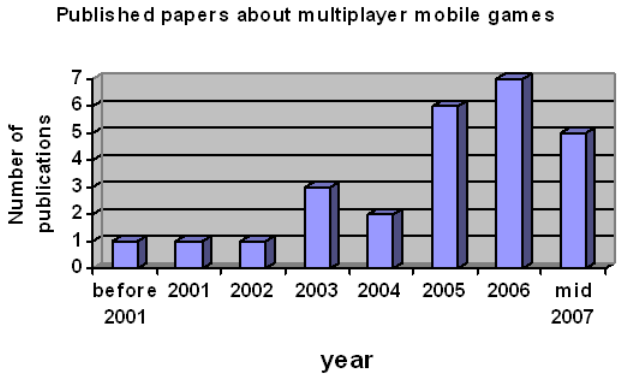

Figure 2.1: Published papers about multiplayer mobile games, period pre-2001-2007

Some of the practical papers often include a part of the theoretical research which is used for the further development process. Thus, we observed research questions for each paper in both sets of articles to identify the most relative and popular topics for discussion. Table 2.1 presents the result of the theoretical papers analysis.

Table 2.1: Theoretical papers analysis outcomes

Study	Research questions
1. [Thomas et al., 2003]	What is the conceptual solution to the potential design problems and what are the benefits for the educationists to be involved in educational mobile gaming?
2. [Savill-Smith and Kent, 2003]	How have palmtop computers been used for learning?
3. [Mitchell et al., 2007]	How have we begun to respond to the challenges from the purely educational to the technical, requiring a multidisciplinary approach to design?
4. [Antonellis et al., 2005]	What are the main objectives of the game based community and what are the special needs that mobile users bring?
5. [Vasudevan, 2006]	What is the future of collaborative mobile gaming?
6. [Koivisto, 2007]	How mobile gaming could be like in year 2010 from three points of view: games and players, technology, and business?

Continued on next page

Table 2.1 – *Continued from previous page*

Study	Research questions
7. [Nova et al., 2005]	How do people use space to solve problems collaboratively in virtual environments? How can we use these results in order to design more effective and more adapted environments? How do people carry out spatial coordination in virtual space when solving a problem collaboratively? How does space is used to improve referential communication between participants? How the use of explicit information about the partner's position could improve collaboration and mutual understanding during a joint activity?
8. [Prensky, 2001]	What are the trends in games and its future possible development directions? What are the opportunities of a game learning?
9. [McGrenere, 1996]	What can motivate children to play electronic games? How can we incorporate educational content into electronic games? And how can we develop appropriate multi-person educational tasks?

For the practical papers we specified the game title to use it in the further research. Table 2.2 describes experimental papers analysis.

Table 2.2: Practical papers analysis outcomes

Study	Mobile game	Aim or Research questions
1. [Benford et al., 2005]	Savannah	How do users experience location-based technologies, focusing on collaborative experiences?
2. [Nova et al., 2006]	CatchBob!	How can location awareness feature modify collaboration in the context of mobile computing?
3. [Sańchez et al., 2006]	BuinZoo	Design, development, application and evaluation of a new pedagogical methodology based on interactive games for mobile devices (PDAs)
4. [Flintham et al., 2003]	Can you see me now? Bystander	How is context more socially than technically constructed? How do players exploit (and resolved conflicts between) multiple indications of context including GPS, GPS error, audio talk, ambient audio, timing, local knowledge and trust?
5. [Mottola et al., 2006]	Save the princess	How the TinyLIME middleware is supports the context-aware interactions necessary for pervasive game development?
6. [Casey et al., 2007]	Gopher	How do the emerging capabilities on offer could be practically used in the real world?
7. [Ballagas et al., 2006] **8.** [Ballagas et al., 2007]	REXplorer	How can we make learning history fun for young (and young at heart) tourists and influence their path through the city?
9. [Koivisto et al., 2006]	Ancient Runes	How can we use text input as the primary method for interacting with the game and other players?

Continued on next page

Table 2.2 – ***continued from previous page***

Study	Mobile game	Aim or Research questions
10. [Schwabe and Göth, 2005]	MobileGame	How the mobile gaming can influence on participants' motivation and what are the features causing this effect?
11. [Björk et al., 2001]	Pirates!	How can computer games be designed to maintain some of the social aspects of traditional game play? How can wireless and proximity-sensing technology be integrated in the design of new game experiences?
12. [Mansley et al., 2004]	Game based on the Capture The Flag and Counter-Strike PC game	What is the effect of the feedback channel on a game play and is Bluetooth technology suitable as a network for mobile devices?
13. [Islas-Sedano et al., 2007]	SciMyst	What elements are important in a pervasive playful application that can trigger the interest of different individuals?
14. [Cheok et al., 2004]	Human Packman	Develop new interactive system that ventures to embed the natural physical world seamlessly with a fantasy virtual playground
15. [Bell et al., 2006]	Feeding Yoshi	Introduce a location-based game that provides an example of "seamful design"
16. [Barkhuus et al., 2005]	Treasure	How players' tactics and strategies are developed as their experience grew with successive games?
17. [Tuulos et al., 2007]	Manhattan Story Mashup	Present a new form of interactive storytelling which lets an unlimited number of players author stories in the Web while a large number of players illustrate the stories with camera phones

As evident for the Tables 2.1 and 2.2 the majority of theoretical papers consider the potential use of educational mobile games in accordance with their author's vision of the mobile technology future [Koivisto, 2007, Vasudevan, 2006, Prensky, 2001], combined with possibilities of innovation in new game spaces [Savill-Smith and Kent, 2003, Nova et al., 2005]. Several publications especially in the practical set, present main principles of multiplayer mobile games or suggest design issues [Björk et al., 2001, Bell et al., 2006, Cheok et al., 2004, Tuulos et al., 2007, Sańchez et al., 2006]. Furthermore, the proper analysis of the tables enables us to see that many scientists consider the problem of collaboration between players as important. In spite of this, there is still not enough information and experience to offer us a complete concept for successful support of collaboration in

mobile games.

From the theoretical discussion we find fundamentals on how to start classifying the practical papers.The first general overview allows us to foresee the technology and equipment used, the type of game developed and since when it was available (as seen in Table 2.3).

Table 2.3: Multiplayer mobile games

Game	**Technologies and equipment**	**Type**	**Availability and location**	**Game concept**
1. Savannah [Benford et al., 2005]	iPAQ PDAs with WiFi and GPS capabilities	Location-based	From 2005, UK	Learn about the ecology of the African savannah.
2. Ancient Runes [Koivisto et al., 2006]	GPRS, Nokia 6600 phones	Card collection game (players can buy cards, handle their deck, practice spell casting and so on)	2006, Finland	Take the role of wizards and battle with each other by casting spells.
3. CatchBob! [Nova et al., 2006]	TabletPC	Location-based	2005, Switzerland	Find a virtual object on campus.
4. BuinZoo [Sańchez et al., 2006]	PDA	Location-based	2006, Chile	Attain a balanced environment.
5. Can you see me now? [Flintham et al., 2003]	Compaq iPAQ, 802.11b wireless local area network, GPS receiver	Location-based	2003, UK	Online participants have to catch runners who were moving through the actual city streets.
6. Bystander [Flintham et al., 2003]	Compaq iPAQ,802.11b wireless local area network, GPS receiver	Location-based	2003, UK	Online participants have to steer the local player through a series of key physical locations.
7. Save the princess [Mottola et al., 2006]	802.11 wireless interface, Crossbow MICA2DOT motes, TinyLIME	Location-based	2006, Italy, Switzerland	Beat the black knight, who kidnapped the princess.
8. Gopher [Casey et al., 2007]	GSM, HTTP, Nokia Series 60 camera phones	Location-based	2007, UK	Solve game tasks:help a gopher complete its mission

Continued on next page

Table 2.3 – *continued from previous page*

Game	Technologies and equipment	Type	Availability and location	Game concept
9. Pirates! [Björk et al., 2001]	HP Jornada 690 handhold computers with IEEE 802.11 WLAN cards	Location-based	2001, Sweden	Solving a number of missions, exploring the islands in search for trading goods, and fighting other players in sea battles.
10. Game based on the popular Capture The Flag and Counter-Strike PC games [Mansley et al., 2004]	GSM, GPRS and Bluetooth, cell phone	Location-based	2004, UK	Capture the flag from the opponents base and return it to team base.
11. MobileGame [Schwabe and Göth, 2005]	GPS, HTTP, Bluetooth, PDA	Location-based	2002, Germany	Support the orientation days at a university.
12. REXplorer [Ballagas et al., 2006]	GPRS, HTTP, Nokia N70 mobile phone, GPS receiver	Location-based	Prototype 2006, development summer 2007 in Germany	Applied to the domain of tourism, helping visitors engage with the history and culture of their destination.
13. SciMyst [Islas-Sedano et al., 2007]	Nokia N80, WLAN	Location-based	2007, Finland	Solve different types of enigmas, which are based on the information from the real world.
14. Human Packman [Cheok et al., 2004]	Laptops, Bluetooth, Wireless LAN serves, GPS	Location-based	2004, UK	Physically move within the game area to collect all virtual plain cookies overlaid in the real world.
15. Feeding Yoshi [Bell et al., 2006]	PDA, WLAN	Location-based	2006,UK	For each team of players to collect as many points as possible, by feeding Yoshis the fruits they desire.
16. Manhattan Story Mashup [Tuulos et al., 2007]	Nokia N80, WLAN Pervasive,	Location-based	2007, Finland	Collect points by shooting photos for illustrating stories written by people in the web.
17. Treasure [Barkhuus et al., 2005]	HP iPAQ PDA with GPS and 802.11 WLAN	Location-based	2005, UK	Collect coins scattered over an urban area and then get them in to the treasure chest, team game.

As evident from the Table 2.3, combination of GPS technology and wireless network connection are used commonly to support collaboration and communication in multiplayer mobile games. Some authors mention suitability of Bluetooth technology for the low-latency location-aware mobile games [Schwabe and Göth, 2005]. Bluetooth connection is fast enough for the game purposes (round trip times between server and client is about 20-40ms), but game area is limited. Besides, Nokia S60 camera phones, in particular Nokia N80, are the more accepted phones among developers to achieve communication and collaboration between players. Moreover, location-based games are most popular in implementing communication and collaboration functions.

2.3 Types of communication in multiplayer mobile games

Further analysis shows that in multiplayer mobile games developers use four types of communication: private and public text, photo and video messages exchange, and calls. At the same time all games have implemented technologies which provide technical information from game server about other player's position or actions to use the modern mobile devices features. We call this type of technologies as peripheral technologies. All these types of communication can be either private or public. Some developers use public photo galleries and at the same time, allow players to perform private picture, video and text exchange. Several games have an implemented functionality for the private and public (voice conference) calls. Public communication through mobile or web interfaces has been implemented in some multiplayer mobile games. In Gopher players can upload pictures and text content, and rate missions of the other players. Save the princess, REXplorer, SciMyst, Treasure, Catch Bob! provide public communication through game interface features - players can leave messages in virtual environment or use it to connect with other participants or game server, another interesting opportunities is virtual objects exchange (Save the princess, Human Packman). Moreover, communication types can present in real and virtual environment, except the voice, which can exist at given moment only in physical world. According to literature overview we compose the Table 2.4 showing different communication types used in educational mobile games. Figure 2.2 represents visually the same data.

Table 2.4: Concept matrix of communication types

Game	Communication types				
	Text	Photo	Video	Calls	Interface features
1. Savannah					x
2. Ancient Runes	x			x	x
3. CatchBob!	x				x
4. BuinZoo					x
5. Can you see me now?	x			x	x
6. Bystander				x	x
7. Save the princess	x				x
8. Gopher	x	x	x	x	x
9. Pirates!					x
10. game based on the popular Capture The Flag and Counter-Strike PC games					x
11. MobileGame	x			x	x
12. REXplorer	x			x	x
13. SciMyst					x
14. Human Packman					x
15. Manhattan Story Mashup	x	x			x
16. Treasure					x
17. Feeding Yoshi				x	x

It is worth noticing that the peripheral technologies are occurring everywhere by game developers to support communication and collaboration embedded in learning experiences between players and the environment. According to Figure 2.2, all reviewed games use peripheral functions for player's communication. Figure 2.3 and 2.4 represent distribution of games by types of communication.

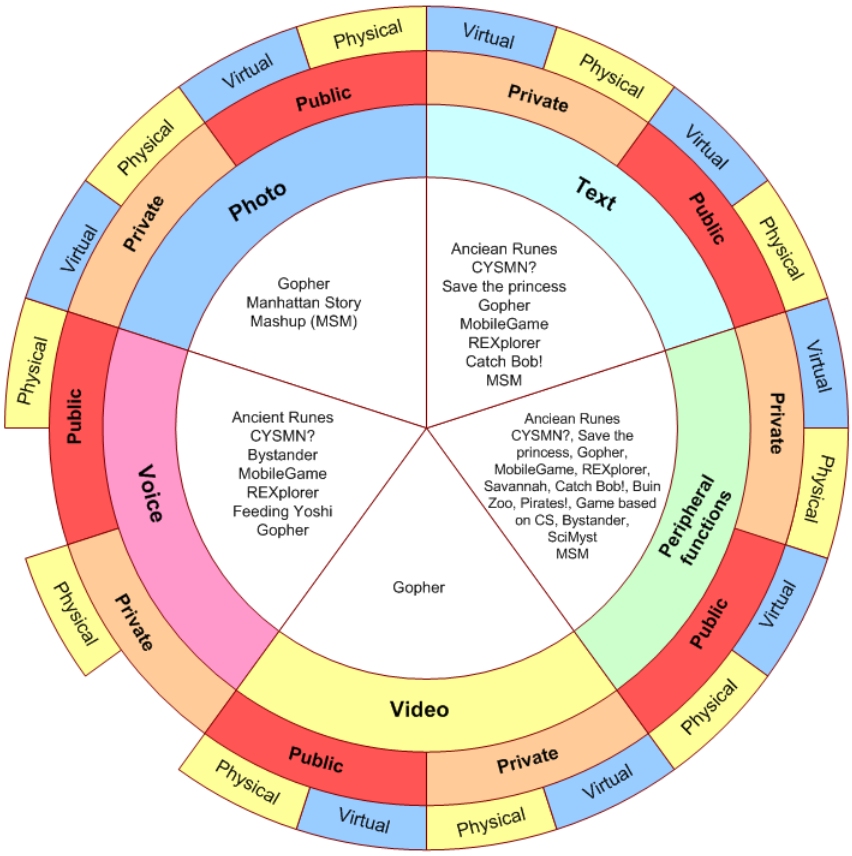

Figure 2.2: Communication types in existing games [Kuts et al., 2007]

From Figure 2.3, peripheral technologies, voice and text messages are the most available tools to implement communication function in educational mobile game environment.

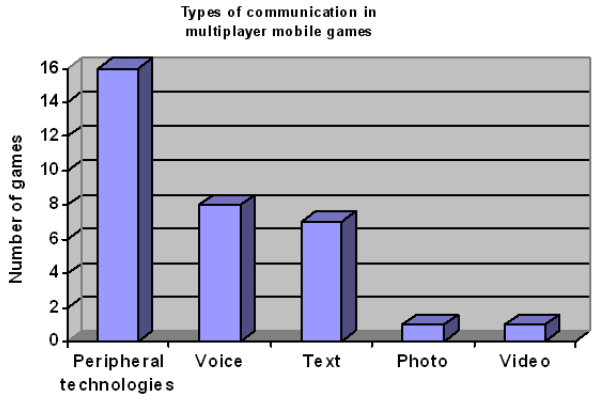

Figure 2.3: Types of communication in multiplayer mobile games

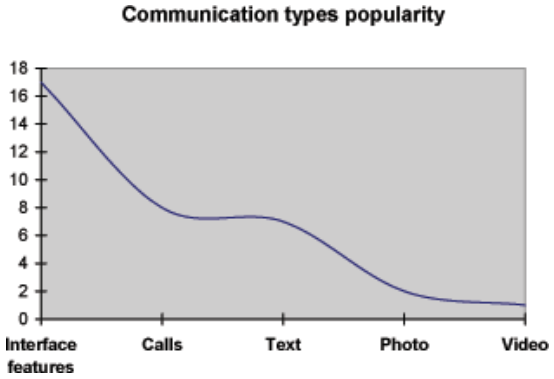

Figure 2.4: Communication types popularity distribution

2.4 Collaboration and communication in multiplayer mobile games

What does collaboration means? We refer to collaboration as the cooperation and joining of intellectual facilities between several participants. Players have to communicate prior to collaborate with each other. As we showed in the previous section several communication channels between players are used in mobile games. Nevertheless, it is not of necessity that these types of communication support collaboration, for some games collaboration function was not even defined.

Many developers use communication requirements as a part of game rules when players have to cooperate in order to reach the goal. It is still not clear **how the communication supports collaboration in multiplayer mobile games**. We need to understand how the communication types [Figure 2.2] were used for the goal collaboration to answer this

question. Let's consider the types of communication between players in details.

1. *Peripheral technologies.* All considered games provide an opportunity to use at least one of these peripheral technologies. They allow detecting other player's position, providing server information or using device opportunities to send information requests and other specific functions.

2. *Personal calls.* Using voice communication is relevant nowadays for many multiplayer mobile games. It provides possibilities for player's interaction, better understanding through explanations. Here can be both private and public calls for groups with several participants. Besides calls there can be voice conferences, which allow people to play in a team and coordinate their action.

3. *Text message exchange.* It is another essential feature of multiplayer mobile games. In view of the fact that sending SMS messages is not free of charge, developers are using game network channel for this purpose, usually it is message exchange via wireless networks. Authors found expedient to use SMS and MMS exchange for player's communication and collaboration for some mobile games. Along private communication multiplayer mobile game provides an opportunity for public communication through mobile or web interfaces. Also the player can leave messages in virtual environment, or use it (environment) to connect themselves with other participants. Another interesting opportunity is virtual objects exchange through message exchange.

4. *Video.* In mobile gaming video provides much broader information. Today developers use video files exchange except real-life video conferences.

5. *Photo.* The use of photos for communication and collaboration in educational mobile games appears to be rare.

2.5 Collaboration challenges in multiplayer mobile games

Thus, even if these communication types offer a set of opportunities for collaboration in multiplayer mobile games, what are the main obstacles to support the collaboration of players? Considering the understanding of collaboration, it is possible to analyze through

the design of collaboration actions in reviewed material and main challenges. We observed problems with game play (e.g. coordination problems), personal understanding, hardware problems, and software implementation. Each group of challenges we divided in two parts according to its type of communication. We present Table 2.5 containing this data, and visualize it with Figure 2.5 and Figure 2.6.

Table 2.5: Collaboration challenges

Game play	
Communication type problems	- voice and text: For games based on the voice communication problems with understanding assist in complications on a game play. This brings lacks in strategy and player' confidence.
Other problems	- synchronization: constantly present in diverse games. It can be inside the partners or team, but also outside them. - time: to achieve a stable player's cooperation and collaboration players have to spend some time in playing together, but normally mobile games do not offer enough time. - rules: for some games the cooperation in not required and as consequence, you can reach the game goal by playing alone and some people prefer to play without any cooperation. Besides this, game rules may not be clear or too difficult.
Understanding problems	
Communication type problems	- peripheral technologies: technological misunderstanding. Some games require special equipment and for some participants it can be problematic to use new devices.
Other problems	- social characteristics: difference in education level, age, social background. Mostly this question lies in ethics sphere of education mobile gaming - incorrect analysis of target groups
Hardware problems	
Communication type problems	- text, voice, video, peripheral technologies: system latency is one of the most limiting factors. Game with game tasks connected with real time, system latency affects not only the game results but also on the player's communication and learning level. For games based on location information sever does not always send a report about new player location,moreover they present a lack in system accuracy. Video streams mostly are not supported by mobile providers. Implementation of voice conferences on mobile devices can also be complex.

Continued on next page

Table 2.5 – *continued from previous page*

Other problems	- device limitations: slow CPU speed, limited storage space, low precision of the location information, low precision on screen and requirement of large battery energy. Even though mobile devices development is improving rapidly, most of people are using old equipment with device limitations.
Software implementation problems	
Communication type problems	- peripheral technologies: some games have implementation problems. They do not enable enough hardware features within software or tools for collaboration support.
Other problems	- user interface: Some games are insufficient in icons, color, characters and other interface features. Participants feel uncomfortable with the game interface. Sometimes it is not clear how to use game functions. - visualization: a number of games have problems with typing, because a player is not able to see a typing symbol. For some people written communication is difficult with the PDA. In location-based games a player does not always see new position on the screen.

Thus, it there are no problems less educational multiplayer mobile games, all of them have a number of challenges [Figure 2.5]. But we can emphasize that in spite of those problems most of the games are successful in player's communication and collaboration. Only in SciMyst and Gopher players do not use collaboration opportunities.

Figure 2.5: Collaboration challenges [Islas-Sedano et al., 2008]

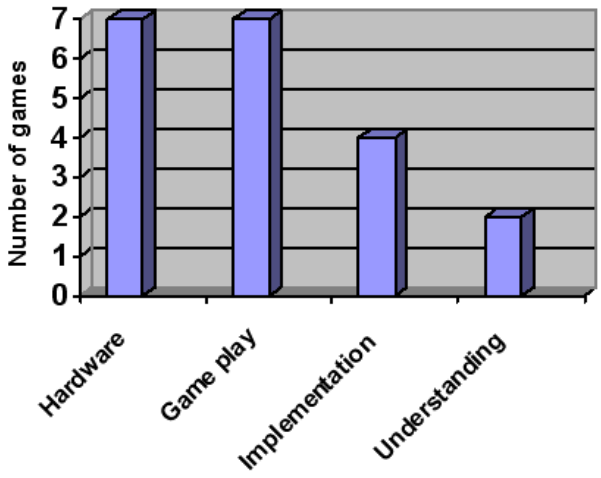

Figure 2.6: Collaboration challenges distribution

2.6 Analysis of the collected data: communication and concerned problems

Compare data from Figure 2.2 and Figure 2.5 to find out the most effective combination of communication types to support collaboration. In this case we used the following metrics: if the games reported no problems, then this game is granted with the 100% successfulness, independently of the communication type used. Otherwise, for each problem reported 25% of its successfulness is subtracted. The two games that do not report any type of collaboration are highlighted in red at the bottom of the graph; however they present their successful communication types (Figure 2.7) has been received. It is noticable that most of the games qualify from 50% towards. On the other hand constantly reported problems are related to hardware, followed by game play. With further reflection it might be discovered that these difficulties are related (hardware and game play). Another is the number of communication types used does not imply successfulness of player's collaboration. However the proper combination of communication types might guide to the successfulness with proper planning.

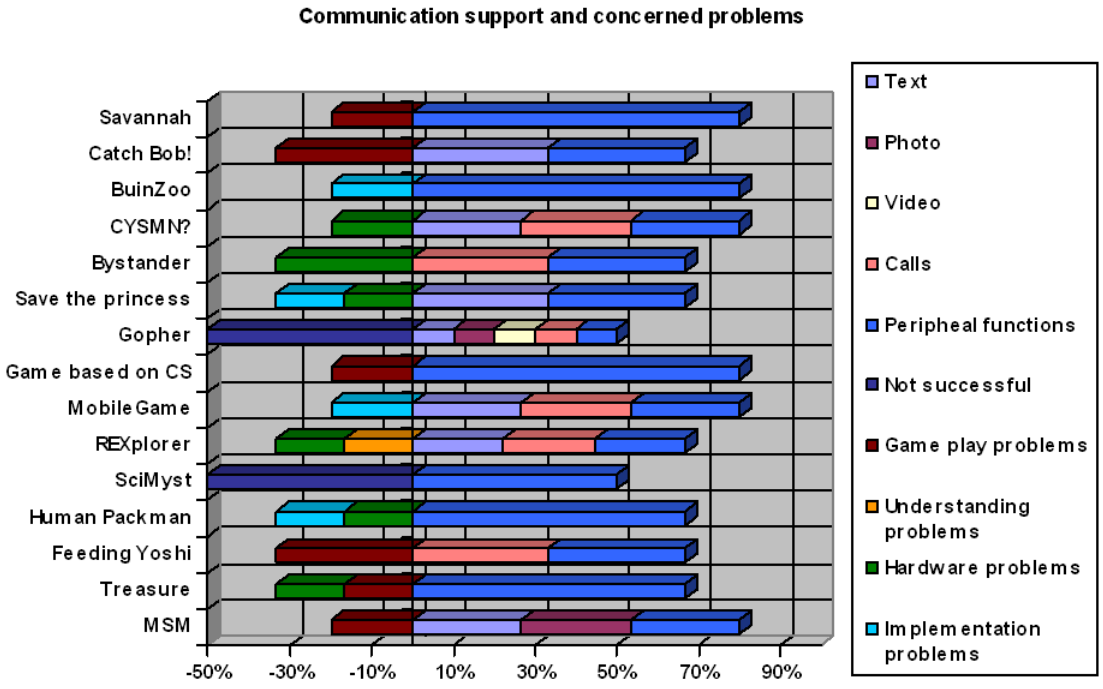

Figure 2.7: Way of communication support and concerned problems

It is possible to observe from this overview that the combination of text, calls and peripheral technologies are the most effective to support collaboration function in multiplayer mobile games.

All the reviewed games use an environment through peripheral technologies. As a result it is possible to see that the environment plays an important role in the player's interaction. Notice that the game takes place in physical and virtual environment.

Moreover, it is possible to emphasize three forms of collaboration: team, community, and network. For example players form a team in case of the specific game tasks when they have to work together to reach the game's goal. Sometimes players from different teams collaborate together in order to find solutions of specific game tasks. It is not common for the mobile games in this review to find community collaboration. Network collaboration is the most common for all multiplayer games because its provide player's interaction during the game's activities.

2.7 Summary

Through this overview the main challenge was to notice that most multiplayer mobile games are not concerning the educational aspects. Instead, they concentrate on the different game characteristics focusing on player enjoyment. The majority of the reported mobile games are oriented on entertainment and fun. Another problem is the lack of validation on claims and results of some articles. Still insufficient attention is given to support collaboration in educational multiplayer mobile games.

The most frequently use technologies to support communication and collaboration between players have been found in this chapter. One question arises, why the use of picture is so unpopular among the games? There can be several reasons for this. From the human perspective, it can be difficult to understand through the picture what exactly the player wants to express because everybody has his/her own view of the surroundings, and with this it will raise several ethical questions. Increased computing resources are needed for image processing calculations. Finally, the problem can refer to the integrated camera use. Currently, a number of the mobile devices equipped with the camera are continuously increasing and it gives a huge potential for developers and intended users.

We will discuss the problem of use photos for communication and interaction via integrated camera in the next chapter.

Chapter 3

Integrated camera interaction to support communication and collaboration in multiplayer mobile games

> Language commonly stresses only one side of any interaction.
>
> Gregory Bateson
> British anthropologist, 1904-1980

In the previous chapter we found technologies to support communication and collaboration between players. The aim of this chapter is to find an answer to how an integrated camera can be used to support communication and collaboration in multiplayer mobile games. Interaction with a mobile integrated camera is a relatively new field of research and just several attempts have been done. This is why it is important to understand the strengths, weakness and trends of the integrated camera use to improve the development experience as well as the human-computer interaction with mobile devices. This section analyzes the opportunities and challenges of the integrated camera use. We provide analysis from three points of view: camera-related actions, interaction and camera usages; applications with an integrated camera use are considered. We have analyzed existing publication related to the integrated camera use and based on theoretical results we highlight the main characteristics of the successful camera-based application.

3.1 Camera of the mobile device

A mobile device provides several opportunities [Sun Microsystems, 2000] to support communication; in particular, the image exchange via multimedia messages is a very popular activity [Kindberg and Spasojevic, 2004], especially for young adults and teenagers. Moreover, almost all modern mobile devices support wireless technology for the communication and access to the Internet. The wireless technology facilitates interaction between people, easily and independently from location. Many providers allow uploading of multimedia files (audio, video, images) to public sites for common use. World trends demonstrate a rapidly increasing interest of the use of visual sensors not only for mobile devices but household articles such as doors, cars and others that are equipped with small cameras. The interaction between people through these devices occupy special places in everyday life.

Currently, many mobile devices are equipped with a camera. Integrated cameras of mobile devices have become smaller and cheaper with increased resolution. Some devices equipped with multiple cameras support different features. The analysis shows that by 2009 almost 85% of the devices will have a digital camera [Krüger and Xiaoyi, 2007] for several reasons. The idea of taking images anywhere and sending it to others attracts people and developers respond to consumer demands. Manufacturers intend to raise their revenue via establishment of devices with the integrated camera for a new generation technologies. In the latter, people will buy this kind of devices only to support their public image but not to use an integrated camera. A camera could be needed for users accessing necessary information by capturing special images [Kindberg and Spasojevic, 2004]. Hence, this analysis offers the enormous potential for future research and development.

We need to understand how the people use an integrated camera, is a person interested in “capturing, sending and sharing” or saving for personal use? Or maybe people are more interested in other possibilities? What are the challenges an integrated camera can provide?

3.2 Brief remarks on mobile system interaction

Our research is focused on collaboration problem and, as consequence, on interaction. Mobile device provides two main types of interaction:

Social interaction: people use mobile device to communicate to each other. Some researchers [Miklas et al., 2007] divide this category into two streams: interaction between friends and interaction between strangers. Interaction in these categories is different: frequency, types of features used.

Physical interaction [Rukzio et al., 2005]: a mobile device as a physical object in a physical world provides interaction in different ways. People use mobile devices to take pictures, send texts and multimedia messages, call each other, for internet, some have implemented GPS navigators and many other features. Researches [Broll et al., 2007] emphasize several techniques for the physical interaction such as touching, scanning, pointing, capturing, direct input, etc. According to Rukzio [Rukzio et al., 2005] physical mobile interaction typically has the following view (Figure 3.1):

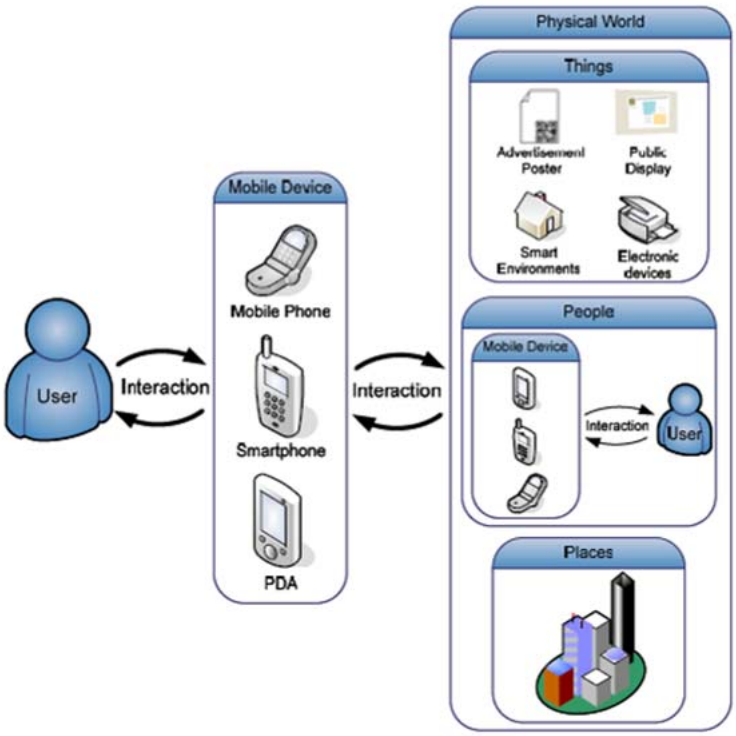

Figure 3.1: Physical mobile interaction [Rukzio et al., 2005]

3.3 Implicit and explicit camera interaction

According to the input from the user, an integrated camera is involved in implicit or explicit user interaction. What does this mean? Let us consider two different situations; for example, you use the personal flight-information display at an airport [Toye et al., 2004]. It is a big display with a several tags - special images- by capturing these tags with your mobile device camera you access information about the boarding and departure times, gate number, flight's current status, airport map pin pointing your current location etc. [Toye et al., 2004]. After use this picture is erased from the phone memory. Thereby, you are not interested in a taken photo itself, and you do not analyze the taken photo or view objects of surroundings but receive important extracted information. In other words, a camera is used as a sensor. This kind of integrated camera interaction is called *implicit user interaction*. It is not necessary should be the tag picture, but also bar-code, label or any other special image. As an output information could be location or instructions for further actions. On the other hand, *explicit user interaction* emphasizes the image itself

when a user wants to snap a specific object or situation [Krüger and Xiaoyi, 2007].

Many applications with camera usage are mobile games. An example of such a kind of application is AC-Soccer [Paelke et al., 2004], a camera-centered mobile game with computer vision based interaction. Usually camera-based applications oriented on implicit user interaction.

The *explicit user interaction* is used in several projects. The most famous research project is done by Nokia (Sensor Planet) and includes a number of smaller projects. For instance, Manhattan Story Mashup [Tuulos et al., 2007, MSM, 2008] a game based on the collaboration between online and mobile users on the street. Street players should hunt photos of nouns which illustrate a story written by online participants.

3.4 Integrated camera actions

In spite of differences in integrated camera use, we can emphasize the common actions which can be performed with this equipment. According to T. Kindberg a mobile camera can be used for the capturing, sharing, receiving, printing an archiving. [Kindberg and Spasojevic, 2004]. Detailed review of these activities will help us to understand camera related challenges.

Capturing: several researchers show that people are interested in capturing images as it is the main integrated camera feature [Kindberg and Spasojevic, 2004]. Besides taking images, a camera can be used for video recording but this opportunity is less popular among users. People are capturing images several times per week and video just several times per month. Research generated by T. Kindberg has shown that it is about eight photos a week and three videos every month.

Sharing: this activity can happen via direct communication between people when they use Bluetooth, Infrared or Wireless connection, or MMS technology for the picture exchange. Some mobile devices support emails exchange. Also this activity can take place through indirect communication. The popularity of the public photo galleries is continuously increasing. There are a lot of opportunities to upload pictures or even video directly from your device to the web-server and, as it is mentioned above, most of the modern mobile devices support wireless technology for Internet.

Receiving: this action is happens when somebody shares a picture or video. Received files can be saved in a device memory and used for the personal purposes or can be used for the further exchange.

Printing: resolution of the modern mobile device makes it possible to print captured images with high quality. Some devices support direct connection with a printer and a user can print pictures without saving it on PC. In spite of this, printing is not popular.

Archiving: some users prefer to upload pictures and video from the device to the personal computer. It saves files and gives an opportunity to share them easily through available PC sources.

3.5 Uses of integrated camera

There are a lot of studies about the future and perspectives of the mobile development market. Mobile devices with the integrated camera are the one of the disputable issues. They have a set of advantages and many people are interested to use mobile devices. Based on a several researches [Kindberg and Spasojevic, 2004, Bolliger et al., 2007] and our own experience we found the main types of the mobile integrated camera use.

Tool for the recording the moments. Mobile integrated cameras give a chance to capture interesting moments anywhere. It has the digital camera functionality but with the smaller dimensions. Moments recording is an important and most needed property. It enables users to record important information about events such as place, time, sounds and so on. Besides, it gives an opportunity to save photos of friends or relatives. This information can be used for sharing or personally. For example, several mobile phones allow us to identify the calling person with the image.

Tool for connecting. Currently some mobile devices are supported the video-call feature when you can see the person you are talking with. Connecting with others can be via MMS or email picture exchange.

Tool for showing the moments. Mobile devices have an opportunity for the connection to the big screens or TV via cable or Bluetooth. High resolution enable user to print taken photos and show them to others.

Tool for sharing the moments. Mobile device functionality allow to share taken pictures with others via several channels (MMS, email, Bluetooth, Infrared or Wireless connections) immediately. It is possible to use public galleries and forums [previous section].

Tool for learning. There are a lot of projects for using mobile integrated camera for the educational purposes. For example, AC-Soccer, a camera-centered mobile game to develop computer vision based interaction [Paelke et al., 2004].

Tool for expanding programming. The mobile camera equipped devices of similar types have similar programming interfaces (for mobile phones it is usually J2ME, APIs, web-services) [Bolliger et al., 2007]. It allows to develop the highly portable software infrastructure that can be used by various mobile devices which have integrated camera.

Tool for reading. Text recognition provides perspectives for the integrated camera use. Text is a rich source of information [Krüger and Xiaoyi, 2007] which requires visual interaction. Some application use text recognition algorithms to convert the text into the speech. This feature can be useful for people with vision problems. Text can be translated to another language [Krüger and Xiaoyi, 2007].

From these examples we see mobile devices equipped with a camera provide huge opportunities for the development and research. It can be used in a various ways. Where are the challenges to integrated camera use?

3.6 Integrated camera use challenges

A mobile integrated camera as any other equipment provides a set of challenges and problems not only for the intended users but for developers. In the following we consider camera related challenges and discuss possible solutions.

Based on a related literature overview we divided all challenges into three groups: those which are related to the human interaction, ones related to the hardware and ones related to software used. We do not consider the ethical problems related to image sharing such as privacy, spying or teasing [Spasojevic et al., 2006]. This topic will be more suitable to analyze widely in other type of research. Table 3.1 represents our research findings.

Table 3.1: Integrated camera related challenges

Human related challenges	
Human-computer interaction (HCI)	Interaction with a mobile device camera can be difficult for the users who are already accustomed to personal computer interaction. Mobile devices have a different data representation and do not have any analogs for the mouse pointer [Krüger and Xiaoyi, 2007]. There is no major freedom in way of interaction.
Cognitive factors	This problem appears in applications with the implicit integrated camera use. It is difficult to recognize tags on full images screens or sometimes the tag size is too small. In this case the image which is used as a tag should be defined clearly.
Users' diversity	An integrated camera interaction can be difficult for people of different social groups, age and educational level. Young adults and teenagers adapt to the new technologies easier than older people.
Software related challenges	
Programming platform standardization	The mobile devices of similar types have similar programming interfaces (for mobile phones it is usually J2ME, APIs, web-services). Manufacturers sometimes do not provide access to some functions of the mobile device via standard APIs [Bolliger et al., 2007].
User interface	User interface of camera-based application can be the reason of misunderstanding to people. Some icons and buttons can confuse users and they can get lost in the application. A good analysis of application interaction style is already in the prototyping phase of the development process. Screen size is relatively small and it is difficult to imagine how an image will look like on wide screen.
Hardware related challenges	
Hardware characteristics	Applications with the implicit camera use have an implemented functionality for the target images recognition. It requires additional resources of the mobile device. Currently, mobile devices have a set of limitations [Chapter 2] and the image recognition takes some time. Image recognition problems can be avoided by developing new algorithms or by device improvement. Camera-based text reading in spite of its perspectives has not yet been commonly used. The main problem is text recognition requires a high resolution camera and good lightening [Krüger and Xiaoyi, 2007]. If a person reads a book, pages should be without noise or damages. Text recognition requires specific device resources and cannot be used at the moment.

Continued on next page

Table 3.1 – *Continued from previous page*

Camera characteristics	High camera resolution requires an additional storage space and consequently additional device resources. Capturing time is increasing with improving resolution. Capture time can be a challenge for some applications. The process of capturing an image takes more than a second on mobile devices because the standard capturing practice creates a jpeg or png image [Bolliger et al., 2007]. This delay is significant for the applications which have strong time limitations (such as mobile games) or for capturing movements. Several algorithms are developed to compensate the delays [Bolliger et al., 2007].

In this table we can observe relations between and inside some categories. Social factors can influence on image understanding and at the same time have a relation with software (see Section 3.2). Figure 3.2 is visually demonstrative data from Table 3.1.

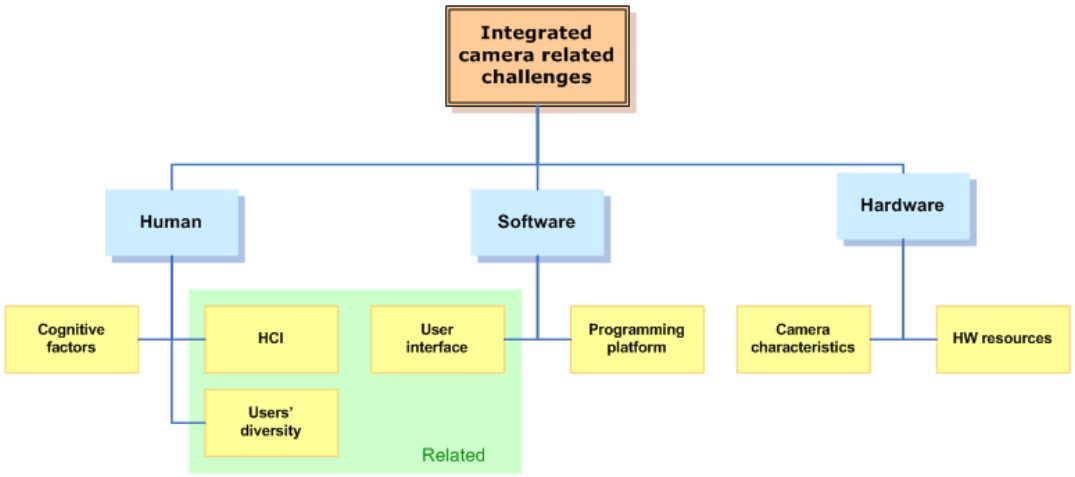

Figure 3.2: Integrated camera related challenges

Based on findings in Table 3.1 we can make conclusions that most mobile integrated camera problems can be solved by developers. User interfaces of the existing applications can be improved in order to make interaction with the camera of the mobile device intuitive and simple. Developers should take into account hardware limitation. There are several algorithms to improve image and text recognition already developed. Set of researches were done to decrease the system latency of the mobile devices. In the next section we analyze an existing application to find the most necessary properties.

3.7 Research findings

There are no exact approaches, techniques or recommendations to develop camera-based applications. It gives potential for scientific research in this field but in the boundaries of our research we are trying to find the most important characteristics to develop camera-based applications. In order to reach our goal we observed a set of applications with the explicit and implicit camera use which successfully achieved their goals [Rohs and Zweifel, 2005, Tuulos et al., 2007, Toye et al., 2004, Hachet et al., 2005]. An overview of the related literature enables us to find the most necessary characteristics of the successful camera-based application [Figure 3.3].

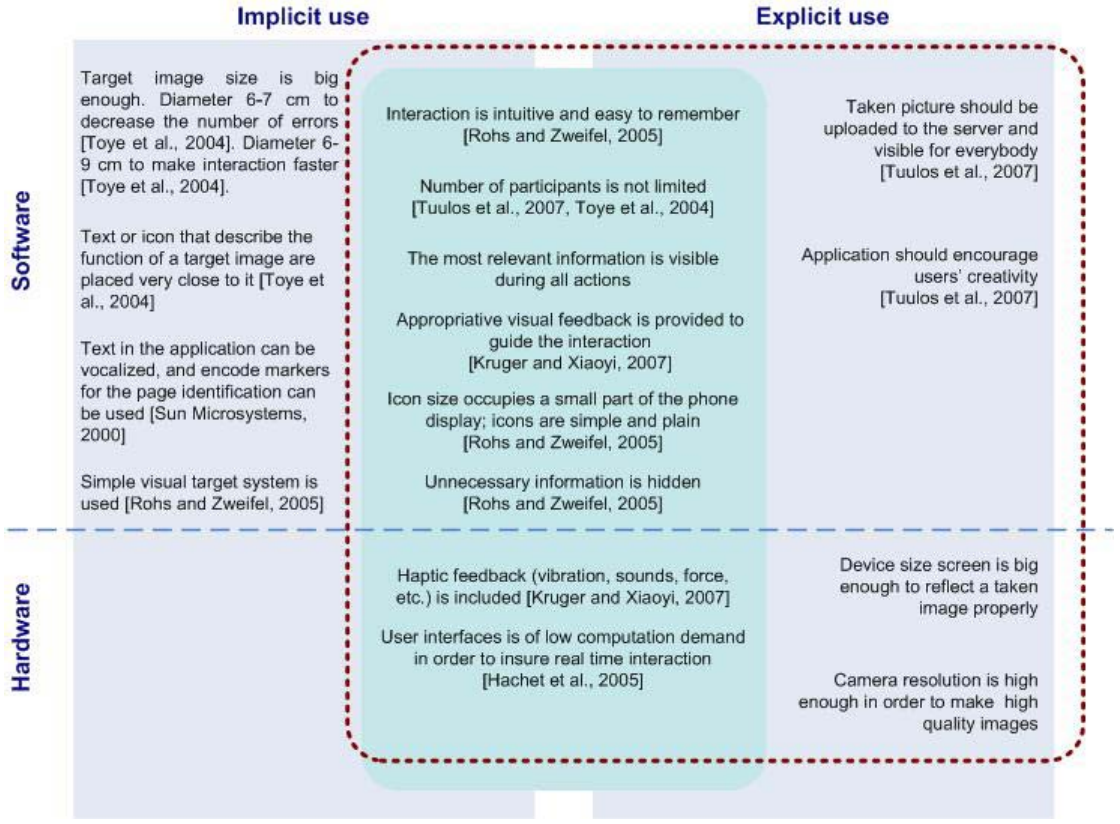

Figure 3.3: The main characteristics of the successful camera-based application

We divided application's characteristics into two sets according to dependence on hardware and software particularities and emphasized characteristics which are important to both ways of camera use (column in the middle of the Figure 3.3).

Figure 3.3 makes it clear that success of any camera-based application depends not

only on software itself but on the internal device characteristics.

Our research shows that there are many mobile applications with the implicit camera use already in existence, and a relatively full analysis has been done. That is why in the scope of our work, our primary interest in the explicit camera use. We selected the area of our interest with the red dashed line in Figure 3.3.

3.8 Summary

This chapter introduced the integrated mobile camera interaction styles. Integrated camera has a number of advantages and can be used in various ways. According to the results of the literature overview we have got characteristics which are relevant for the successful camera-based application. It enables us to design a scenario for our own camera-based application to explore explicit camera use more in detail. Next chapter is devoted to this purpose.

Chapter 4

Collaborative multiplayer mobile application

> Communication works for those who work at it.
>
> John Powell
> British film score composer

Popularity of the integrated mobile camera use is continuously increasing. There is a small amount of research done in the area of using this technology for players' communication and collaboration. Based on the research findings of the previous sections, in this chapter we introduce the concept of the new collaborative multiplayer mobile application - the PiX game. The principle of this application is collaboration through exchange of images taken with a device's camera. In the following, the main principles and development challenges are introduced.

4.1 PIX – Collaborative multiplayer mobile game

Many applications with a camera use are mobile games. Mobile games are multidisciplinary field of study and they are the most popular applications for mobile devices [Islas-Sedano et al., 2008]. Games are still an experimental area but they develop successfully and experience in this area can be expanded to the other types of applications (learning, marketing, etc.).

Tzvil Treeman defined a list of characteristics [Thomas et al., 2003] of a good game: it helps your imagination; it makes you feel in charge; a good game is transparent, you only

feel your mind, the other player and the ideas; it lets you into the creator's imagination and lets its players feel each other's personality; "a good game fits the human being like a glove".

According to these characteristics and research findings of the previous sections we develop a mobile game with the focus that should be simple, fast, and can be played anywhere and by anyone. For its development, we took into account possible challenges of the integrated camera use. We call our game "PiX (Picture eXchange)". PiX is designed for attracting players to communication and collaboration by increasing their interest in another persons' vision of the environment. The game enables players to see how different people interpret or label similar objects of the surroundings and what attracts people attention.

The main goal of the game design is to achieve player's communication and collaboration through the learning, understanding and game play.

4.2 Game description

The idea of the PiX game is that it involves various people's daily activities and knowledge in the game play. Routine tasks become a part of the game. The game dynamics transforms regular tasks into an enjoyable opportunity for discovery. The player takes a picture via phone camera, labels it with the most appropriate key word from the proposed set of words in accordance to the individual style of thinking, perceptions and associations. Afterwards it can optionally be sent to other players. When other players receive the picture, their task is to discover the train of thought of picture owner and guess the key word. For this purpose the guesser is allowed to take advantage of three help hints given by the picture owner. Each label group list contains ten words according to the main characteristics (Origin, Emotions, and Description). Moreover, there is possibility for a single game with a game server. Table 4.1 represents the list of functionality available from different game modes.

Table 4.1: PiX functionality

Functionality	Modes	
	Individual game	Collaborative game
Take a picture	-	x
Guess the picture	x	x
Send picture	-	x
Save picture on server	-	x
Help other players	-	x

For the correct answers both players are granted with bonuses and extra-lives. For every hint used both players are fined with penalty (points or life).

Figure 4.1 represents simple visualization of the PiX game concept. For more details refer to Appendix A. Figure 4.2 and Figure 4.3 show the game dynamics via game interface.

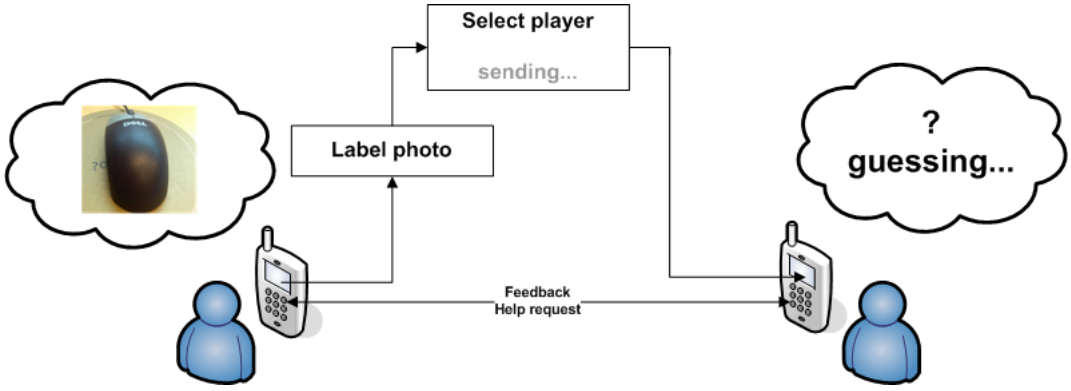

Figure 4.1: Simple visual representation of the PiX game dynamics

Figure 4.2: Take a picture interaction example

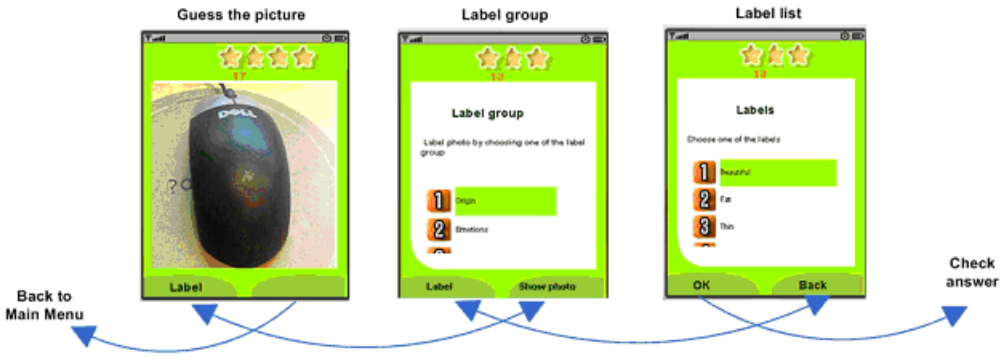

Figure 4.3: Guess the picture interaction example

PiX is designed to have two interfaces: a mobile game and web interaction. Currently, PiX has a website with a gallery of the photos taken by players in the game. Later after some further development, it will be synchronized with the game server and allows users to rank the published photos as well. Furthermore, several language supports are planned to be implemented in future.

Use of the real life environment as a connection between players via mobile devices makes this game innovative. Avoiding the verbal communication leads to PiX, being language independent; it allows any individual to play independently of his/her skills. The player chooses appropriate language in the beginning of the game and all labels are written in the selected language. At the same time another person can select another language and still can play together. Since both players deal with the very same set of entities, the server easily substitutes corresponding words from the selected language establishing the communication between players. PiX can be played anywhere and by anyone, it enables everybody to be involved in the game (developers, observers and players) to see how others discover and label their environment. Figure 4.4 represents an example of the PiX game interface.

Picture exchange can be fundamental not only for personal communication within one social and language group, but for intercultural communication and collaboration. Communication through images and graphics make game independent in many other aspects such as age, sex, background and nationality. Thus, through the game scenario we avoided some human related problems (users' diversity, cognitive factors) but we could not avoid the hardware related challenges.

Figure 4.4: Example of the game interface

4.3 Development challenges

For the development platform we chose MUPE [MUPE, 2008] from Nokia which already has implemented client-server functionality and has used all phone features to develop complete mobile application. The first version of PiX has been tested on Nokia N80 smart phone equipped with 3-megapixel camera and Wi-Fi support for accessing the game server without any charge. During development we were faced with some state-of-the-art problems related to the camera use. After taking some images, phone became "buzzed" and required a full restart. It resulted in additional problems and time to solve them. During December 2007 - January 2008 we tested the game on several types of mobile devices and found that there is a direct dependence on camera resolution. Our development heuristics is shown in Table 4.2. Tests included the game play for 10-15 minutes. We observed different internal characteristics of the mobile devices which can be the reason of the camera-related problems, such as camera resolution, SDRAM, operation system, series of the user interface, Java version. Data which is represented in Table 4.2 were collected from the mobile device developer's official web-site. We conducted the tests

partly in Educational technology laboratory at the University of Joensuu, Finland, and partly in Nokia Corporation in Tampere, Finland.

Table 4.2: Mobile devices' characteristics

Mobile device	**Camera resolution**	**SDRAM**	**OS**	**UI series**	**Java**	**Success of the PIX tests**
Nokia 7610	1 MP	8 Mb	Symbian v 7.0s	S60	MIDP 2.0	**yes**
Nokia N71	2 MP	Up to 10 Mb	Symbian v 9.1	S60	MIDP 2.0	**yes**
Nokia N81	2 MP	96 Mb	Symbian v 9.2	S60	MIDP 2.0	**yes**
Nokia N9500	2 MP	Up to 50 Mb	Symbian v 7.0	S60	MIDP 2.0	**yes**
Nokia N80	3.15 MP	Up to 40 Mb	Symbian v 9.1	S60	MIDP 2.0	**no**
Nokia N93	3,2 MP	Up to 50 Mb	Symbian v 9.2	S60	MIDP 2.0	**no**
Nokia N95	5 MP	Up to 128 Mb	Symbian v 9.2	S60	MIDP 2.0	**no**

From Table 4.2 we found direct relation between camera resolution and success of the application run. We can see that the problems start with the cameras with the resolution higher than 2 Megapixels. We consider the reasons for the camera-related "bug" in internal organization of MUPE client and phone memory use. For the further game analysis and evaluation we have developed a new user interface and run the game on Communicator Nokia N9500.

Our experience makes it obvious that a camera can provide additional challenges for developers and there is not devoted enough attention to these problems. Moreover, this kind of application problems can be the reason for misunderstandings or challenges for the intended user in the future if such kind of an application is installed on a phone with specific characteristics. It makes some camera-based applications dependent on parameters of the specific phone model.

Further exploration, analysis and evaluation will give us conclusions about correctness of the theoretical results received in Chapter 2 and Chapter 3. By this time we can say that most of the technical problems are connected with camera resolution and organization of the phone memory use.

4.4 Summary

In this chapter we introduced the new camera-based multiplayer mobile game and its development challenges. This application refers to achieve collaboration between people during the game and learning activities. Game scenario is based on the previous chapters' research findings. It makes possible to examine theoretical results via practical testing. Next chapter refer to the analysis and evaluation of the PiX game.

Chapter 5

Experiments and Evaluation of the multiplayer mobile game "PiX"

> There is no such thing as a failed experiment, only experiments with unexpected outcomes.
>
> Richard Buckminster Fuller
> US engineer and architect, 1895-1983

In development of the application we distinguished the aspect of collaboration between players. But what criteria should be used in evaluation of collaboration and communication in multiplayer mobile game? In order to answer this question we launched the first version of the PiX project to analyze the usability and its effectiveness in achievement of the main goal. The current chapter presents the evaluation of the PiX game in the aspect of players' collaboration; the following questions are essential for this aim:

- how users experience the game,
- what changes or benefits the mobile game brings about,
- how the game organization works,
- how the players experience the collaboration.

We would like to emphasize here that goal of this section is to represent the gathering data and opportunities of the integrated camera use but not deep theoretical analysis.

5.1 What is evaluation in the context of a mobile game?

There are several different definitions of the term "*evaluation*". According to COBUILD English Language Dictionary [Sinclair et al., 1990] "*evaluation*" is a decision about significance, value, or quality of something, based on careful study of its good and bad features. From the other source [Interlink, 2008] it is

> *"the process of gathering information in order to make informed decisions. It is broader than testing, and includes both subjective (opinion) input and objective (fact) input. Evaluation can take many forms including tests, assessments, and self-reflection".*

These definitions are rather general and can be used for evaluation of any system. In case of software development we are interested in usability evaluation. Usability is an evaluation of system intuitive interface and easy to use and learn. Specific characteristics of the mobile applications, in particular mobile games, make some changes in the traditional understanding of the software usability evaluation process. Some properties of the mobile systems are unique and require specific methods for the design and evaluation [Kjeldskov and Stage, 2004]. Interaction with a mobile device is a complex process which involves many factors, and as consequence, many problems may occur during this process. Evaluation helps to fix many of them and predict the new ones.

5.2 Usability evaluation methods

Usability evaluation of mobile systems is a new area of research [Kjeldskov and Stage, 2004]. There are no universal approaches or methods in development of the mobile system evaluation study. Many factors play a significant role in the evaluation process, among the most relevant we can emphasize the context, surrounding and other people influence [Stoica et al., 2005]. Kjeldskov and Stage reported three fundamental problems in mobile system evaluation [Kjeldskov and Stage, 2004]: (a) it is difficult to model required real-life situations, (b) it is very difficult to use observation and think aloud evaluation techniques, (c) the data collection is complicated and the control of the environment is very limited.

Usability of mobile application, as any other software product, can be evaluated in three ways [Stoica et al., 2005]:

- analysis of the *features of the product*. Final product features are compared to requirements. This analysis is performed according to the specific features of the system.
- analysis of the *process of interaction*. This analysis is done by simulating of the user interaction in laboratory or by testing with real users. However, it is very complicated process because of the unpredictability of humans' behavior and dynamic nature of the human brain.
- analysis of the *effectiveness and efficiency*. Herein developers test results of the product use and estimate the user satisfaction. This analysis is the direct measure of the system usability.

In general, determination of usability-related factors includes (1) inspection methods, (2) testing methods and (3) inquiry methods.

The combination of these techniques can be applied to mobile systems. In scope of this research we used the testing method with involving intended users to evaluate the process of interaction and the effectiveness of our system. We consider game experience and usability as the most important factors of the system analysis and evaluation.

Based on research findings among existing methods for collecting data we choose **questionnaire**. This choice is affected by the purpose of our research: It worth to notice that this is not a methodological work and there is no deep theoretical analysis done in evaluation. Our evaluation analysis is conducted in order to get feedback from user and make preliminary conclusion. After each game session we asked participant to fill questionnaire (Appendix B). The aim of the questionnaire was to collect data about participant background, experience, and game impression.

5.3 PiX usability evaluation study settings

The game testing was conducted in Educational Technology laboratory at the University of Joensuu during December 2007 and January 2008. There are no particular requirements

for the players' location, age, education and other personal characteristics to play the game that is why we invited arbitrary visitors of our laboratory. They could play PiX at anytime and without any time limits. 20 participated in the study.

We installed the game on Nokia Communicators N9500 and launched the application in advance. Players started playing from the game registration screen (Appendix A). Although the game does not have any limits for number of players, we had a maximum of two players at the same time because we were restricted by the number of communicators. We asked participants to try multiplayer and individual game modes and fill the questionnaire afterwards. Figure 5.1 shows how participants playing PiX and filling in the questionnaire.

Figure 5.1: Playing PiX

5.4 Data analysis and results

This section presents the analysis of the test results and proposals for the further system evaluation. It is worth mentioning that our questionnaire contains many questions related to mobile gaming, but in scope of this research, our focus is on integrated camera use and only part of collected data have been used in further analysis.

5.4.1 Participants profile

There are no restrictions to the participants' age or background. Altogether 20 volunteers participated, the PiX game testing: sixteen males and four females (Figure 5.2).

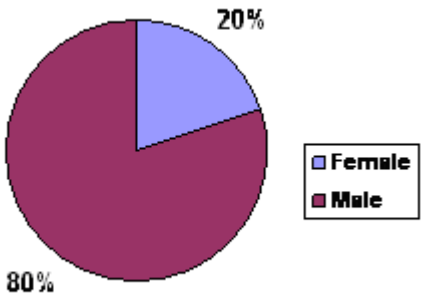

Figure 5.2: Participants' sex distribution

The youngest, 13 and the oldest 53; most of the participants are between 20 and 30, see Figure 5.3.

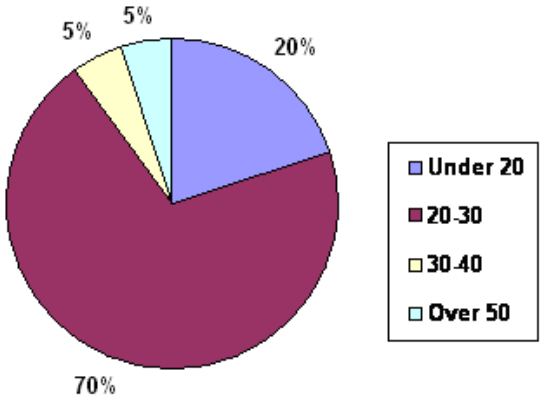

Figure 5.3: Participants' age distribution

In order to understand the background of participants, they were asked about their experience in mobile device use and playing mobile games. All participants were familiar with the mobile device itself (Figure 5.4). Most of them use mobile phone no less than one hour a week and have played in mobile games before (Figure 5.5).

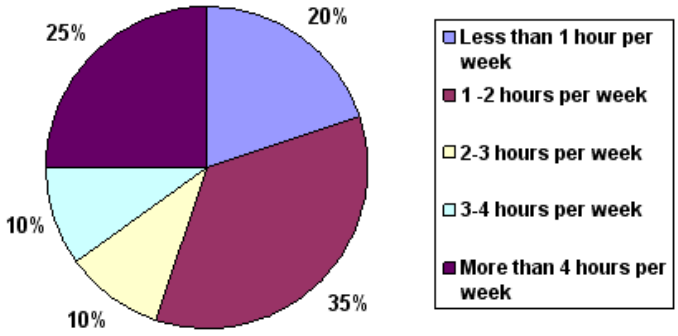

Figure 5.4: Participants' phone use distribution

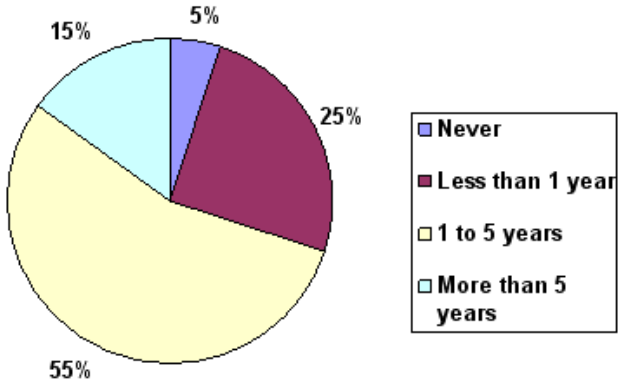

Figure 5.5: Participants' mobile game play experience

We found that three participants are not interested in playing mobile games, while others play at least some time during a week (Figure 5.6).

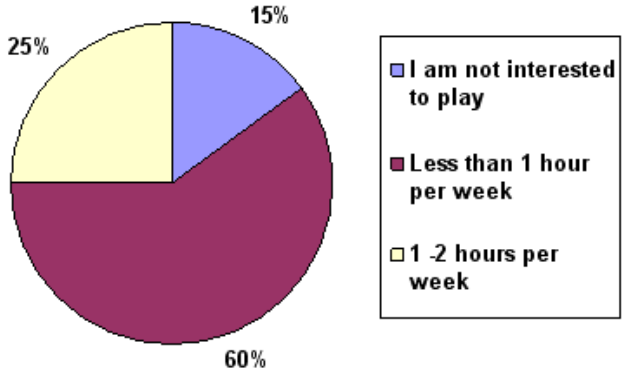

Figure 5.6: Mobile game play distribution

Detailed statistical data is presented in Appendix C.

We consider all participants as experienced users of mobile devices, thus making further research more valuable.

5.4.2 User experience

Difficulties

User experience analysis enables us to find the directions for the future work by indicating the application challenges. The questionnaire contained a question about difficulties during the game. We asked participants to fill the table by specifying their consent about pre-defined statements. Data which is presented in Table 5.1 in number of answers; Figure 5.7 shows graphically distribution of the users' answers.

Table 5.1: Difficulties during the PiX game

	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
The Language being used		2	5	13
Using the phone for playing was intuitive	3	9	8	
Taking pictures was difficult	3	10	6	1
The screen is too busy		1	12	7
It was fun to play with the phone	4	16		
The size of the text is big enough	6	9	5	
I can find information I look for	5	11	4	
It was easy to use a phones as tool for playing		16	4	
I am more comfortable using my own mobile phone	9	6	5	

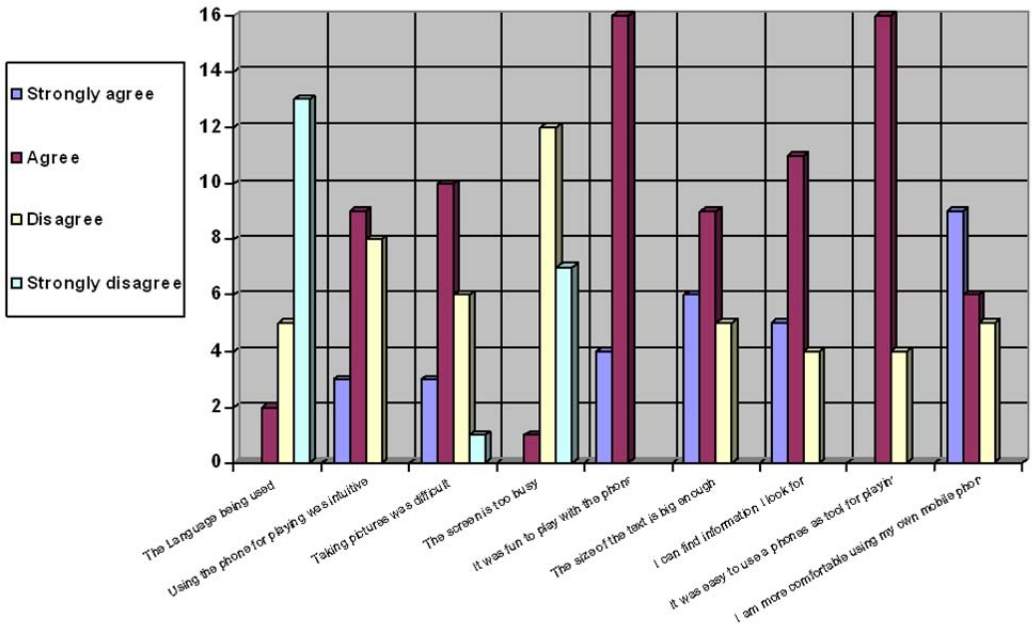

Figure 5.7: Difficulties with the PiX game

Table 5.1 shows that the most frequent difficulty is in the mobile device itself, the half of the participants found that use of the mobile device for playing was not intuitive while others consider it as intuitive. Many users agree that they are more comfortable using their own mobile device. In the same time only four users disagree that it is easy to use a phone as a playing platform. And *all participants think that it is rather fun to play with the phone.*

Another significant outcome questionnaire poll was that almost all participants have not considered the game screen as too busy, almost everybody could find information s/he looks for, the text size was big enough for the most of the users, used language (English) was difficult only for two players. Hence, we can concluder that the PiX game has user-friendly interface. We found interesting feedback about taking pictures with the mobile device camera vary considerably. Three participants strongly agreed and nine agreed that it was difficult to take pictures while seven of the users did not have any problems.

Game play

The next part of the questionnaire consists of the open questions about the game play. We asked participants to answer the questions what do they like about PiX and what

they dislike or find more difficult (Appendix D).

We have got different feedbacks on the game. Some users draw attention to the interaction part, others to the game design. Three players mentioned that they were interested to guess a keyword given by the picture owner; one of the players said:

> *"Game is fast and fun. It is interesting to find what other players mean under the picture".*

Some of the users like the concept of the game:

> *"Idea is new for me and I was happy as a child", "The basic idea is nice, and the means of communication that comes with it is really something new and interesting".*

Five players noted that they like graphics and game interface which make game interaction more users friendly:

> *"GUI looks great and it's easy to use".*

One player mentioned that the PiX game

> *"used high technology and allows us to communicate with other people"*,

and another one was interested to play with friends.

Besides positive feedbacks we have got a set of the negative ones. According to classification presented in Chapter 3, section 3.6 there are three main groups of camera-related challenges, we use this classification for the further data analysis:

Hardware related challenges: Four users mentioned problems with the camera when it was difficult to take a picture with the Nokia Communicator.

Software related challenges: Two participants had problems with the game application, it crashed. Control keys were defined as a disadvantage of the PiX game.

Human related challenges: One player noted that

"it was a bit difficult to guess the right thing from the photo" and another ones said that "it is not clear what other player mean under the picture", "somehow the labels are not so intuitive, it takes a while to get used to them".

These feedbacks will be the basis of the future system evaluation.

Collaboration experience

As we stated in the previous chapter, the main foal of the PiX is to achieve collaboration between participants via picture exchange. Following this aim we included into the questionnaire two questions about the user experience in taking pictures with the device integrated camera and sharing these pictures with others. Thus, we got promising results (detailed description is in Appendix E).

Nineteen participants were agreeing that it was fun to take pictures with the camera (Figure 5.8).

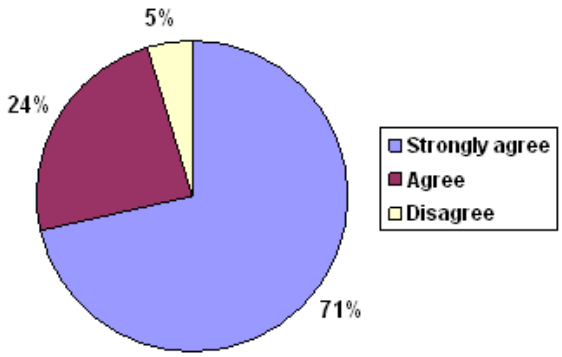

Figure 5.8: It was fun to play taking photos

We asked them why did they like or dislike taking pictures. The answers were different. Some people think that it is fun to take photos and make friends try to guess. One participant said

"Taking photo is my hobby. It was fun to me to select object to be shoot and select the proper word that present emotion, feelings".

In the same time many people dislike the camera, they mentioned that it is uncomfortable to work with camera on communicator,

"it was difficult to understand how to capture. I could not capture myself".

Moreover, we got another significant result. All participants enjoyed sharing their own pictures with others (four were strongly agreed and sixteen agreed, see Figure 5.9).

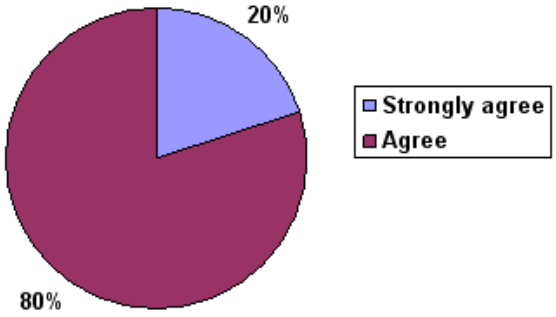

Figure 5.9: I enjoy sharing pictures

One user said that

"this is a good "socializing" game, people learn how to express themselves and how to understand other people using photo as "carrier" of emotions and feelings".

And another one mentioned

"I like it because other people can play with my picture".

From one participant we have got an interesting remark s/he said that it is

"possible feeling of 'invasion of privacy' as all pictures are kept on a server".

Users' proposals

Evaluation of the system is always based on users' feedbacks, experience, and suggestions. We asked our participants what they would like to improve in PiX and received many meaningful suggestions (Appendix F). Participants were interested to have an opportunity to see taken photos on web-site and be able to have and modify their own profile. One

user suggests implementation of access to the site from the phone and being able to send private messages to other players. Currently the game can be installed on the Nokia N80 Smartphone and Nokia Communicator 9500 and users would like to install it on their own devices. Participants would like also to improve the game play, for example

"allow picture owner to see suggested answers",

"to see everything in one screen without moving cursor",

to have some activities on waiting screen.

5.5 Summary

In this chapter the term *evaluation* has been defined and different evaluation methods were briefly described. We presented the analysis of user feedback for PiX. For data collecting, users filled in questionnaire with open questions and pre-defined statements. Analysis shows that users like to play with the phone camera and share their own pictures with others. The main difficulty was the use of the device (Communicator Nokia N9500). We received limited user suggestions on system improvement but it is clear that users are interested in opportunity to see pictures on a web-site immediately.

Selection of the just one method (questionnaire) to collect data could be the reason of limited information from the users. Analysis of the gathering data enables us to find the directions for the further work and system evaluation which will be discuss in the next chapter.

Chapter 6

Conclusion and future work

> The important thing is not to stop questioning.
>
> Albert Einstein, 1879-1955

6.1 Conclusion

The work describes that combination of the game development with the use of mobile technologies offers us a wide set of opportunities. Mobile technology is a relatively new field of research. Although a lot of efforts in research of this area have been done, less of them touch upon the issue of communication and collaboration problem. In this work we provided literature overview, we showed the current state of the multiplayer educational mobile game development field and solved main research questions. Based on these achievements we have developed a new collaborative multiplayer mobile game. Experiments and evaluation were performed in order to support research results. Let us briefly overview our research findings.

Research question: *How does communication and collaboration between people through mobile games take place? What are the advantages of multiplayer mobile games for educational purposes?*

We demonstrated the relevance of the collaboration between people and analyzed existing multiplayer mobile game applications in Chapter 2. From the analysis of the theoretical and practical papers we concluded that there are five widely used types of

communication in multiplayer mobile games, namely: private and public text messages, photo and video messages, calls and peripheral technologies. This readily leads to the main challenges which can affect interaction between participants. The main result of the literature overview is that pictures are not commonly involved in people communication even when the number of the mobile devices equipped with the camera is continuously increasing. It gave us the reasons to find the answer for the next research question.

Research question: *How is an integrated camera used to support communication and collaboration in multiplayer mobile games?*

We analyzed the possible reasons for the seldom use of pictures for the people collaboration. In general, integrated camera can be used for the following activities: recording and showing the moments, connecting, learning and many others. All these actions could be the origins of user difficulties. Further analysis in Chapter 3 indicates three groups of possible camera-related challenges connected with hardware, software and/or human factors. During the analysis of the existing integrated camera-based applications we marked out the set of characteristics of the successful application. Taking them into account we designed a scenario for the new collaborative multiplayer mobile game "PiX" which is based on picture exchange. We described in Chapter 4 research and development findings and launched the first version of "PiX" project to analyze usability and effectiveness of this application.

Research question: *What criteria should be used in evaluation of collaboration and communication in multiplayer mobile game?*

We consider the game experience and usability as the most important factors of the system evaluation. In order to estimate these factors, 20 volunteers of the different age were invited to participate. We have chosen the questionnaire as a method for collecting data. The analysis of the obtained data in Chapter 5 shows that all participants enjoy the idea of sharing their own photos with others. Most of the users were agree that it was fun to make picture with the integrated camera and one of the participants mentioned that it is *"a good "socializing" game"*. Thus, even if we used only one method for the collecting data from users, we can say that pictures can be successfully used for the players' collaboration but there are still a lot of open questions related to integrated cameras of the mobile devices.

6.2 Open questions and future work

Some of the open questions connected to the privacy and other social factors: What happens when possibility to capture image become a part of everyday life? What kind of control should we use and where are the limits? How developers can design effective privacy control system? What social groups are involved in picture sharing?

Some questions deal with technology itself: What are the implications for technology? What are the main problems affected on integrated camera use? Many questions refer to the educational and creative components: How picture capturing can develop creativity or other skills of participants. How to improve learning through the media mobile systems? These and many other questions are not considering in this research.

The data collected from the users needs to be verified by other methods and we should consider the users' proposals for the future system development. We are planning in the future to make an application platform-independent and continue development of the game web-site.

There are still open questions for further and deeper analysis of the collaboration in educational multiplayer mobile games. For example, we need to understand motivation of players and conduct analysis of the different types of knowledge involved (tacit and explicit).

Consequently, the thesis has touched upon many subtopics among mobile gaming, which offer interesting future research challenges.

References

[Antonellis et al., 2005] Antonellis, I., Bouras, C., and Poulopoulos, V. (2005). Game based learning for mobile users. In *6th International Conference on Computer Games: AI and Mobile Systems*, Lousville, Kentucky, USA.

[Ballagas et al., 2006] Ballagas, R., Walz, S., and Borchers, J. (2006). Rexplorer: A pervasive spell-casting game for tourists as social software.

[Ballagas et al., 2007] Ballagas, R. A., Kratz, S. G., Borchers, J., Yu, E., Walz, S. P., Fuhr, C. O., Hovestadt, L., and Tann, M. (2007). Rexplorer: a mobile, pervasive spell-casting game for tourists. In *CHI '07: CHI '07 extended abstracts on Human factors in computing systems*, pages 1929–1934, New York, NY, USA. ACM Press.

[Barkhuus et al., 2005] Barkhuus, L., Chalmers, M., Tennent, P., Hall, M., Bell, M., Sherwood, S., and Brown, B. (2005). Picking pockets on the lawn: The development of tactics and strategies in a mobile game. In Beigl, M., Intille, S. S., Rekimoto, J., and Tokuda, H., editors, *Ubicomp*, Lecture Notes in Computer Science, pages 358–374. Springer.

[Bell et al., 2006] Bell, M., Chalmers, M., Barkhuus, L., Hall, M., Sherwood, S., Tennent, P., Brown, B., Rowland, D., and Benford, S. (2006). Interweaving mobile games with everyday life. pages 417–426. ACM.

[Benford et al., 2005] Benford, S., Rowland, D., Flintham, M., Drozd, A., R, R. H., and Reid, J. (2005). Life on the edge: supporting collaboration in location-based experiences. In *Proceedings of the 2005 CHI Conference on Human Factors in Computing Systems*, pages 721–730, Portland, Oregon. ACM Press.

[Bergeson, 2008] Bergeson, T. (2008). Communication: Overview. `http://www.k12.wa.us/CurriculumInstruct/Communications/default.aspx`, accessed November 22,2007.

[Björk et al., 2001] Björk, S., Falk, J., Hansson, R., and Ljungstrand, P. (2001). Pirates! using the physical world as a game board. In *Proceedings of Interact 2001 Conference on Human-Computer Interaction*, Tokyo, Japan.

[Bolliger et al., 2007] Bolliger, P., Köhler, M., and Römer, K. (2007). Facet: Towards a smart camera network of mobile phones. In *Proceedings of Autonomics 2007 (ACM First International Conference on Autonomic Computing and Communication Systems)*, Rome, Italy.

[Britannica, 2008] Britannica (2008). Encyclopedia britannica online. `www.britannica.com`, accessed October 15,2007.

[Broll et al., 2007] Broll, G., Siorpaes, S., Rukzio, E., Paolucci, M., Hamard, J., Wagner, M., and Schmidt, A. (2007). Comparing techniques for mobile interaction with objects from the real world. In *Workshop Permid 2007 in conjunction with Pervasive 2007*, Toronto, Ontario, Canada.

[Casey et al., 2007] Casey, S., Kirman, B., and Rowland, D. (2007). The gopher game: A social, mobile, locative game with user generated content and peer review. In *Proceedings of the International Conference on Advances in Computer Entertainment Technology*, Salzburg, Austria. ACM.

[Cheok et al., 2004] Cheok, A. D., Goh, K. H., Liu, W., Farbiz, F., Teo, S. L., Teo, H. S., Lee, S. P., Li, Y., Fong, S. W., and Yang, X. (2004). Human pacman: a mobile wide-area entertainment system based on physical, social, and ubiquitous computing. In *Advances in Computer Entertainment Technology*, pages 360–361. ACM.

[Dempsey et al., 2002] Dempsey, J. V., Haynes, L. L., Lucassen, B. A., and Casey, M. A. (2002). Forty simple computer games and what they could mean to educators. *Simulation & Gaming*, 33(2):157–158.

[Flintham et al., 2003] Flintham, M., Anastasi, R., Benford, S. D., Hemmings, T., Crabtree, A., and Greenhalgh, C. M. (2003). Where on-line meets on-the-streets: experiences

with mobile mixed reality games. In *Proceedings of the CHI 2003 Conference on Human Factors in Computing Systems*, pages 18–30, New York, USA. ACM Press.

[Hachet et al., 2005] Hachet, M., Pouderoux, J., and Guitton, P. (2005). A camera-based interface for interaction with mobile handheld computers. In *SI3D '05: Proceedings of the 2005 symposium on Interactive 3D graphics and games*, pages 65–72, New York, NY, USA. ACM Press.

[Interlink, 2008] Interlink (2008). Interlink referral center. `http://www.interlinktc.com/public_html/definitions.html`, accessed December 2,2007.

[Islas-Sedano et al., 2008] Islas-Sedano, C., Kuts, E., and Sutinen, E. (2008). Computer science students can help to solve problems of multiplayer mobile games. In *Proceeding of Koli Calling*, Koli National Park, Finland.

[Islas-Sedano et al., 2007] Islas-Sedano, C., Laine, T., Vinni, M., and Sutinen, E. (November 14-18, 2007). Where is the answer? - The importance of curiosity in pervasive mobile games. In *Future Play 2007 Conference*.

[Kindberg and Spasojevic, 2004] Kindberg, T. and Spasojevic, M. (2004). How and why people use camera phones. Technical report, Tech. report HPL-2004-216, HP Labs.

[Kjeldskov and Stage, 2004] Kjeldskov, J. and Stage, J. (2004). New techniques for usability evaluation of mobile systems. *International Journal of Human-Computer Studies*, 60(5-6):599–620.

[Koivisto, 2007] Koivisto, E. (2007). Mobile games 2010. Technical report, Nokia research Center.

[Koivisto et al., 2006] Koivisto, E. M. I., Suomela, R., and Koivisto, A. (2006). Ancient runes: using text input for interaction in mobile games. In *Sandbox '06: Proceedings of the 2006 ACM SIGGRAPH symposium on Videogames*, pages 159–167, New York, NY, USA. ACM.

[Krüger and Xiaoyi, 2007] Krüger, A. and Xiaoyi, J. (2007). Improving human computer interaction through embedded vision technology. In *Multimedia and Expo, 2007 IEEE International Conference on Volume Issue*, pages 687 – 690.

[Kuts et al., 2007] Kuts, E., Sedano, C. I., and Sutinen, E. (2007). Communication and collaboration in educational multiplayer mobile games. In *Proceeding of Cognition and Exploratory Learning in Digital Age*, Alarve, Portugal.

[Kuts et al., 2008] Kuts, E., Sedano, C. I., and Sutinen, E. (2008). Let's play together with the camera of your mobile device. In *Proceeding of the Nordic Serious Games conference*, Jyväskylä, Finland.

[Mansley et al., 2004] Mansley, K., Scott, D., Tse, A., and Madhavapeddy, A. (2004). Feedback, latency, accuracy: exploring tradeoffs in location-aware gaming. In *NetGames '04: Proceedings of 3rd ACM SIGCOMM workshop on Network and system support for games*, pages 93–97, New York, NY, USA. ACM.

[McGrenere, 1996] McGrenere, J. L. (1996). Design: Educational electronic multi-player games: A literature review. Technical Report 96-12, The University of British Columbia.

[Miklas et al., 2007] Miklas, A. G., Gollu, K. K., Chan, K. K. W., Saroiu, S., Gummadi, P. K., and de Lara, E. (2007). Exploiting social interactions in mobile systems. In *Ubicomp*, pages 409–428.

[Mitchell et al., 2007] Mitchell, A., Cisic, D., and Maxl, E. (2007). Mobile game-based learning issues emerging from preliminary research and implications for game design. In *20^{th} Bled eConference eMergence: Merging and Emerging Technologies, Processes, and Institutions*, Bled, Slovenia.

[Mitchell and Savill-Smith, 2004] Mitchell, A. and Savill-Smith, C. (2004). The use of computer and video games for learning. London, UK. Learning Skills Development Agency.

[Mottola et al., 2006] Mottola, L., Murphy, A. L., and Picco, G. P. (2006). Pervasive games in a mote-enabled virtual world using tuple space middleware. In *Proceedings of 5th ACM SIGCOMM workshop on Network and system support for games*, New York, USA. ACM.

[MSM, 2008] MSM (2008). Manhattan story mashup. `www.storymashup.org`, accessed December 1,2007.

[MUPE, 2008] MUPE (2008). Multi-user publishing environment (mupe). `www.mupe.net`, accessed July 5,2007.

[Nova et al., 2006] Nova, N., Girardin, F., and Dillenbourg, P. (2006). A mobile game to explore the use of location awareness on collaboration. In *HCI International 2005*, Las Vegas, USA.

[Nova et al., 2005] Nova, N., Traum, D., Montandon, L., Ott, D., and Dillenbourg, P. (2005). Do partners care about their mutual location? spatial awareness in virtual environments. Technical report, Center for Research and Support of Training and its Technologies, Ecole Polytechnique Fédérale de Lausanne.

[Paelke et al., 2004] Paelke, V., Reimann, C., and Stichling, D. (2004). Foot-based mobile interaction with games. In *ACE '04: Proceedings of the 2004 ACM SIGCHI International Conference on Advances in computer entertainment technology*, pages 321–324, New York, NY, USA. ACM.

[Prensky, 2001] Prensky, M. (2001). *Digital Game-Based Learning*. McGraw-Hill, New York.

[Reeves, 2006] Reeves, T. (2006). It design based resarch. saving instructional technology from irrelevance: The promise of design research. `http://www.uga.edu/grepit/events-it-design-based-research.html`, accessed September 10,2007.

[Rohs and Zweifel, 2005] Rohs, M. and Zweifel, P. (2005). A conceptual framework for camera phone-based interaction techniques. In *Pervasive Computing: Third International Conference, PERVASIVE 2005*, number 3468 in Lecture Notes in Computer Science (LNCS), Munich, Germany. Springer-Verlag.

[Rukzio et al., 2005] Rukzio, E., Wetzstein, S., and Schmidt, A. (2005). A framework for mobile interactions with the physical world. In *Invited paper special session "Simplification of user access to ubiquitous ICT services" in Wireless Personal Multimedia Communication (WPMC'05)*, Aalborg, Denmark.

[Sańchez et al., 2006] Sańchez, J., Salinas, A., and Saénz, M. (2006). Mobile game-based science learning. In *Proceedings of the Distance Learning and Internet Conference*, pages 18–30, Tokyo, Japan. APRONet.

[Savill-Smith and Kent, 2003] Savill-Smith, C. and Kent, P. (2003). The use of palmtop computers for learning: A review of the literature. Technical report, Learning & Skills Development Agency, London.

[Schwabe and Göth, 2005] Schwabe, G. and Göth, C. (2005). Mobile learning with a mobile game: design and motivational effects. *Journal of Computer Assisted Learning*, 21(3):204–216.

[Serious Games, 2008] Serious Games (2008). Serious games initiative. `www.seriousgames.org`, accessed December 2,2007.

[Sinclair et al., 1990] Sinclair, G., Hanks, P., Fox, G., Moon, R., and Stock, P. (1990). *The Collins Cobuild English Language Dictionary*. Collins, Glasgow.

[Spasojevic et al., 2006] Spasojevic, M., Ito, M., Van House, N., Koskinen, I., and Kato, F. (2006). Proposal for the second workshop on pervasive image capture and sharing. `http://www.pewinternet.org/pdfs/PIP_Cell_phone_study.pdf`.

[Stoica et al., 2005] Stoica, A., Fiotakis, G., J., S.-C., Mun oz Frutos, H., Avouris, N., and Dimitriadis, Y. (2005). Usability evaluation of handheld devices: A case study for a museum applicatio. In *Proceedings PCI2005*, Volos.

[Sun Microsystems, 2000] Sun Microsystems (2000). Applications for mobile. information devices. helpful hints for application developers and user. `http://java.sun.com/products/midp/midpwp.pdf`, accessed July 15,2007.

[Thomas et al., 2003] Thomas, S., Schott, G., and Kambouri, M. (2003). Designing for learning or designing for fun? setting usability guidelines for mobile educational games. In *Proceedings of MLEARN 2003: Learning with Mobile Devices*, London, UK.

[Toye et al., 2004] Toye, E., Madhavapeddy, A., Sharp, R., Scott, D., Blackwell, A., and Upton, E. (2004). Using camera-phones to interact with context-aware mobile services. Technical Report UCAM-CL-TR-609, University of Cambridge.

[Tuulos et al., 2007] Tuulos, V., Scheible, J., and Nyholm, H. (2007). Combining web, mobile phones and public displays in large-scale: Manhattan story mashup. In *In proceedings of the Fifth International Conference on Pervasive Computing*, pages 37–54, Toronto, Canada.

[Vasudevan, 2006] Vasudevan, V. (2006). Collaborative mobile gaming enabling socially interactive, participatory, media-rich gaming experiences. posiion paper. Technical report, Motorola Inc, Illinois, USA.

[Wagner, 2005] Wagner, E. D. (2005). Enabling mobile learning. *Educause Review*, 40:40–53.

Appendix A

PiX game flow diagram

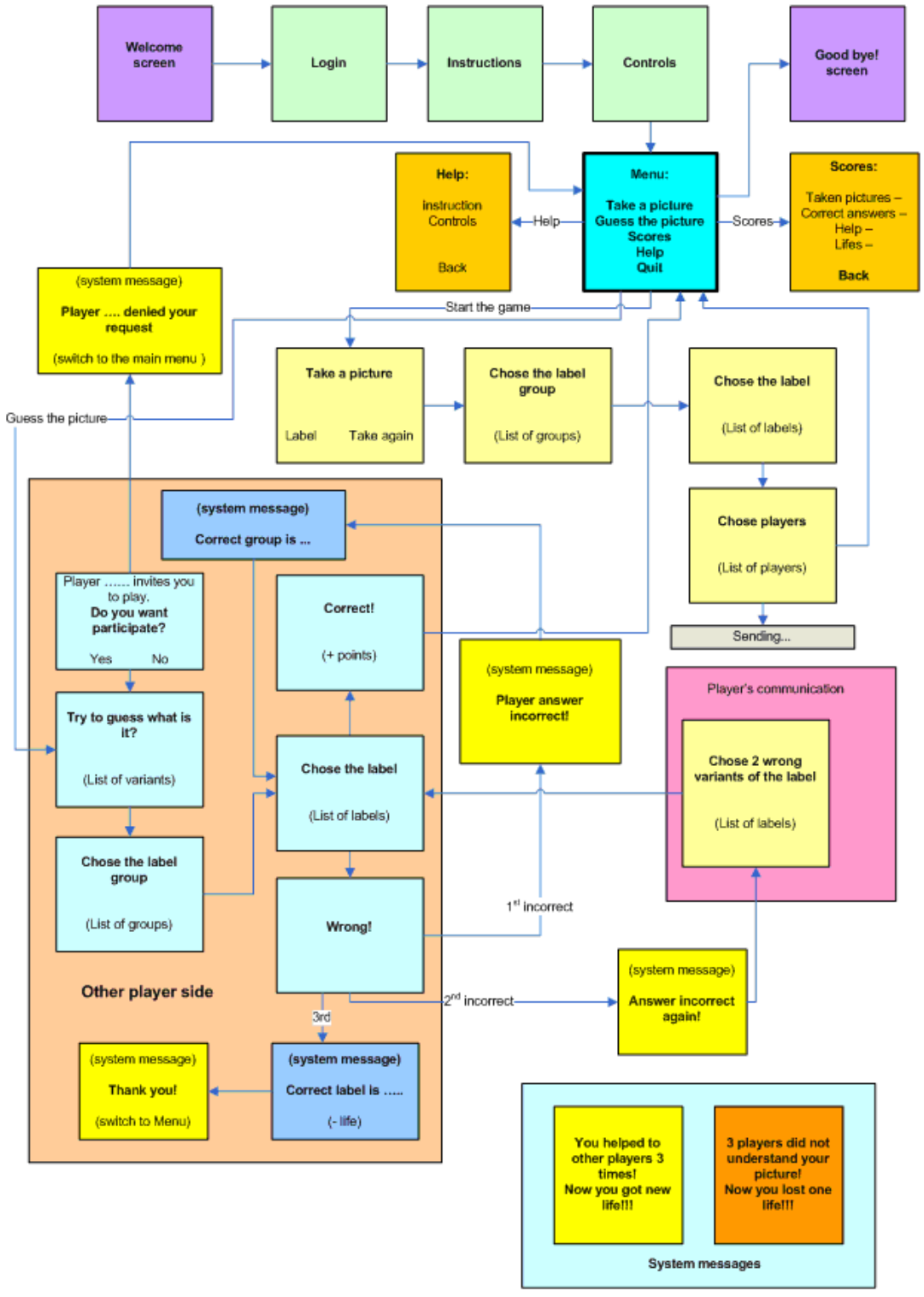

Figure A.1: PiX game flow diagram

Appendix B

Game questionnaire

PiX QUESTIONNAIRE

Thank you for being willing to complete this questionnaire.

The purpose of this questionnaire is to explore the attitudes and expectations of active players who form part of the PiX game testing.

It is important that you answer all the questions as honestly as possible.

Your answers to this questionnaire are confidential.

We would appreciate it if you could provide the following information:

1. Are you?

☐ **Male** ☐ **Female**

2. What is your age range?

☐ **Under 20** ☐ **30-40** ☐ **Over 50**

☐ **20-30** ☐ **40-50**

This questionnaire aims to explore the attitudes and expectations of players into mobile phones games. Please answer all questions accurately and honestly by circling (O) a number in a shaded box or by writing your answer in the shaded space provided. The information will be treated confidentially.

Question 1

For how long have you been playing with mobile games?

I have never had played mobile games before	1
Less than 1 year	2
1 to 5 years	3
More than 5 years	4

Question 2

How much do you use your phone in a week?

I don't own a mobile phone	1
Less than 1 hour per week	2
1 -2 hours per week	3
2-3 hours per week	4
3-4 hours per week	5
More than 4 hours per week	6

Question 3

How often do you play with your mobile phone?

My mobile has not game capabilities	1
My phone has game capabilities but I am not interested to play	2
Less than 1 hour per week	3
1-2 hours per week	4
2-3 hours per week	5
3-4 hours per week	6
More than 4 hours per week	7

Question 4

Which of the following do you consider your greatest motivation to mobile games?

Rank these following factors from 1 to 10, where 1 represents the factor you consider most important and 10 the factor you consider least important.

Self	
Communication	
Self expression	
Curiosity	
Challenge	
Control	
Social Pressure	
Other (specify)	

Question 5

While playing PiX, which one was your motivator in order to accomplish the game?

	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
I wanted to know what happen next	1	2	3	4
I wanted to win	1	2	3	4
I wanted to be at charge of what it was happening in the game	1	2	3	4
I like to pretend I am a researcher/magician adding information and guess information in the game	1	2	3	4

Question 6

What where your difficulties while playing the game?

	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
The Language being used	1	2	3	4
Using the phone for playing was intuitive	1	2	3	4
Taking pictures was difficult	1	2	3	4
The screen is too busy	1	2	3	4
It was fun to play with the phone	1	2	3	4
The size of the text is big enough	1	2	3	4
I can find information I look for	1	2	3	4
It was easy to use a phones as tool for playing	1	2	3	4
I am more comfortable using my own mobile phone	1	2	3	4

Question 7

What expectations do you have of playing with mobile phones?

	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
It provides an opportunity to learn new things	1	2	3	4
It will give me an opportunity to share and play with other friends	1	2	3	4
I will develop skills and competencies that will help me in everyday life	1	2	3	4
It will give me self-confidence	1	2	3	4
I will be able to develop a digital presence	1	2	3	4

Question 8

	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
It was fun to play taking photos	1	2	3	4

Why did you **like/dislike taking pictures** in PiX?

	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
I enjoy sharing what I can see through the photo with others	1	2	3	4

What did you **like/dislike** about the **sharing photos**?

Question 9

What do you **like/enjoy** about PiX?

Question 10

What do you **dislike or find more difficult** about PiX?

Question 11

What would you suggest us to improve in PiX?

Question 12

What do you like to see more in mobile games:

Question 13

What do you like to see less in mobile games:

Thank you for taking the time to fill out this questionnaire. You do not have to put your name in the box below, but if you do you will be thanks personally for your help with this project. Any comments you make will be treated by us in the strictest of confidence, regardless of whether you leave your name or not.

Name

If you'd like to volunteer to be interviewed, and get the chance to express your feelings and ideas on PiX in greater depth, please contact Ekaterina Kuts [*ekuts@cs.joensuu.fi*] or Carolina Islas Sedano [*cislas@cs.joensuu.fi*].

Appendix C

Collected data about participants background

Participants:

Male	**16** (80%)
Female	**4** (20%)
Total	**20**

Age:

Under 20	20-30	30-40	40-50	Over 50
4	14	1	0	1

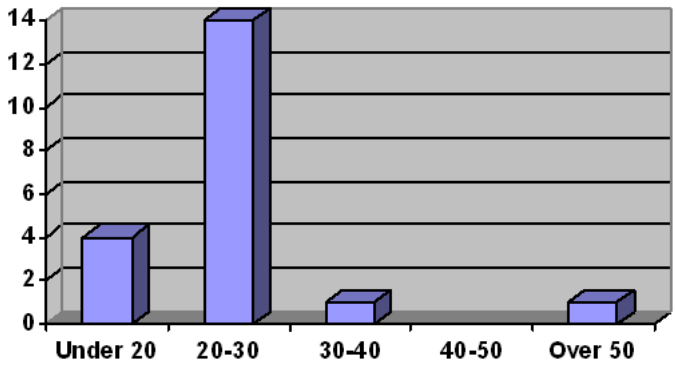

Figure C.1: Age distribution

For how long have you been playing with mobile games?

Never	Less than 1 year	1 to 5 years	More than 5 years
1	5	11	3

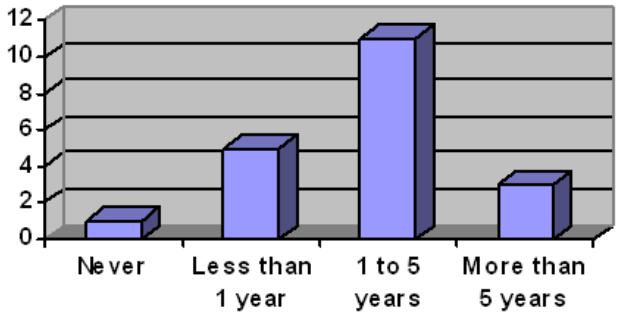

Figure C.2: Mobile game experience (in years)

How much do you use your phone in a week?

I don't own a mobile phone	Less than 1 hour per week	1-2 hours per week	2-3 hours per week	3-4 hours per week	More than 4 hours per week
	4	7	2	2	5

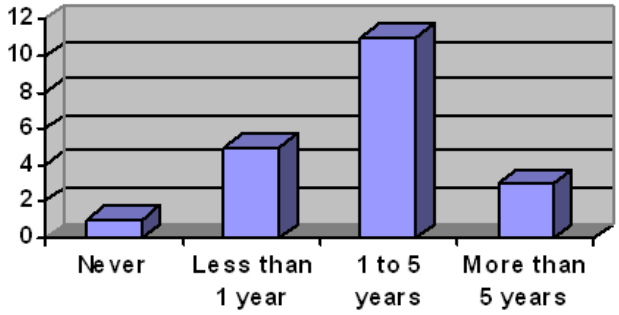

Figure C.3: Time of phone use (hours per week)

How often do you play with your mobile phone?

My mobile has not game capabilities	I am not interested to play	Less than 1 hour per week	1-2 hours per week	2-3 hours per week	3-4 hours per week	More than 4 hours per week
	3	12	5			

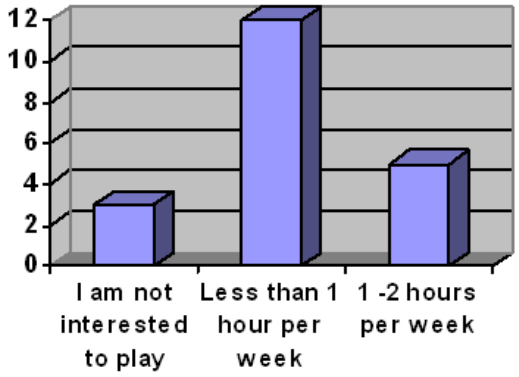

Figure C.4: Time of playing mobile games (hours per week)

Appendix D

The PiX game experience

What do you like/enjoy about PiX?

- It was interesting to guess a key word given by author of the photo
- The game had good graphics
- Good interface and an innovative idea
- Good graphics, interface
- It was interactive
- The concept of the game
- It is used high technology and allows us to communicate with other people
- It is funny and easy
- GUI looks great and it's easy to use
- Game is fast and fun.
- It is interesting to find what other players mean under the picture
- Guessing, see what it will come
- Guessing of the right answer
- The basic idea is nice, and the means of communication that comes with it is really something new and interesting

- Nice theme, nice colors, able to play with friends
- Idea is new for me and I was happy as a child.
- Good graphics and good interaction most of the game
- Easy to use, gets fast to the action

What do you dislike or find more difficult about PiX?

- The camera was a bit odd It was a bit difficult to guess the right thing from the photo
- It was difficult to take the picture
- Dislike green screen
- To transfer photo is used WiFi and it would be better to use other technology too
- The crash of the application
- The labels are not clear enough
- Taking pictures with some phones is difficult (Nokia communicator).
- Somehow the labels are not so intuitive, it takes a while to get used to them
- Control is hard, it is not clear what other player mean under the picture
- When request and picture came together
- Control keys
- The idea is quite simple but might be as an advantage too
- Problems with server
- Change the label for the “Change group” to “Back”
- Camera crashed, long waiting time if other player doesn’t respond, race between labeling your
- Photo and trying to guess the photos of others taking pictures

Appendix E

Collaboration experience

	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
It was fun to play taking photos	**4**	**15**	**1**	

Why did you like/dislike taking pictures in PiX?

Like	**Dislike**
- Taking photo is my hobby. It was fun to me to select object to be shoot and select the proper word that present emotion, feelings.	- I dislike that I had to turn around the phone to take picture
- I liked take photos and making my friend try to guess	- The camera was slow and it was difficult to search for the picture (screen is too wide)
- I liked to take the photos because it was fun to sent it to other person	- Dislike camera
- Taking pictures made it more interactive	- Not comfortable to work with camera on communicator, unused
- I made stupid pictures to make fun of others, it's funny	- Problems with camera when I try to take a picture

Continued on next page

Table E.1 – *continued from previous page*

Like	**Dislike**
- It's interesting for me to know new mobile technology	- It was difficult to understand how to capture. I could not capture myself.
- It was funny	- The communicator made taking photos hard.
- Make my friend going crazy with guessing	- Awkward the mobile camera, photo taking is confusing.
- Like to look for things	
- I like the opportunity to play and share pictures with other players.	

	Strongly agree	**Agree**	**Disagree**	**Strongly disagree**
I enjoy sharing what I can see through the photo with others	**4**	**16**		

What did you like/dislike about the sharing photos?

- This is a good "socializing" game/ people learn how to express themselves and how to understand other people using photo as "carrier" of emotions and feelings
- I found it cool that you can share your own pictures
- I liked sharing photos, I liked that other person can guess what the photo was
- Possible feeling of "invasion of privacy" as all pictures are kept on a server
- Imaging the reaction of people
- It was easy to use
- I like the idea of communicating through photos
- It was fun to see how others label my pictures
- Easily to send and receive

- I like it because other people can play with me picture
- I like to see what catches the attention to others and they will see what catch my attention
- Ability to have several categories for different groups of people, like for kids, or artists styles for art students

Appendix F

Improvement suggestions

What would you suggest us to improve in PiX?

- More groups, more words. Maybe define "distance" of your word from the label
- I would like to see everything in one screen without moving cursor
- Allow picture owner to see suggested answers
- Add new telecommunication technology
- Store pictures in own profile
- Faster display of photos, taking photos, user defined labels, being able to send also labels with the photo
- Web-site has to be accessed from the phone
- It should have possibility to send messages to others
- When request of labels and picture guessing came together
- Display name of the label group when I choose it
- As a game that will be published it really need more content, or it should be cheap. But otherwise nothing much. Maybe the controlling could be a bit better, I mean new function for the left and the right buttons change all the time.
- I would like to use this game on my own phone

- To make it cross-platform application.
- Add button “Back”, camera use was difficult.
- Sometimes I have got a wrong answer from the server.
- The waiting screen: maybe some others activities in there
- It will be good to have some tips how to take pictures