Computer-supported collaboration using Pick-and-Drop interaction on handheld computers

Henrik Gelius
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Abstract

This study investigates a new interaction technique for collaboration on handheld computers called Pick-and-Drop. The technique is an extension of the popular Drag-and-Drop method used in many graphical interfaces today, but with Pick-and-Drop on-screen objects can be picked from one screen with a pen and dropped onto another. To the user, the pen appears as a virtual storage while moving the digital object in real space, while the data really is transferred in the background using a standard wireless network.

The aim of the study is to answer whether Pick-and-Drop promote collaboration among children by letting them focus more on other users and the task at hand than on the computer interaction. The study also investigates in what way collaborative situations can benefit from Pick-and-Drop.

A prototype Pick-and-Drop system was implemented on four customized handheld computers equipped with wireless network communication. The prototype allowed spontaneous collaboration using ad-hoc networks and peer-to-peer communication. Radio Frequency Identification (RFID) tags were used to identify the pens when picking and dropping objects from the screen.

Ten children aged 6-7 years old participated in the study at an after-school recreational centre. They tried Pick-and-Drop by playing a collaborative game of buying and selling apples using golden coins represented as icons on the screen. The test was video filmed for later analysis.

The study showed that Pick-and-Drop offers effective collaborative interaction based on a mix of turn taking and concurrent interaction. Users do not have to switch focus when using an application or sharing data as the interaction style stays the same. There was an interesting difference in control over the interaction when users shared objects by “giving” or by “taking”. Users stayed in better control when they shared objects through giving.
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My appreciation also goes to the children and teachers at the after-school recreational centre Alfen who were kind to let me come and test the handheld computers with them. I wish to thank Susanne Arpsten, who helped video filming the children and offered positive support throughout the whole thesis process. Last but not least my thank you goes to Hillevi Sundholm who chose to do the opposition and presentation of my master’s thesis.

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## Contents

**Chapter 1 - Introduction** ................................................................. 1  
  Background ......................................................................................... 1  
  Proposed System ............................................................................... 5  
  Research Questions and Aim .............................................................. 6  

**Chapter 2 - Theoretical Background** ............................................. 8  
  Cognitive Development ...................................................................... 8  
  Development in Children ................................................................. 8  
  Distributed Cognition ....................................................................... 11  
  Human-Computer Interaction ........................................................... 12  
  Direct Manipulation Interfaces ......................................................... 12  
  Tangible User Interfaces .................................................................. 17  
  Multiple Device Interfaces ............................................................... 17  
  Computer-Supported Collaboration and Learning ......................... 18  
  CSCL .................................................................................................. 19  
  Collaborating Across Handheld Computers ...................................... 20  
  Social factors ................................................................................... 21  
  Comments .......................................................................................... 22  

**Chapter 3 - Implementation** .......................................................... 23  
  Prototype Design Goals .................................................................... 23  
  Prototype Game ................................................................................ 23  
  Hardware Architecture ..................................................................... 24  
  Software Architecture ...................................................................... 27  

**Chapter 4 - Empirical Study & Methodology** ................................. 31  
  Pilot Study ........................................................................................ 31  
  Main Study ........................................................................................ 32  
  Subjects ............................................................................................ 32  
  Equipment ......................................................................................... 32  
  Tasks ................................................................................................ 33  
  Procedure ......................................................................................... 34  
  Data Collection and Analysis ......................................................... 35  
  Video as Data ..................................................................................... 35  

**Chapter 5 - Results & Discussion** .................................................. 36  
  Analysis of Results .......................................................................... 36  
  Learning and Using the Interface ...................................................... 36  
  Collaborative Interaction Styles ....................................................... 38  
  Control of Actions .......................................................................... 40  
  Learning Arithmetic ........................................................................ 41  
  Communication ............................................................................... 41  
  Non-verbal Interactions ................................................................... 42  
  Methodological Discussion ............................................................... 42  
  Validity & Reliability ........................................................................ 43
List of Figures

Figure 1. Conceptual difference between remote copy and Pick-and-Drop (Rekimoto 1997) .......................................................... 3

Figure 2. Data exchange between PDAs and a wall-sized display (Rekimoto). 3

Figure 3. The Geney Palm interface and a group of children playing (Danesh et al. 2001) ............................................................ 5

Figure 4. The main areas of this study are HCI for Collaboration, and to a lesser extent Learning ........................................... 7

Figure 5. Zone of Proximal Development ............................................. 10

Figure 6. Collaborative knowledge construction using externalizations to “think-with” and to “talk about” (Fischer & Palen 1999) .............. 12

Figure 7. Subjects picked up the solid box and placed it on top of the outlined box (Inkpen et al. 1996) .................................................. 15

Figure 8. Beaming data as compared to picking data with a stylus (CILT 1998) ................................................................. 20

Figure 9. First, second and third design idea ........................................ 23

Figure 10. Example of game objective shown as start and goal states .... 24

Figure 11. Wireless network modes, Ad-hoc versus Infrastructure ........ 25

Figure 12. Peer-to-peer network architecture compared to Client/Server network ....................................................................... 26

Figure 13. RFID-tagged pen contains information that can be picked up by an RFID-Reader ............................................................. 26

Figure 14. Components of the system .................................................. 27

Figure 15. Screen design ..................................................................... 28

Figure 16. Pick-and-Drop action of prototype system, icons are colour-faded when picked .......................................................... 29

Figure 17. Pick-and-Drop action of Rekimoto’s system adopted from (Rekimoto 1997) ............................................................. 30

Figure 18. Pilot study participant testing the iPAQ computer ................. 31

Figure 19. Four customized iPAQ computers and their coloured styluses .. 33

Figure 20. Final prototype design that was used in the main study ......... 33
Figure 21. First group before testing and third group of children playing the game................................................................................................................................................................34
Figure 22. Remote Pick-and-Drop in action (time elapsed 1 second)......................36
Figure 23. Turn taking vs. concurrent Pick-and-Drop between user A and B............39
Figure 24. Concurrent Pick-and-Drops between user A, B and C..............................39
Figure 25. A girl protecting the screen with her hand..................................................40

List of Tables
Table 1. New features of thinking in Concrete Operational stage (Cole & Cole 1997)...................................................................................................................................................................9
Table 2. Status of pens broadcasted among computers..............................................28
Table 3. Groups in the experiment...............................................................................32
Table 4. Transcript in Swedish for test group 1..........................................................56
Table 5. Transcript in Swedish for test group 2..........................................................62
Table 6. Transcript in Swedish for test group 3..........................................................66

Abbreviations
CSCL  Computer Supported Collaborative Learning
CSCW  Computer Supported Cooperative Work
HCI  Human Computer Interaction
GUI  Graphical User Interface
LAN  Local Area Network
MCUI  Multiple Computer User Interface
PDA  Personal Digital Assistant
SDG  Single-Display Groupware
RF  Radio Frequency
RFID  Radio Frequency Identification
TUI  Tangible User Interface
UDP  User Datagram Protocol
ZPD  Zone of Proximal Development
Chapter 1 - Introduction

The goal of this study is to investigate if a new interaction technique called Pick-and-Drop, can facilitate collaborative learning by offering a natural interaction for information exchange between PDAs (Personal Digital Assistants) – small handheld computers.

This chapter gives a background to the research study. It also presents a prototype Pick-and-Drop system and research aims to follow.

Background

Throughout the history of humans we have been working together in groups to successfully solve problems. Even though geniuses like Galileo, Newton and Einstein stand out from the crowd solving complex problems on their own, many of our problem solving activities are best done as a group activity. The introduction of the computer provided new opportunities for supporting such collaboration.

In the last couple of years opportunities for computer-supported collaboration on small handheld computers have also emerged, although the area of research is still largely unexplored. Instead of being restricted to sharing fixed workstations or remote collaboration via networks (e.g. Internet) when collaborating using computers, users can experience situations where both the users and computers come together physically at almost any place. This style of supporting human activities with computers is more in line with the highly flexible and situated nature of human behaviour (Suchman 1987). Handheld computers will probably become an increasingly compelling choice for classrooms because they will enable a transition in use from being occasional and supplemental to frequent and integral use (Soloway et al. 2001).

Research regarding collaboration supported by computers has formed their own fields of research such as CSCW (Computer Supported Cooperative Work) and CSCL (Computer Supported Collaborative Learning) that emerged in the late 1980s (Bannon 1993). These are interdisciplinary fields concerned with many different issues, ranging from highly technical aspects to sociological interpretations of work and learning.

Much of the CSCW and CSCL work has been focused on collaboration at a distance, probably because the new computer networks can overcome long distances between users using email and videoconferencing for example. However, still the computers cannot express the full experience of a group of people collaborating in the same room face-to-face, where all our senses can be used to better understand the situation and problem at hand. There is
some work in CSCW and CSCL taking aim on group process and group dynamics that requires face-to-face collaboration and this study will explore these further.

The connection between learning and collaboration can also be explored when investigating group activity supported by computers. For example a collaborative situation ought to provide the group members with easier access to other members reasoning (Ekeblad & Lindström 1995) and may therefore be used advantageously in the learning process.

Some potentials of using handhelds in a collaborative learning setting have been studied recently, e.g. in the Geney game (Danesh et al. 2001) where children can explore concepts of genetics together in a game. However, the study showed that the interaction techniques used for sharing data among the computers was not seamless and natural.

There is a need to create a new interaction paradigm for handhelds that would support collaboration better. So far the design of user interfaces for handhelds has mainly allowed users to collaborate in ways inherited from desktop GUIs (Graphical User Interfaces). From a user's point of view, data such as files or email can be sent by means of using various graphical menus, even though the menus are typically accessed using a stylus (the pen used on handheld computers) rather than a mouse (cf. Miller & Myers 1999). Though highly useful in some situations, such user interface approaches do not fully acknowledge the fact that handheld computers are used in many different situations which might warrant other types of human-computer interfaces (Björk et al. 2000, Kristoffersen & Ljungberg 1999a), nor do they take advantage of humans' highly developed skills for dealing with physical objects (cf. Ljungstrand et al. 2000).

This master's thesis will argue for an alternative interaction technique that take better advantage of our physical skills but also have parts inherited from the desktop GUIs, hopefully to let the user focus more on the situation and people and less on the interface.

The Pick-and-Drop interaction technique invented by Rekimoto (1997) at the Interaction Laboratory group of SONY Computer Science Laboratories in Japan is of particular interest. It is a new interaction paradigm that makes use of both physical movements and inherits some features from standard GUIs. The Pick-and-Drop interaction technique is an extension of the popular drag-and-drop method used in many GUIs today, but with Pick-and-Drop on-screen objects can be picked from one screen with a pen and dropped onto another. To the user, the pen appears as a virtual storage while moving the
digital object in real space, while the data really is transferred in the background using standard network protocols.

The Pick-and-Drop system presented by Rekimoto was implemented on handheld computers and a large screen that worked as whiteboard. It can make co-located collaboration easier using a multiple-computer user interface (MCUI) where users can take advantage of and use each other’s screens.

The Pick-and-Drop interface could offer a more natural sharing method compared to indirect manipulation using commands and menu-based interfaces, partly because it is less abstract, and partly because it allows the user to take advantage of his/her skills on working with physical objects. With Pick-and-Drop, this is accomplished by direct engagement with the manipulated objects, analogous to picking and dropping physical objects in the real world. This supposed naturalness of a pen interface is also based on the pen and paper metaphor, implying that the user’s experience with this medium will be an advantage. Studies have shown that gesture commands are easier to remember than keystroke commands (Wolf 1988). This form of communication should require less attention from the users than using on-
screen commands, allowing them to pay more attention to other important things, such as for instance other co-present people.

The original research on Pick-and-Drop (Rekimoto 1997) mainly focused on the technical aspects of the interface. While Rekimoto introduced the idea and showed the technical feasibility of a Pick-and-Drop system, there was not much publicised data on user testing or a deeper explanation of why Pick-and-Drop would be a better alternative to other user interfaces in certain settings.

Previous empirical studies of collaborative interfaces for handhelds have also showed that they can require too much of the user’s attention, so that other important external tasks suffer (Kristoffersen & Ljungberg 1999a). As Inkpen (1997) points out, an important part of the learning activity when children collaborate using handhelds takes place as an external task, so the face-to-face communication is a strong factor in people’s success when collaborating. This should be reflected in the interface, and here Pick-and-Drop offers a social way of collaboration since the users have to walk up to each other to be able to share information.

There is little research on new interaction paradigms for collaboration on handheld computers, but research at the EDGE (Exploring Dynamic Groupware Environments) Lab of Simon Fraser University in Canada is one exception. They explore a variety of projects, all with the common aim of designing better computer support for collaboration. For example they have a project called Geney that deals with handheld computers for collaboration.

Geney is a collaborative problem solving application designed to teach children about genetics. The project explores development of handheld educational applications for children using a user-centred, iterative design process. The design methodology utilized mock-ups of representative tasks and scenarios. Results of this work provide important insights into the design of handheld applications for children and illustrate the necessity of user-centred design.
The main idea of the game is to make it necessary for users to collaborate and share knowledge in order to complete the goal of breeding a specific fish.

The present study of a new interaction technique for collaboration was inspired by Rekimoto’s technical achievements in using Pick-and-Drop. It also draws inspiration from the EDGE Lab regarding the purpose and use of applications for collaboration.

Proposed System
Taking Pick-and-Drop further to become a better interaction technique for collaboration on handheld computers requires more experiences from users to see what and how it works in real-world situations. This also means that we need to be able to use the interface everywhere users might want to be able to collaborate or share information. The original Pick-and-Drop by Rekimoto (1997) doesn’t support this ad-hoc “spontaneous” collaboration so it would be one thing to improve to allow collaboration in many different situations.

The concern of this study has been to develop a prototype for investigating user interaction and collaboration effects of Pick-and-Drop in real-world settings. Two or more users should be able to come together and share information in a simple and convenient way that requires no extra configuration or infrastructure, only using their PDAs and spontaneous wireless networking.

To accomplish this, the system was implemented on standard handheld computers equipped with wireless network communication. The system allows for a great number of handheld computers to be connected using peer-to-peer communication and ad-hoc wireless networking.
Apart from the changes in how the network communication will be used in this Pick-and-Drop system there are also changes in the interface compared to Rekimoto’s system (1997). The pens are identified using RFID (Radio Frequency Identification) technology. Both audio and visual feedback to the user will be used to enhance the experience of picking and dropping objects hopefully to let the user focus more on the collaborative activity.

Research Questions and Aim
The ambition of this study is not on the technical side, but rather to understand how, when and why Pick-and-Drop interfaces can be appropriate to human users. It is interesting to see what can be gained from a new interface such as Pick-and-Drop, and see what features that can be found. For example Pick-and-Drop is a rather physical interface that requires the user to move in space and not only move an object on the screen.

In a face-to-face collaborative situation, we probably want the human-computer interaction to require less attention, leaving more attention available to focus on other people and tasks. The social aspect is an important factor in both learning and collaboration so the Pick-and-Drop interaction should support this.

To explore these thoughts the research question of the study is twofold:

1. Does the Pick-and-Drop interaction technique let users focus more on other people and the task at hand than on the interaction itself without losing control of the interaction?

2. Can learning and collaborative situations benefit from the Pick-and-Drop interaction technique, and if so in what way?

A prototype Pick-and-Drop system was implemented on handheld computers. The system was tested on children at an after-school recreational centre. They got to play a simple game involving collaboration while picking and dropping objects from each other’s screens.
The choice of children as users was made due to several factors. To start with there is a research gap leaving young users out. Using children to evaluate a new interface will probably give straight and early answers if this is an interface that is easy to learn and use. Although children are eager to learn new things they often have a short attention span to concentrate for longer periods of time. This can be used to see if the Pick-and-Drop interaction supports collaboration also under somewhat trying conditions. As children often are more physical than adults the physical properties of Pick-and-Drop might suite them well. Previous research has shown that young children learn best while engaging physically in tasks (Beaty 1984).

Children are also sociable beings (Vygotsky 1978) that like to spend time and play with other people. This behaviour fit well to test a collaborative task like playing a game were children can enjoy a learning experience. Personal technology like Pick-and-Drop on handheld computers can hopefully fulfil some important needs for children like; social experiences, control of their world and ways to be creative (Druin & Inkpen 2001).

Some time into the project I found out about the DataGotchi project (CILT 1998) at the Center for Innovative Learning Technologies. They had “imagineered” a future low-cost, handheld mathematical tool for collaborative learning. Their imaginative project proposal was very much in line with my own project, and although they imagined beaming as data transfer method their hope for a collaborative tool for children encouraged me to continue.
Chapter 2 - Theoretical Background

This chapter aims to show a theoretical foundation upon which the study is based. Relevant articles have been reviewed in areas such as HCI, CSCL, cognitive psychology, learning theories and theories on collaborative activities.

There are many factors affecting computer-supported collaboration of different kinds, for example our cognitive and social abilities. Another inevitable factor we come across when using computers is the computer user interface. To explore this area we need to study Human-Computer Interaction and in this study especially HCI for collaboration on handheld computers. However, the more important areas are those of computer-supported collaboration, especially theories that take in consideration children’s collaborative learning and use of computers.

Cognitive Development

To learn and use something we must reach some level of sufficient cognitive development. In this study we are dealing with learning to use a computer user interface and also a simple game that involve some collaboration and arithmetic thinking. One question we can ask is how young users can we use in the study if they should be able to learn these things.

Development in Children

There are different perspectives on how learning takes place, and therefore also slightly different views on when and how sufficient cognitive development is reached.

According to Piaget’s constructivist view, knowledge is developed through action and the process of adaptation (Cole & Cole 1997). To Piaget, an action reflex is a primitive schema, the basic unit of psychological functioning in his theory. A schema can be thought of as a mental structure that provides us with a model for action in similar or analogous situations.

The processes of assimilation and accommodation make up adaptation, which refers to the child’s ability to adapt to his or her environment. Assimilation is the way the child tries to understand new knowledge in terms of their existing knowledge while accommodation means a change in the child’s cognitive structure in an attempt to understand new information.

Young children lack the ability to solve logical problems, but a change takes place around the age of 6-7 according to Piaget. The child enters the “concrete operational” way of thinking at this time. To get a hint of what we
can expect from this stage a more detailed table overview of the Concrete Operational stage follows:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decentration</td>
<td>Children can notice and consider more than one attribute of an object at a time and form categories according to multiple criteria.</td>
</tr>
<tr>
<td>Conservation</td>
<td>Children understand that certain properties of an object will remain the same even when other, superficial ones are altered. They know that when a tall, thin glass is emptied into a short, fat one, the amount of liquid remains the same.</td>
</tr>
<tr>
<td>Logical necessity</td>
<td>Children have acquired the conviction that it is logically necessary for certain qualities to be conserved despite changes in appearance.</td>
</tr>
<tr>
<td>Identity</td>
<td>Children realize that if nothing has been added or subtracted, the amount must remain the same.</td>
</tr>
<tr>
<td>Compensation</td>
<td>Children can mentally compare changes in two aspects of a problem and see how one compensates for the other.</td>
</tr>
<tr>
<td>Reversibility</td>
<td>Children realize that certain operations can negate or reverse the effects of others.</td>
</tr>
<tr>
<td>Declining egocentrism</td>
<td>Children can communicate more effectively about objects a listener cannot see. Children can think about how others perceive them. Children understand that a person can feel one way and act another.</td>
</tr>
<tr>
<td>Changes in social relations</td>
<td>Children can regulate their interactions with each other through rules and begin to play rule-based games. Children take intentions into account in judging behaviour and believe the punishment must fit the crime.</td>
</tr>
</tbody>
</table>

Table 1. New features of thinking in Concrete Operational stage (Cole & Cole 1997)

These features in the table above suggest that these children should be perceptive to learn in a simple rule-based game at this stage. More on learning arithmetic is presented in a later section of this chapter.

Zone of Proximal Development

The kind of finely tuned adult support that assists children in accomplishing actions that they will later come to accomplish independently creates what Vygotsky (1978) called a zone of proximal development (ZPD). Vygotsky attributed great significance to such child-adult interactions throughout development. The zone he referred to is the gap between what children can accomplish independently and what they can accomplish when they are interacting with others who are more competent (Cole & Cole 1997). The term “proximal” (nearby) indicates that the assistance provided goes just slightly beyond the child’s current competence, complementing and building on the child’s existing abilities instead of directly teaching the child new behaviours.
Central to the notion of the ZPD is that people learn through social interaction: Skills first appear on a social plane, through interaction between child and adult, and later appear on individual plane, that is: the individual appropriates the skills. In this way Vygotsky sees learning and development as the result of social interaction.

When adults or more competent peers assist children systematically the learning processes in children are scaffolding the processes (Wood, Ross & Bruner 1976). For example, young primary-school children who don't recognize the written digits need help with decoding these symbols. This help could, for example, involve writing the numbers under a dice drawn with the correct number of spots. When children have learnt to recognize the written digits, this scaffolding is no longer needed. Perhaps now the children need help with other tasks. Teachers then move their help, the scaffolding, to a new work area in order to assist children constructing new knowledge.

Earlier studies have shown that peer dialogue through technological aids can lead to better outcomes than traditional in-class instruction (Iles et al. 2002). Research in psychology and education has also consistently demonstrated that working in pairs and small groups can have advantageous effects on learning and development, especially in young children (Rogoff 1990). This implies that peer interaction in groups can lead to greater attention and thought by children.

Learning Arithmetic
As one sub-goal of this study is to use Pick-and-Drop for collaborative learning of simple arithmetic, we need some basic understanding of how learning basic mathematical knowledge works. Learning mathematics requires the acquisition and coordination of three kinds of knowledge according to Gelman et al. (1986):

Figure 5. Zone of Proximal Development
1. Conceptual knowledge - the ability to understand the principles that underpin the problem.
2. Procedural knowledge - the ability to carry out a sequence of actions to solve a problem.
3. Utilization knowledge - the ability to know when to apply particular procedures.

Most children arrive at school with some of each kind of knowledge. For example, young children know that numbers and objects can be put into one-to-one correspondence and that when they count candies in a dish, the last number arrived at in the count stands for the total (conceptual knowledge). They have an intuitive grasp of how to add and subtract very small quantities (procedural knowledge). They also know that if Anna has two candies and her mother gives her one more, they need to add, not subtract, to arrive at the total (utilization knowledge). These basic kinds of knowledge provide an essential starting point for learning more advanced mathematics in school.

A study on mathematical knowledge in children by Doverborg & Pramling (1999) showed that in a group of forty children aged 6; everyone knew how to count to at least twenty.

For learning mathematics (and for doing mathematics) it is often more convenient to use visual interaction and natural behaviour than it is to conduct symbolic substitutions devoid of meaning (Bricken 1992).

Distributed Cognition
Distributed cognition is a theoretical framework that differs from mainstream cognitive science by not privileging the individual human actor as the unit of analysis (Hutchins 1995a). Distributed cognition acknowledges that in a vast majority of cases cognitive work is not being done in isolation inside our heads but is distributed among people, between persons and artefacts, and across time.

This has a natural fit for human-computer interaction and computer supported collaboration (Nardi 1996), where the behaviour we are interested in is the interaction of the whole system of people and artefacts. A study by Pea & Gomez (1992) showed that the use of external representations among students helped building joint representations of their knowledge.
The visibility of communication exchanges and of information enables learning and greater efficiencies according to Hutchins (1995a).

**Human-Computer Interaction**

This section describes human-computer interaction that is relevant to Pick-and-Drop. Pick-and-Drop can be categorized as a direct manipulation interface sharing features with traditional GUIs and tangible (physical) user interfaces. Other common interaction styles for HCI apart from direct manipulation are command entry, menus, form-fills and natural language dialogue.

Different interaction styles have different problems and advantages, so the problem of choosing the best interaction technique often comes down to choosing an appropriate interaction for the task at hand. Donald Norman describes the problem in meeting the goals of users as two gulfs between the user and the system (Norman 1986). The gulf of execution is the difference between the intentions of the person and the perceived, allowable actions. Do the actions provided by the system match those intended by the person?

The gulf of evaluation reflects the amount of effort that the person must exert to interpret the physical state of the system and determine how well the expectation and intentions have been met. The distance is then the mental effort required translating goals into actions at the interface and then evaluating their effects.

**Direct Manipulation Interfaces**

The basic principles of a direct manipulation interface are that graphical objects on the screen represent real-world objects, actions on the computer resemble real-world actions and there is immediate feedback on the user’s actions. This style of interaction puts the user in control through active manipulation of graphical objects rather than making a sequence of
selections or typing text, Shneiderman who coined to term refer to interfaces with the following properties (Shneiderman 1982):

1. Continuous representation of the objects and actions of interest with meaningful visual metaphors.
2. Physical actions of presses of labelled button, instead of complex syntax.
3. Rapid incremental reversible operations whose effect on the object of interest is immediately visible.

Continuous representation of the objects allows the user to see the effects of user actions on the object immediately. An effective direct manipulation design would directly map objects/actions in the task domain to corresponding objects/actions in the interface domain. Meaningful metaphors when applied in the interface domain allow users to make associations between the interface actions and objects and the high-level task domain. Physical actions (e.g. clicking or dropping) are employed to interact with objects in the interface domain, instead of written complex syntax, which gives users the visual feedback to directly manipulate objects in the task domain. Rapid, incremental, and reversible actions with immediate feedback follow the physical model of the real world (i.e. task domain).

In direct manipulation there is typically a small articulatory distance. This is the relation between the meanings of expressions and their physical form. Potential advantages of direct manipulation are good learnability, easy recognition and correction of errors and a pleasant feeling of “direct engagement”. A limitation is the semantic distance that is often large. This is the relation between what the user wants to express and the meaning of the expressions available at the interface.

Shneiderman (1992) have put forth a number of usability benefits for direct manipulation systems. He argues that they are comprehensible and predictable systems that offer good controllability:
• Learnability - the system should be easy to learn so that the user can rapidly start getting some work done with it.

• Memorability - the system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.

• Better feedback than text-based interfaces

• Fewer error messages - the system should have a low error rate, so that few error messages are needed

• Enhanced expert performance - the system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.

• Increased control and reduced anxiety

Although direct manipulation interfaces are predominantly GUls they are not restricted to this according to Shneiderman (1997), who gives robot programming by demonstration as an example.

Most graphical interfaces of today’s handheld computers do not take advantage of the highly developed human ability to handle physical objects (Ljungstrand et al. 2000). However, interfaces such as direct manipulation benefit from physical movements as part of the activity of using the interface. In this way one make use of the human ability to remember movements to make the system easy to use, and the more complex syntax of writing commands instead is avoided. Studies have shown that gesture commands are easier to remember than keystroke commands (Wolf 1988).

Although a positive idea about direct manipulation interfaces is its function to lower the cognitive load in human-computer interaction, this can have a negative effect on learning. Studies have shown that direct manipulation offers less room for reflective cognition and planning, but rather a more trial-and-error based interaction because their ease of use (Holst 1996, Guttormen Schär 1998).

However, a study by Druin et al. (1997) showed that preschool children usually had to depend on trial-and-error to remember what button did what on a three-button mouse. Many of them wanted to get rid of the mouse all together and point at the screen.

The negative learning effect of using a too intuitive interface should be less dramatic when the interface is only a part of the collaborative learning situation, as much of the learning process will take place interacting with other people. Also in the case of Pick-and-Drop, there are also “gesture like”
movements involved, picking up the object and moving it to the screen where it should be dropped. This should lessen the effect of continuous trial-and-error without any reflective thinking, as the interface requires greater physical movement and gesturing than a standard drag-and-drop interface like Microsoft Windows.

Drag-and-Drop Interaction
Drag-and-drop is a common direct manipulation interaction technique that is used on standard Microsoft Windows and Apple Macintosh systems. Typically the user performs tasks on the computer by clicking onto items, moving them across the screen (drag) with the mouse, and releasing them (drop) on a particular icon.

A study by Inkpen et al. (1996) comparing drag-and-drop to point-and-click mouse interaction among children showed differences in terms of speed, error rate, and preference.

![Figure 7](image.png)

Figure 7. Subjects picked up the solid box and placed it on top of the outlined box (Inkpen et al., 1996)

The drag-and-drop movement required the children to position the cursor over a solid box and press the mouse button down. While maintaining pressure on the mouse button, the cursor was then moved over to an outlined box and the mouse button released to drop the icon. The point-and-click movement required the children to position the cursor over the solid box and press and release the mouse button. The cursor was then moved over to the outlined box (maintaining pressure on the mouse button was not necessary) and the mouse button was pressed and released again to drop the icon.

The results of Inkpen’s study suggest that utilizing a point-and-click interaction style was more effective than using a drag-and-drop interaction style. Children are able to perform the action faster, they make equivalent or fewer errors, and many of the children studied prefer it.
According to Inkpen the point-and-click interaction style decomposes the task into two atomic tasks, pick up the object and drop the object. The drag-and-drop interaction style attempts to "chunk" the tasks together into one physical motion. Buxton (1986) suggests that grouping tasks together by muscular tension and closure can achieve significant cognitive savings. The difficulty with this approach for children, as suggested in Inkpen’s study, is that the physical difficulty of performing a combined gesture (holding mouse button down and moving mouse) may outweigh the benefits achieved from chunking in this case.

Pick-and-Drop Interaction

Pick-and-Drop is an extension of drag-and-drop with the added possibility to move objects between different screens. Although it is an extension of drag-and-drop it lends more physical characteristics from the point-and-click interaction described in last section. The point-and-click interaction has two distinct “tensions” in the picking and dropping action and at the same time chunking the task together in one physical motion. Pick-and-Drop doesn’t require the user to hold a mouse button pressed down throughout the motion however, the object can be moved without additional cognitive effort.

Although very little earlier user experience exists for the Pick-and-Drop interaction technique, Rekimoto (1997) says it makes interaction more physical and visible as opposed to symbolic drag-and-drop.

In Rekimoto’s experiment users first had to copy information using a standard GUI between computers. It turned out users interchange symbolic concepts extensively. A copy operation could not be completed without verbal support. For example, a typical conversation was: "Mount Disk C: of my computer on your computer".

In the example sequence, "Disk C:" is a symbolic concept and unnecessary information for simply exchanging files (Rekimoto 1997). Information exchange using Pick-and-Drop is more direct. The users simply moved the icon as if it was a physical object. Although this operation could have been supported verbally, it is more like a conversation for exchanging physical objects (e.g., "Pick up this icon", or "Drop it here"), but it wasn’t necessary or intuitive in this case.

Rekimoto (1997) argues that Pick-and-Drop draws upon the pen & paper metaphor. It makes better use of physical affordances than the desktop metaphor of standard GUIs. This makes it interesting to further investigate the physical properties of this interaction technique.
Tangible User Interfaces

Tangible user interfaces (TUIs) is a research area that investigates the manipulation of physical objects to interact with computers and can be a means of supporting face-to-face collaboration (Scott, Shoemaker & Inkpen 2000). Pick-and-Drop interaction makes use of the physical pen to transfer virtual data objects and therefore lends properties from TUIs.

The tangible user interfaces take advantage of the fact that physical objects naturally afford certain interactions (Ishii & Ullmer 1997). These affordances help us take advantage of skills humans develop in the real world and make TUI interfaces more intuitive to interact with than indirect manipulation devices such as a mouse (Ishii & Ullmer 2001). The stylus used with handheld computers as a pointing and inscriptive device has some advantages over the mouse as it makes it especially easy to correlate user control with spatial representations (Roschelle & Pea 2002).

Manipulating TUIs requires body movement and body positioning within a physical space (true also for Pick-and-Drop). This promotes collaboration because it provides a rich source of non-verbal communication that helps manage the collaboration (Suzuki & Kato 1995). As an example, AlgoBlocks is a tangible programming language developed as a collaborative learning tool for children (Suzuki & Kato 1995). This TUI consists of physical blocks that represent commands of the programming language. When assembled in the proper configuration, the blocks create a computer program and show the result on a screen. In the AlgoBlocks study, it was found that a user’s body movement, such as picking up or placing a block, made the user focus on the task, drew the attention of the other group members, allowed the group to see the user’s intention, and allowed the members of the group to monitor that user’s progress. These are important observations that should apply to the Pick-and-Drop interface also.

According to Stanton et al. (2002) asynchronous interaction allow reflection and reaction time, the visibility of actions when using tangible technologies on the other hand allows multiple users to carry out synchronous interaction while maintaining awareness of the collective collaborative action. A major advantage of tangible technologies is also that less literate children can express themselves better.

Multiple Device Interfaces

Traditional user interfaces are mainly designed for an environment consisting of a single display and a single set of input devices. These are for use by one person at a time. However, just as we often combine several physical devices to perform tasks in the real world, it should be possible to use multiple computers and interfaces more effectively.
Examples of multiple device interfaces are Geney’s shared display feature (Bilezikjian et al. 2000) or user interfaces that span several handheld and fixed devices (Myers et al. 1998). The Pick-and-Drop interaction technique is based on such multiple device interfaces consisting of several displays and input devices (Rekimoto 1998). It is designed for use by several persons at a time.

Inkpen (1997) pointed out that multiple input devices on standard PCs often require turn taking, where one user has to wait for the other to leave over control. This can lead to a lack of motivation to perform, especially for children, who have shorter attention span than adults. To address this issue in the interaction users should be able to work concurrently when they wish.

For example in Pick-and-Drop, one user doesn’t have to give up their input and wait for another to interact with the interface when picking and dropping objects.

Some support for multiple-input can be seen in a recent study by Stanton et al. (2002). Their study uses multiple mice and tangible technologies to support young children to collaborate in the creation of re-telling of stories. They hypothesised that the use of multiple mice would produce less off-task behaviour and also greater synchrony of mouse in line with Inkpen’s et al. (1999) findings. It was found that using two mice gave higher levels of engagement with the task and increased productivity with more overall time for creation.

Multiple input devices at the desktop have been seen to facilitate children working on a shared task. However there are limitations in using standard desktop PCs, the physical size of the screen means it could never support more than a few users working simultaneously. At most 3 or 4 children could sit around and interact with a standard PC.

Computer-Supported Collaboration and Learning

Collaboration can be seen as pedagogy for learning. When a collaborative situation makes group members dependent on each other’s actions for success, their negotiations during problem solving ought to provide a window into their reasoning (Ekeblad & Lindström 1995). But for small children this is not straightforward. At first sight the collaboration among children may look like it creates more opportunities for misunderstanding than for learning, and the children’s reasoning does not make the conceptual content very explicit. It seems, according to Ekeblad & Lindström (1995), that when children try to share knowledge they do not always
succeed, but on the other hand they may provide each other with learning experiences even in the midst of misunderstanding.

The appeal among children to use peer-to-peer constructions of knowledge seems spontaneous according to Crook (1994). He notes a striking tendency that children turn to peers as resources of support in computer-based problem solving, instead of making use of on-line help facilities. Crook argues that the possibility of creating a shared cognitive context depends upon the participants’ mutual appropriation of motives, intentions and understanding. Three basic presses in peer-interaction that are afforded by working collaboratively in relation to computers are:

1. Articulation – self-talk leading to meta-cognition and also to expert tutoring as it expands knowledge and skills in the zone of proximal development.

2. Conflict – leading to cognitive restructuring.

3. Co-construction – constructing meaning by pulling in distributed expertise and knowledge from the group.

Collaborating is a discursive achievement that extends the construction of mutual knowledge, of shared understanding. The success of encounters between collaborating peers often resides in how effectively the participants co-construct a shared mental context for their problem-solving efforts.

CSCL
The research on Computer Supported Collaborative Learning (CSCL) has emerged from the earlier field of research of Computer Supported Cooperative Work (CSCW). According to Koschmann (1996) the foundation for CSCL is based on three different theories: the sociocultural perspective, social constructivism and situated cognition.

The sociocultural perspective is important because it emphasizes that our way of learning begins with information that people share (Vygotsky 1978). The information doesn’t become knowledge until it becomes a part of the individual (Säljö 2000).

Within social constructivism the social context where learning takes place is central. A focus is put on collaboration and interaction among people instead of the actual learning. The social collaboration is important, but the individual forms knowledge on his own.
Situated cognition is also part of the theoretical foundation of CSCL and explains that learning is only meaningful when it takes place within the social and physical context where it later will be practised (Lave 1996). As Lave states, learning is a function of the activity, context and culture in which it occurs.

It has been assumed within CSCL & CSCW that face-to-face collaboration provides a richer experience (Gutwin et al. 1996), and therefore distributed collaboration systems (e.g. distance learning) are often designed to mimic the feeling of “being there”. Unfortunately standard PCs offer limited support for face-to-face, synchronous collaboration. As a result, children who wish to collaborate using computers must adapt their interactions to the single-user paradigm most PCs are based on. Here handheld computers offer the possibility of a new interaction paradigm because they are portable and could support multiple-user interaction better in many situations.

Only in recent years increased attention has been directed towards the use of mobile computing devices, such as PDAs and wireless networks. There are however still very few contributions on this topic within the research areas of CSCW and CSCL. Some exceptions are Kristoffersen & Rodden (1996) and Bellotti & Bly (1996).

Collaborating Across Handheld Computers
Some potentials of using handhelds in a collaborative setting have been studied recently, e.g. in the Geney game (Danesh et al. 2001) where children can explore concepts of genetics together in a game. The study showed that the overall collaborative learning- effects using PDAs was very positive, even though the interface could be improved. For instance, beaming data using infrared communication between PDAs was problematic, and some of the children needed step-by-step instructions to be able to use the beaming feature. If data is being sent over a wireless network using only GUI manipulations, it might be less obvious whom the recipient really is.

Figure 8. Beaming data as compared to picking data with a stylus (CILT 1998)
Using a Pick-and-Drop system, however, this would not be an issue. A wireless ad-hoc network can provide the backbone for transferring data between any number of adjacent PDAs and the pen-based picking and dropping allows for a very intuitive user control of how the data is being moved.

The Geney project also showed that children were very excited by the notion of sharing information across handheld computers, and were very motivated to interact in this environment. The richness of interactions in a face-to-face environment could help children synthesize information, creating a dynamic and engaging learning environment (Danesh et al. 2001).

According to Engelbart (1962) information exchanges augment or amplify existing physical space. The space that the children are engaged in during their activity includes the handheld computers, but is not limited to the space within the screen. This is in line with the distributed cognition perspective.

Inkpen and colleagues (Inkpen, Mandryk & Scott 2000) talk about the implications of wireless technologies. They see a disadvantage in that the users must actively engage in the transfer of information and that communication is primarily peer-to-peer. The users must then switch their focus from an application to the act of transferring the information.

Social factors
One important factor in co-located computer-supported collaboration is the social factor. Sharing the same location means sharing the same physical and social space, being able to see what actions other participants take and how they react to your actions.

In collaboration with others we need good social knowledge and verbal communication to be able to increase our learning also. Studies have shown that verbal communication can promote learning and social interaction provides resources for learning (Hutchins 1995b, Miyake 1986).

A study by Iles et al. (2002) on student collaboration using handheld computers to take notes found that the effectiveness of the technology is highly contingent on the social context that it is being used in. In particular, users seem to generate social rules and conventions that fill in for missing or inaccessible technical features to enable communication to take place effectively.

Whereas cooperative learning is still measured by evaluations of individual children learning based on teacher defined goals, collaborative learning is
concerned with evidence of social cognition (Crook 1994, Koschmann 1996)
Social cognition may involve the creation of new socially shared meanings, the increasingly skilled enactment of social practices by children, or the evolution of the learning community as such.

Comments
According Piaget's theory, children enter the stage of concrete operational thinking around the age of 6 or 7. The new ways of thinking at this stage should allow them to perform collaborative tasks and do simple arithmetic as planned in this study.

Using external representations on handheld computers could be used to enhance understanding in line with the theory of distributed cognition. The visibility of communication exchanges and of information enables learning and greater efficiencies according to Hutchins (1995a). This seems to fit the Pick-and-Drop interaction naturally where sharing information is a visible action.

I agree when Rogoff (1990) points out that both guidance and participation in culturally valued activities are essential to children’s cognitive development. As a consequence the Pick-and-Drop interface was not designed for use in isolation from human interaction, but rather invites it.

Inkpen et al. (2000) see a disadvantage in that the users must actively engage in the transfer of information. Contrary to Inkpen, I see this as advantageous in some collaborative situations. The users should be aware of what information they are sharing and do it in an active kind of way, like through “picking” and “dropping”. This should facilitate the mind of the user, to know where information has been put, instead of information just being accessible without any action. Of course there are situations where such “access to all” information without user intervention can be good, but in the case of collaborating face-to-face and sharing different information among users I believe they should play an active role in the interaction of information sharing.
Chapter 3 - Implementation

This chapter describes the implementation of the prototype Pick-and-Drop system. The interface designs as well as technical aspects are presented.

Prototype Design Goals

The prototype was designed with an idea to use wirelessly connected PDAs equipped with RFID-readers and tags to implement Pick-and-Drop. On this system a simple game utilizing Pick-and-Drop would be implemented to explore some of its capabilities regarding interaction, collaboration/sharing of information as well as learning. The hardware developed could later be used as a test bed for experiments with different kinds of Pick-and-Drop and application environments.

The task became to design an interface that could be used to test children's collaboration in playing a simple game using Pick-and-Drop. It is interesting to use a game since it can create some conflicts, which in turn can lead to cognitive restructuring (Crook 1994). If possible it should be possible to learn something by playing the game, in our case to learn simple arithmetic and negotiation.

Figure 9. First, second and third design idea

The original idea was to design a game where apples and pears represented as icons on the screen could be exchanged. This idea later gave way to a design where apples could be bought using golden coins. It was possible to design an interesting game around this concept and it felt more realistic. Feedback to the user is given both by audio and visual means. In the final design an image of a coloured pen was also placed on the screen as feedback.

Prototype Game

The prototype game, intended for children, use a screen with a number of icons representing apples and coins that can be picked using the pen. The use of visual interaction through icons that represent real-world objects
such as apples and coins is used to give the objects and arithmetic activities meaning (Bricken 1992).

The goal of the game is to start with a certain number of apples and coins and end up with another specified number (decided by the experimenter) of apples or coins. To get from start to end the children have to buy and sell apples from each other. This means they will have to collaborate with at least one other child to get the correct amount of apples or coins.

Each of the handheld computers is marked by coloured stickers and the pens are different colours to keep them separated. There is one red, green, blue and yellow computer with a matching pen.

Hardware Architecture

Four Compaq iPAQ H3630 computers equipped with IEEE 802.11b wireless LAN cards were used for the prototype system. They were chosen because they offered the possibility of ad-hoc networking and were also sufficiently inexpensive. These handheld computers feature a 206 MHz Intel processor, 32 Mb RAM and a small colour screen (resolution 240×320 pixels). Customized RFID-readers (from IB technology, UK) were attached to the bottom of the PDA and connected to the serial port. Four pens were equipped with RFID-tags.

The original design by Rekimoto was based on Mitsubishi Amity palmtop pen computers and a large WACOM PL300 liquid crystal display as whiteboard (Rekimoto 1997). In the second experiments they used
PalmPilots and WACOM Meeting Staff whiteboard which can sense the existence and position of up to three untethered electromagnetic pens (Rekimoto 1998). The palmtop and whiteboard computers were connected by a spread spectrum wireless network.

Rekimoto’s Pick-and-Drop system was based on client/server technology where each pick and drop action resulted in communication with a server that kept track of what each pen contained. This prototype system instead uses a wireless LAN operating in ad-hoc mode. This mode allows for direct peer-to-peer communication between the PDAs, without the need for central base station or fixed infrastructure.

Ad-hoc networks are wireless, mobile networks that can be set up anywhere and anytime, outside the Internet or another pre-existing network infrastructure. The technology relies on wireless communication such as the Bluetooth or IEEE 802.11 standards. It allows network communication within a room or up to 50 m distance depending on physical conditions, such as walls.

Figure 11. Wireless network modes, Ad-hoc versus Infrastructure

Peer-to-peer is a communications model in which each party communicates at the same level and anyone can initiate the communication (this can be applied to both humans and computers). The model stands in contrast to the Client/Server model, which uses hierarchy and more strict rules for the communication.
Rekimoto's system used an electromagnetic pen that could be positioned-tracked in space. The system could sense three pens simultaneously, but they really only used one pen with three different identifier buttons on it.

The prototype of this study uses passive RFID (Radio Frequency Identification) technology to identify what pen is using the handheld computer. Instead of sensing electromagnetism and the position of a pen that was the case for Rekimoto, this system uses small RFID-tags to identify the pens. These tags, which contain a unique code, can be read by an RFID-reader from a short distance (approximately 10 centimetres) without contact or line-of-sight. The tags operate through induction power created by the RFID-reader and do not require any battery.

Each RFID-tagged stylus has a unique identification number that lets us keep track of which stylus is working with the interface on each PDA. The small cylinder shaped RFID-tags were glued into standard coloured plastic pens after the ink-tube had been removed. The pen was thicker than the normal stylus and had a better grip as the pilot study had indicated this would be a better choice. Unlike Rekimoto's system this radio based prototype system doesn't allow sensing the spatial position of the pen outside the screen, just the presence.
The small RFID-reader and RS232 communication unit was mounted in a cradle (a modified iPAQ tabletop cradle) and connected to the iPAQ serial communication port. The unit required one standard 9V battery and voltage regulation to 5V to work properly.

The RFID antenna coil was placed on the front of the cradle next to the bottom of the screen. The prototype has a miniature antenna coil that can only read the RFID-tag at a close distance of a few centimetres, which does not cover the whole screen (as was planned originally). There are ways for the tag to be recognized over the entire screen area, using a different antenna coil shape and placement, as well as better fine-tuning and impedance matching.

Placed on the cradle there are two LEDs that indicate when the RFID-reader sense an RFID-tag (green LED) and when there is power to the unit (red LED).

Software Architecture

The actual Pick-and-Drop interface on the PDAs was programmed using Microsoft embedded Visual Basic v3.0 (eVB) together with a demo version of devSofts IP*Works ActiveX v4 software. The operating system on the handheld computers was Microsoft PocketPC.

The prototype was implemented somewhat differently compared to Rekimoto’s solution which was programmed in Java and used client/server technology. In the present prototype I use peer-to-peer communication instead of client/server. This technique makes it easier to realise on-the-spot communication in real world settings without infrastructure backing up the system.
To confirm when an object has been picked and dropped onto another (or the same) handheld computer, communication via the standard UDP networking protocol is used. The IP*Works software mentioned earlier is used here because eVB didn’t support UDP. With this peer-to-peer solution one can add as many handhelds as one wants to the system. During picking and dropping the status of each stylus is broadcasted to the network. For example, if the red pen picks up an apple all the computers will know that the red pen contains an apple until it is dropped. The table below shows an example of the information each computer has about the pens to make out whether a local/remote and pick/drop was executed.

<table>
<thead>
<tr>
<th>PenID</th>
<th>Stored</th>
<th>StoredBefore</th>
<th>From (Computer name)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Apple</td>
<td>Apple2</td>
<td>Midnight</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Coin2</td>
<td></td>
<td>Scarpine</td>
</tr>
<tr>
<td>4</td>
<td>Apple</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Status of pens broadcasted among computers

The prototype screen (below) shows a maximum of eight apples and eight golden coins as well as two counters of how many apples and coins there are. To provide feedback on what pen that is currently using the screen a coloured pen image is showed in the right-hand corner of the screen. It shifts from red, green, blue or yellow colour depending on what pen the RFID-reader has identified. To start out with, the pen image on screen is the same colour as the colour stickers attached to the computer.

Figure 15. Screen design
The objects are picked or dropped when the pen touches the screen. The picked object remains on screen, but in faded colours, until it is dropped (figure below). This is to illustrate that the object is not available for another pick while the pen is virtually holding the object. If someone else is trying to pick an object that is already picked but not dropped, a sound is given. When the object has been dropped it disappears from its old location and appears in normal colours at the new location.

Figure 16. Pick-and-Drop action of prototype system, icons are colour-faded when picked

Four different sounds are used to give feedback for the events of picking, dropping, object not available, and screen full. Audio feedback is used to support the users’ need to focus attention on other things after picking up an object.

To perform a drop means to drop the object on some free spot on the screen, or the same spot it was picked from. A message that the object has been dropped is then broadcasted to all computers. The object then disappears from the old screen and appears on the new screen where it has been dropped. This implementation supports almost concurrent picking and dropping, so that several users can Pick-and-Drop objects simultaneously. According to Inkpen (1997) collaboration that requires turn taking can hinder effective computer-supported collaboration.

Apart from the screen interface, two buttons just below the screen on the handheld computer were also programmed with functions. One “apple button” tells the user how many apples there are on the screen using a sampled voice like “You have five apples”. There is also a “coin button” with similar function. These functions are thought of as additional feedback from the interface if the children want to use it. In total there are three ways to count the number of apples and coins on the screen; either count the visible objects, read the counters or hear the computer tell you in a sampled voice.

Rekimoto implemented the Pick-and-Drop interaction somewhat differently due to his ability to use a position sensing system on the pen. The pen first has to get in contact with the screen and then the object can be lifted (and
remains on screen while the pen is close). When the pen has moved some distance away from the screen the object disappears.

Figure 17. Pick-and-Drop action of Rekimoto’s system adopted from (Rekimoto 1997)

There is no feedback of what is currently “in” the pen so the user has to drop the object to see what was picked. As a comparison the prototype of this study leaves the object visible on screen in faded colours to support the user’s memory.
Chapter 4 – Empirical Study & Methodology

This chapter presents the pilot study and main study along with data collection and analysis methodology. A pilot study was performed in the early stages of the design process and interface programming. The goal was to confirm that young children around the age of 6 could handle the handheld computers properly. Later on when the complete pick-and-drop interface had been completed a main study was performed.

Data was collected through field notes, video filming and asking questions. The children’s responses were then transcribed and analysed together with the video film using qualitative methods.

Pilot Study

In the pilot study three children were tested for their ability to handle a handheld computer. The subjects were two 6-year-old children (a boy and a girl) and one 3-year-old boy. The test took place in their home and they were tested for about an hour for their ability to handle an iPAQ computer and stylus.

An early prototype of the pick-and-drop game with apples and pears was used to see if the children could pick and drop small icon objects on the screen. Also a more advanced game was tested along with a drawing program too see if they could handle the stylus with enough precision and follow verbal instructions.

The two older children had no problems following instructions and using the device without previous knowledge. I was convinced that later on other children at this age would be able to pick and drop icons that were used in the game. The three-year-old boy could draw on the screen and tried to play games, but often lacked in precise motor skills required to use the stylus effectively. He also had problems keeping his fingers away from the screen when he noticed it was touch-sensitive, despite instructions not to use his fingers.
A minor concern was that the children could be a little rough with the handheld computers, for example press the stylus on the screen a bit too hard when things did not go their way. Also it’s sometimes hard for younger children to hold the computer without touching the edge of the screen with their gripping thumb. I had to show them the proper way to hold the computer a couple of times.

Nevertheless all three children were enthusiastic when using the small computer and amazed that they could draw on the screen. They all thought the computer was great fun! The standard stylus worked fine for the older children although it wouldn’t have hurt if it was a little bit thicker for them to get a better grip.

**Main Study**
The main study took place at the after-school recreational centre Alfen in Gothenburg. Three groups of children were taught the Pick-and-Drop interface and then played a buy and sell game using the handheld computers. The whole study took about an hour and was video filmed for later analysis.

**Subjects**
The subjects were children 6 years old with the exception of a girl and a boy who were 7 (in group 1 and group 3 respectively). The children had no earlier hands-on experience from handheld computers although one or two of them had seen adults use such computers.

<table>
<thead>
<tr>
<th>Group</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3. Groups in the experiment

The subjects were selected arbitrarily from the after-school recreational centre Alfen by their teacher. All children who had got their parents written consensus (the teacher had asked parents to sign a paper from me) were participating in the study.

The first group consisted of four children while the next two groups had to be restricted to three children as one of the handheld computers failed to work properly. The groups were mixed with boys and girls for sake of validity.
Equipment

Four customized iPAQ computers and styluses were used. Each computer had been colour-coded with stickers so that the computer and stylus belonging to that computer had the same colour (red, green, blue or yellow).

Figure 19. Four customized iPAQ computers and their coloured styluses

The video capturing of the study was filmed by my assistant using a standard JVC camcorder. The batteries of all equipment had been charged fully to prevent any loss of power during the testing.

The customized iPAQ handheld computers used in the main study were designed as shown in the figure below (real size is about 10x20 cm).

Figure 20. Final prototype design that was used in the main study
Tasks
The subjects’ first task was to learn the Pick-and-Drop interaction so everyone could pick and drop objects to remote screens successfully. This learning took place under my guidance. The second task was to play a simple game of buying and selling apples using golden-coins, both represented as icons on the screen. In the buy & sell game my expectations were that the children could do without much help.

Procedure
The tests took place in a spacious playroom at the children's recreation centre where we could prepare the iPAQs and video camera undisturbed before letting the first group of children in. The room was quiet and group activities were normally located here. After preparing the equipment we let a group of children enter and I introduced the computers while the children sat comfortably in a sofa.

The session took place at a low table where the children could use the handheld computers on the table, minimizing the risk of dropping one to the floor and breaking it.

The children first learned about the interface and then most of the time was spent on learning the Pick-and-Drop interaction. When I saw all children could perform a pick and drop to another computer the next task was presented.

The game was presented as buying and selling apples using the golden coins. One apple would cost one coin. The last couple of minutes in each session we played the game during which the children could ask me for advice.

Figure 21. First group before testing and third group of children playing the game
After this procedure was complete, the children had to sit in the sofa again and were asked questions about their experience. The computers had to be restarted for the next group to begin.

Data Collection and Analysis
The focus of the study was to get an understanding of the difficulties of using Pick-and-Drop in a collaborative situation. This was done through qualitative analysis methods.

Qualitative data can be used to supplement, validate, explain, illuminate, or re-interpret quantitative data (Miles & Huberman 1994).

Due to the fact that I would guide the children through the test and help them out it would not have been possible to base the study only on my observations made there. I was much too busy to write down but a few field notes during the test. Instead the whole test was video filmed for later analysis.

Verbal and non-verbal communications were analyzed from the video using Microsoft Movie Makes software. The dialogues from the video were also transcribed (see Appendix B). A multiple-pass procedure was used to minimize the number of events missed due to pausing and rewinding the video.

An attempt to use quantitative data collected through log files was made. The log files recorded the Pick-and-Drop activities on each computer, but unfortunately the log file recordings only worked partially in the real experiments due to a program malfunction. Only two computers logged properly, but only for the first session. Therefore data from these log files will not be used in the analysis.

Video as Data
A problem in using video as data is that the researcher has to rely on a reconstruction of an event. However, this can be a problem with direct observations as well because human memory reconstructs data in a continuing process (Neisser 1994).

Advantages in using video as compared to field notes are for example that video recordings replace the bias of the researcher with the bias of the machine (Jordan & Hendersson 1995).
Chapter 5 – Results & Discussion

This chapter presents the results of the main study and relates them to the research aim stated in the introduction of this study. Each result is followed by a short discussion and then the methodological approach as a whole is discussed. The conclusions sum-up the most important theoretical and practical findings in this study and finally prospective future work is mentioned.

Analysis of Results

The original goal was to build a prototype that could be used to teach children arithmetic. The idea was that children would learn arithmetic in collaboration with other peers using the handheld computers and some educational software. The goal shifted somewhat away from learning arithmetic due to difficulties in the development phase and a more realistic goal to evaluate collaboration and use of the interface was taken.

Generally the study went well and the children mastered the Pick-and-Drop interaction technique in under a minute. The children were able to collaborate, mostly two-and-two but sometimes involving three children in the game of buying and selling apples. However, there are some particular problems with the interface that can be improved.

Learning and Using the Interface

All children succeeded in learning the Pick-and-Drop interaction technique very quickly. They were told that using a pen they could pick and drop apples on their screen, and within seconds everyone had got the hang of picking and dropping on their own screen. The next step was to do a remote pick and drop. It required a bit more attention from the children before they understood they had to change the colour of the pen on screen first. After a couple of tries everyone was able to do remote pick-and-drop as well.

![Figure 22. Remote Pick-and-Drop in action (time elapsed 1 second)](image)

Illes et al. (2002) noticed some general disruptions in usage of their handheld wireless system for collaboration. There were slow responses to
stylus inputs and server lag, also users had problems switching between verbal conversations and the interface. I could not find these particular disruptions in use for the Pick-and-Drop interface, but some other problems.

There were some minor problems for the children when picking and dropping objects. For example, they did sometimes not realize that they had already picked an object and tried to pick another while the pen was “full”. This is probably due to lack of appreciation of the visual and audio feedback that is given when an object is picked or dropped. They did not seem to fully comprehend or take notice of these things when they worked in groups. When they tried the interface on one individual screen they stood a better chance to notice the feedback (i.e. one of the girls held the computer to her ear to better hear what it said).

This situation could perhaps be improved by making the feedback more visible as a lot of information in a group situation focus on the group, not the interface. This is in line with the goal of the interaction, but the users should also know when the pen is full and when it’s free to pick up something new. A light indication (LED) on the pen when it contains something might prove helpful to solve this problem.

It seems that capturing the children’s attention is harder when they are doing a group activity as it is hard to distinguish which computer some audio feedback originates from. Maybe personalised sounds (like people have personalised ring-signals on their mobile phones) would achieve better recognition and attention.

The children did not get the idea fully that they had to change the colour of the pen on the screen in order to pick something properly from someone else. They seemed to grasp the Pick-and-Drop metaphor very quickly, but the extra movements necessary because of technical flaws in the antenna system (so the pen had to be moved outside the screen area to be recognised) caused trouble. In a better implementation of Pick-and-Drop this problem would most likely disappear.

Some children thought the RF antenna that was used to change the pen colour was a button to press. So on a couple of occasions some of the children tried to press the antenna down with the pen. Unfortunately this resulted in one malfunctioning system, as the antenna lost contact with the rest of the electronic circuits. This didn’t cause the computer to crash but the possibility to move objects the screen to other computers became very limited. One solution to this was to use this pen colour on all computers but then no overlapping pick-and-drops would be possible for several users. The problem of pressing the antenna like a button was perhaps my own fault of
not giving good enough instructions on how to use the system. Anyway it was a design flaw because the affordances of the antenna made it similar to a button.

Some children seemed to want to drag the objects on screen while keeping the stylus in touch with it, like drag-and-drop movements on desktop computer. This could be seen as a normal action if the child has come in contact with standard drag-and-drop user interfaces such as Microsoft Windows. It also points out that it would have been a good feature to have local drag-and-drop on the handheld computers as it wouldn’t interfere with the Pick-and-Drop action when working with more computers. Drag-and-drop could have been implemented in the software by using a timeout to see if a pen still touched the screen (but the screen can only sense one touch at a time).

Collaborative Interaction Styles

Children working together often use a variety of collaboration styles (Scott et al. 2002). On standard computers users are restricted by the interaction technology (e.g., only one mouse and one keyboard). In the case of Pick-and-Drop the technology supports simultaneous multi-user interaction. When children are provided with this additional resource the potential flexibility of their collaboration process can be increased.

The game prototype worked well as far as concerning the actions of buying and selling apples using golden coins on the screen. However it was not possible to keep the overall collaboration goal presented in the implementation chapter, instead the children bought and sold apples of their own will and head. The goal that different children should end up with a certain amount of apples or coins could possible not be kept due to a lack of ability to focus and pay attention. But nevertheless collaboration could be studied without the aim for a certain amount of apples. In the third group, the children managed to successfully pick-and-drop apples towards a common goal of reaching four apples each.

Like in earlier studies by Inkpen (1997) and Stanton et al. (2002) where children use multiple mice, turn taking was the prevalent interaction style for Pick-and-Drop also. The children used the interface in pairs most of the time and it might be the most natural interaction between two persons to take turns. This is the simplest interaction style that allows the children to evaluate their partner before doing their next move. This can be seen in the figure below where user A first picks and drops something and then user B do the same, each waiting for their turn.
On occasions concurrent (as simultaneously as the technology permitted) Pick-and-Drops between two children were seen; they picked objects from each other almost simultaneously. Using this method they didn’t have control of what happened to their own screen while picking on someone else’s.

![Turn taking Pick-and-Drop vs. Concurrent Pick-and-Drop between user A and B](image)

The game of buying and selling apples using golden coins resulted in a general interaction pattern of giving objects to each other. First the child would proclaim a transaction like “I will buy an apple from Axel”. Then they give something from their screen to the specified person. After that they expected to get something in return.

Although all interactions started as turn taking in the study, more advanced interaction styles to make multiple picks and drops was encountered as the test progressed.

When there was interaction between more than two children some interaction allowed better control of the screen. For example on some occasions two children could start dropping objects onto another screen (Concurrent Pick-and-Drop TO someone). The owner of the middle screen (user B in the figure) had good control when others gave away objects as he kept focus on his own screen.

![Multiple concurrent Pick-and-Drop](image)

It also happened that two children started picking objects from a third person (Concurrent Pick-and-Drop FROM someone). Instead of giving objects they were taking them and the third person had a hard time controlling which objects were taken. This was probably because the unlucky third person tried to focus on the other screens as well to see what was happening, which became too difficult. They had to protect their screen physically so no one could “steal” their objects as they called it.
The notion of giving or taking objects is interesting because it started different reactions in the children. The children seemed happier when someone gave them an object than if someone took something from them. Maybe this was because taking objects wasn’t part of the game interaction and negotiating. It was more an act of mischief, trying to “steal” apples or golden coins to their own screen.

A study by Inkpen et al. (1995) noticed gender differences in giving or taking control of the interface in multi mice collaboration. Boys took control more often and girls gave away control more often. I haven’t investigated gender differences here but noticed that it was three boys who said they had “stolen” some apples or coins from someone else’s screen.

The reason why the children formed groups of two was perhaps natural when there were not more than three or four users. Involving more than two persons might be seen as increased complexity of the task.

Control of Actions

Visual focus seems to play a role in users’ awareness of each other’s actions. The distance between the handheld computer screens demands visual focus to be further away from their own displays. The children seemed to comprehend what one other user had on their screen at the same time as they knew what was on their own screen. To lose attention of the screen was to risk that apples and coins would be taken from it. The reason for losing attention of the interface is probably an inability to keep up with the fast paced environment of face-to-face group collaboration (Iles et al. 2002). In the present study this could be seen where children were able to “steal” apples and coins from other screens while that user had her attention focused elsewhere. This action could be seen more often when multiple users interacted as compared to two children interacting. An explanation to this is probably that it was easier to keep control and see what the others did when there were only two users involved.
This highlights the problem of shared attention of smaller screens that may be problematic when compared to a single-display or negotiating control of a single mouse (Roschelle & Pea 2002). Perhaps this is also a consequence of the computers all being on the same table. Walking around with the handheld computer would have made it harder for someone to pick something they shouldn’t.

Another interesting feature of collaboration using Pick-and-Drop is that reversible actions are easy. When an object has been picked up the user still has time to think first before dropping the object. If the user changes his mind and wants to keep the object he just drops the object back on the private screen. Even when an object has been dropped to another screen it can quite easily be taken back, undoing the action. Examples of this could be seen in the study. This feature where an object could be kept in the pen was also used to mix turn taking and concurrent interaction. One user didn’t have to finish a pick and drop before another user could begin his actions. This allowed efficient but controlled interaction.

In earlier studies regarding collaboration using handheld computers a problem of switching focus between the act of using an application and the act of sharing data have been recognised (Inkpen et al. 2000, Iles et al. 2002). I could not identify this problem in this study, maybe because Pick-and-Drop uses the same interaction technique both for the local screen and for sharing data. This supports the argument that Pick-and-Drop offers natural and seamless interaction in a collaborative setting.

Learning Arithmetic
Although learning arithmetic was planned as a part of the game this only worked out to a lesser extent. The children all knew how to count to ten and were able to keep track of the objects on the screen. Most children counted the visible objects on screen by pointing a finger towards the objects and counted aloud. Some used the buttons instead to let the computer tell them how many apples or coins they had. It was easier that way they proclaimed. No one used the counter digits visible on-screen before I explained their purpose, and not even then.

The children seemed too young to learn arithmetic while using this new interaction technique. Everyone enjoyed to buy and sell apples through picking and dropping but didn’t pay much attention to common collaborative goals that I suggested. The third group managed to pick and drop objects reaching a common goal of four apples each though.
I believe all the children in the study had reached what Piaget referred to as the concrete operational stage, as they could negotiate and buy and sell correctly. They understood the meaning of adding or subtracting objects but could not add or subtract numbers yet.

Communication
When people view shared objects in the real world, an individual has an understanding of both where the object is and where their partner is in relation to themselves. This can provide an implicit understanding of how their partner views the object, potentially leading to a better shared understanding of the workspace (Scott et al. 2002). In this study the Pick-and-Drop interaction allow digital objects to be contained in the physical form of a pen. The actual object cannot be seen so users have to talk about what their pen contains.

The results of this study show that users use verbal communication to negotiate and direct the interaction in sentences like “and then you should give me an apple” or “now I will buy from you”.

Non-verbal Interactions
The impact of Pick-and-Drop interaction on the children’s non-verbal interactions with each other is important to understand. In the physical world our interpersonal non-verbal interactions are refined and play an important part when collaborating face-to-face. How a computer environment enhance or decrease these interactions will impact its effectiveness as a collaborative tool.

Video analysis showed that the children looked at their partner and used gestures when they wanted to share feelings or to do something about the interaction. When users tried to stop someone from taking objects from their screen they used physical gestures covering the screen or putting away the other user’s hand.

Methodological Discussion
When experimenting with children it is important that they first have the opportunity to familiarize themselves with the materials. Otherwise they will have a hard time receiving instructions on what to do (Furness 1998). This was considered an important part of the study as none of the users had used handheld computer or Pick-and-Drop before.

I’m satisfied in using a game for the study as this conflict solving invites different interaction to take place in a joyful environment. Play can actually be seen as children’s equivalence to scientific experimenting (Doverborg & Pramling 1999). It also seems that a handheld computer interface lends itself
to many different feedback techniques that could be used in learning situations. For example when the children had to count the number of apples and coins they could count visible objects on screen, let the computer tell them in a sampled voice or check the digits at the bottom the screen. Most of the children pointed their fingers to the screen and counted visible objects while some understood the use of the buttons to let the computer tell them. The children didn’t make use of the digits at the bottom of the screen, probably because most of them were too young to understand their significance.

Validity & Reliability
When collecting data, two important questions must be answered. First, do we measure the right thing (validity) at all? And secondly, do we measure it in a reliable way (reliability). In case we use quantitative data it is often easy to decide on validity and reliability, but in the present case using qualitative data, it is more difficult to decide these factors due to different biases.

A bias that I brought to this research was my interest and belief in Pick-and-Drop for collaborative situations. Although this bias was positive I found evidence for Pick-and-Drop in theories before I began the study.

Using children in the study can make it hard to know if questions asked are answered truly. Sometimes children think the researcher expects a “correct” answer and answer accordingly. To avoid this I tried to be careful of what and how I asked questions. For example it’s probably better to ask non-subjective questions like “how do you think it works?” instead of suggesting anything like “it works like that maybe?”

The results from the study should apply to adults also when it comes to collaborative styles of interaction, control of actions and focus of attention. I believe that if the children were able to make good use of the interaction technique, adults should be able to do even better. It might be that adults are too indoctrinated in using standard GUIs though. In that case the consistency gap between such standard interaction and Pick-and-Drop could make children without previous experiences better users. But as Pick-and-Drop is an extension of the familiar drag-and-drop method I doubt it.

Although good validity can be reached through the video analysis it would have been even better if qualitative analysis were complemented with quantitative log files. It is difficult to track several users’ actions on video and would have been easier to track using complementary data files on the pick-and-drops made.
The study accomplished to test Pick-and-Drop, no doubt about it. However, better reliability could perhaps be gained if not the extra procedure of changing pen colour had to be taken (it should be sensed automatically over the whole screen). On the other hand, the children had to work with a Pick-and-Drop interface that wasn’t perfect and still managed to learn and use it very well. The technology in itself was also a bit too vulnerable for use by children at this age. As a consequence of someone pressing too hard on the RF-antenna one of the computers failed to work properly for remote Pick-and-Drop.

Technical Improvements
There are several technical improvements that can be made to this prototype system. First of all the prototype was too vulnerable physically. An improved system would not have crucial hardware parts (like RF antenna, battery) visible; instead everything should be put inside the handheld computer.

The RF antennas made testing real Pick-and-Drop more difficult, as the pen had to be so close to the antenna to be recognized. The original idea was that the antenna would recognize the pen anywhere on the screen. It is possible that with a lot more time for calibration this would be feasible.

The pen hardware worked excellent but as mentioned earlier there was a problem of knowing when the pen holds something. This could be improved by some technology in the pen (e.g. a light emitting diode) that gives feedback when information has been picked. A different technique than RFID would probably have to be used to solve this.

Future Research
In future work it would be interesting to test the interaction on a larger number of PDAs to see effects on larger groups of people collaborating. Usability testing and collaboration effects could be investigated with this Pick-and-Drop system in different environments and using a variety of applications. Also, it’s interesting to study different kinds of selection and feedback methods for picking and dropping as audio feedback didn’t work out too well.

For example, I would like to try to confirm a study regarding the easiest selection method using pen interaction. According to Ren & Moriya (2000), the easiest strategy is “Slide Touch”, where selection can be made either with a direct tap on the object or sliding into the object. Perhaps it would also be possible to implement gesture recognition for the pen interface. For example a gesture of shaking the pen could mean to get rid of the information in the pen.
When it comes to the choice of users it would be interesting to let older children try the game and see how they manage to collaborate. Some indications from this study show that the system would be better suited for older children. Also a comparative study between mouse use and Pick-and-Drop might get interesting results on what advantages the interaction techniques can achieve in different settings.

The results of this Pick-and-Drop prototype system has led me to believe that Pick-and-Drop is a good way of making collaboration using handhelds better and I expect to see more work in this area when wireless technologies like Bluetooth and IEEE 802.11 are making their way into more handheld and mobile devices.

Conclusions

In this master's thesis I have studied the Pick-and-Drop interaction technique in a real-world setting. Children collaborated successfully using the handheld computers and some interesting results were found. The findings support the idea that Pick-and-Drop interaction can improve synchronous face-to-face collaboration.

The first research question was:

1. Does the Pick-and-Drop interaction technique let users focus more on other people and the task at hand than on the interaction itself without losing control of the interaction?

It does not seem that users focus more on other users than on the interface when using Pick-and-Drop. However, they seem to be able to focus more on the task at hand. This is probably because Pick-and-Drop offers seamless interactions were no special distinction is made between private interaction and collaborative interaction. The act of using an application becomes the same as sharing data in an intuitive way.

Users have the interaction under control as long as they don’t have to focus on more than two screens at a time, their own and their partners. When multiple users are involved they rely on the notion of “giving” information to prevent losing control over the interaction.

When more than two users are “taking” information from a third user simultaneously he often loses control over the interaction. The third user can prevent this by physically covering the screen or walk away and not let anyone else access it.
The second research question was:

2. Can learning and collaborative situations benefit from the Pick-and-Drop interface, and if so in what way?

Face-to-face collaborative situations can benefit from Pick-and-Drop in that it allows efficient “giving” of information among several users. Using a standard PC for collaboration cannot accomplish this because it has to rely on a single mouse and turn taking to share information. Using handheld computers and infrared beaming to share information it is possible to “give” information. However, this solution does not solve this effectively because each user has to be beamed in turn.

Collaborative situations can benefit from Pick-and-Drop because it solves the problem of waiting for a turn by allowing a mix of turn taking and concurrent behaviour to create efficient interaction. Multiple users can share information almost simultaneously and they keep in control by focusing visually on those who are sharing. Using a standard GUI to share information would not allow this visibility of interaction.
References


Appendix A – Questions
This is a summary of the instructions and explaining made to the children as well as the questions asked (all in Swedish).

Presentation


*** Videofilma härifrån

Frågor

Men först skulle jag vilja veta vad ni heter och hur gamla ni är?

<table>
<thead>
<tr>
<th>Namn</th>
<th>Ålder</th>
</tr>
</thead>
<tbody>
<tr>
<td>__________</td>
<td>___</td>
</tr>
<tr>
<td>__________</td>
<td>___</td>
</tr>
<tr>
<td>__________</td>
<td>___</td>
</tr>
</tbody>
</table>

Vilka färger är det här? Röd, Grön, Blå, Gul

Kan ni räkna till 10? Vi provar tillsammans en gång! 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Har ni provat såna här datorer förut?

*** Dela ut handdatorerna

Hur många äpplen har ni på skärmen?

Hur många guldmynt har ni på skärmen?

(äldre barn - kolla addition) Hur många äpplen har ni tillsammans?

*** Visa man kan trycka på en knapp för att höra hur många äpplen/guldmynt man har
*** Dela ut pennorna och visa hur man kan plocka saker från skärmarna

Barnen får prova att plocka saker från skärmarna några minuter.

Nu ska vi spela ett spel med äpplen och guldmynt.

Samla in och resetta datorerna

*** Presentera spelet

Ni har olika många äpplen och guldmynt på skärmen. Vi ska spela ett spel där ni får köpa och sälja äpplen av varandra.

Ni som har fem äpplen ska sälja två äpplen till de som bara har tre äpplen. Ett äpple kostar ett guldmynt.

Ska vi prova?

Frågor efter

Var det svårt?

Vad var det som var svårt?

Att använda pennan?

Att använda datorn?

Hålla i datorn?

Att veta hur många äpplen man hade?

Kan ni läsa skrivna siffror?
### Appendix B – Transcripts

These are the transcripts (in Swedish) of 48 minutes of video filming from the after-school recreation centre Alfen. Each group was filmed for approximately 16 minutes. Merged columns for the children means they answered unanimously.

#### Group 1

<table>
<thead>
<tr>
<th>1</th>
<th>Interviewer</th>
<th>Child 1 - Axel</th>
<th>Child 2 - Joel</th>
<th>Child 3 - Josefina</th>
<th>Child 4 - Johan</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Kan ni räkna till tio? Vi provar att göra det tillsammans.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ett, två, tre, fyra, fem, sex, sju, åtta, nio, tio</td>
<td>Ett, två, tre, fyra, fem, sex, sju, åtta, nio, tio</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Jag tror ni kan det. Hur många pennor är det här, kan ni se det? Ett, två, tre, fyra, fyra pennor.</td>
<td>Fyra</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Har ni sett såna här datorer förr eller provat såna?</td>
<td>Nå</td>
<td>Viika tuffa datorer!</td>
<td>Tufft!</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Ja man får vara försiktig med dom. Dom är ganska dyra.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Om ni tittar på skärmen här så finns det äpplen och det finns guldmynnt på skärmen. Och så finns det en penna där nere.</td>
<td>Mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Hur många äpplen har ni på skärmen?</td>
<td>Tre</td>
<td>Jag har sex</td>
<td>En, två,...</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>När man trycker på skärmen så plockar man saker från skärmen.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Tryck inte på skärmen än. Bara räkna hur många äpplen ni har på skärmen.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Du hade? [indikerar Josefina]</td>
<td>Fem</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Fem stycken äpplen. Och du hade också fem stycken äpplen? [indikerar Joel]</td>
<td>Tre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Du hade? [indikerar Axel]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Och du hade? [indikerar Axel]</td>
<td>Tre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Då tänkte jag visa, man kan höra hur många äpplen man har genom att trycka på den här knappen.</td>
<td>[testar]</td>
<td>[testar]</td>
<td>Då ska jag testa! [testar]</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Och så kan man höra hur många guldmynnt man har med den där andra knappen.</td>
<td>[testar] och berättar hur många guldmynnt de har</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Då ska ni få varsin penna i samma färg som datorn. Så kan man plocka saker från skärmen med den här pennan. Om ni prövar att plocka ett guldmynnt. Tryck på ett guldmynnt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Funkar inte</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
plockat en sak. Så, nu kan du prova.

1 Fungerar det för er?
   Nå inte jag iallfall.

2 Och så kan man släppa myntet på ett annat ställe.
   Nu!

3 Fungerar det nu?
   Ja!


5 Får ni det att fungera att plocka och släppa?
   Nej jag kan inte det.

6 Där har du redan plockat ett, så måste du släppa där det är ljus. Där det är vitt närstans.
   Jag gjorde det men det funkar inte.

7 Ska du prova igen.

8 Ni får vara försiktiga mot skärmen. Man trycker lite lätt. Man får släppa det närstans där det är fri yta, där det är vitt.

   [följer instruktioner]

10 Börjar det fungera och plocka litegrann?
   Ja

11 Va bra! Då ska vi spela det här lilla spelet tänkte jag.
   Hur gör man där?
   Jag vill. Jag vill.

12 Ska du prova igen.

13 Man måste hålla nere så det Blinkar till grön här.
   Fröken det hände ingenting.

14 Hon fick en gul penna!

15 Ta det lite lugnt nu.
   [skrattar]

16 Så börja med att trycka på pennan och släppa där det är vitt.
   [ändrar penfärg hos Josefina]

17 Så kan du ta tillbaks så blir det blå.

18 Man måste hålla nere så det Blinkar till grön här.
   Hon fick en gul penna!

19 Ta det lite lugnt nu.
   [skrattar]

20 Så börja med att trycka på pennan och släppa där det är vitt.
   [ändrar penfärg hos Josefina]

21 Så kan du ta tillbaks så blir det blå.

22 Man måste hålla nere så det Blinkar till grön här.
   Hon fick en gul penna!

23 Ta det lite lugnt nu.
   [skrattar]

24 Så börja med att trycka på pennan och släppa där det är vitt.
   [ändrar penfärg hos Josefina]

25 Så kan du ta tillbaks så blir det blå.

26 Man måste hålla nere så det Blinkar till grön här.
   Hon fick en gul penna!

27 Ta det lite lugnt nu.
   [skrattar]

28 Så börja med att trycka på pennan och släppa där det är vitt.
   [ändrar penfärg hos Josefina]

29 Så kan du ta tillbaks så blir det blå.
Hallå allihop, nu vill jag veta hur många äpplen ni har. Nu vill jag veta hur många äpplen var och en av er har.

(Datorns kommunikation går inte längre)

Den den kan inte få äpplen, den funkar inte att plocka ifrån.

Den funkar ju inte!

Ok du har fem äpplen.

Tre har jag

Jag räknade inte jag tryckte på den här

Den kan inte få äpplen, den funkar inte att plocka ifrån.

Nej men så här är det. Hallå lyssnar du på mig? Joel?


Ska vi prova?

Joel heter jag.

Ska du köpa ett äpple av Joel?


Sen släpper du på hennes skärm

Haha det vill jag göra!

Ja jag får köpa av dig [joel]

Och så måste du göra pennan gul där.

Då måste du först göra pennan grön.

Ska vi prova om att du också får prova [johan] Ska vi prova om den fungerar nu.

Ja jag får köpa av dig [joel]

Då måste du ge mig ett äpple [pratar med axel]

Ja vi bara köper tills vi

Ja jag fick ett äpple!

Ja jag fick en grej här på!
<p>| 1 | får slutför att på pengar! | 6 | Jo, då måste ju du köpa lite äpplen? [Joel] | Han har bara äpplen och jag har bara guldmynt! | Å jag vill bara ha guldmynt. |
| --- | --- | 2 | Men äpplen är väl godare! | 7 | Men vi vill ha det så här. |
| 3 | Ska ni prova och köpa av varandra då? [Josefina &amp; Johan] | 8 | Kom igen vi köper! | [datorns kommunikation fungerar inte] |
| 4 | Nej, vi får använda den röda pennan då. Om du (Johan) ger henne ett guldmynt. Ta ett guldmynt. | 9 | Nu ska du få ett äpple av mig [plockar till Axel] | [släpper guldmynt] |
| 5 | Så ger du till henne. | 10 | Ta det lugnt nu! | [plockar vidare] |
| 6 | | 11 | Ta det lugnt nu! | | [kolikar pennfärg] | Du kan få. | Vad händer om man trycker på de här? [omärkta knapparna] |
| 8 | | 13 | Så ska vi avsluta programmet nu. Om ni trycker på den knappen så kommer ett kryss där då kan ni trycka på den och avsluta det hela. Då får ni sätta ner igen så ska jag fråga er lite. | | | | |
| 9 | Vi avslutar det där nu. | 14 | Vi avslutar det där nu. | Hur gjorde du det där? | Hon filmar |
| 10 | Nu sätter ni er i soffan och lyssnar på mig. Det här med att plocka saker från skärmen, kändes inte det konstigt? Var försvann äpplet närstans? | | | | |
| 11 | När man plockar äpplet så finns det i pennan alltså? | | | | | ja |</p>
<table>
<thead>
<tr>
<th></th>
<th>Äpplet fastnade här, tror ni det?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Nej</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Vad tror ni hände då?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>[inget svar]</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Det var svårt att förklara va</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Äpplet åker in i pennan!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Hur var det att använda den här datorn, var den tung? Ni hade den på bordet. Det var lite svårt att bära på den och så?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Ja</td>
<td>Nej</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Var det svårt att veta hur många äpplen man hade?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Nehe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Nå det var bara och trycka på den här knappen.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Så fick man reda på det.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>[vill prova igen]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Nå nu har jag stängt av datorn.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Men det var så kul att ni vill prova senare kanske?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>ja</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sålå ni att det fanns siffror här nere på skärmen?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Nå jag får kolla!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Där nere fanns det ju. Det står men ni kanske inte kan läsa så bra?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>ja</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Kan ni se vad det står där?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Tre äpplen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Eller så kunde man trycka på knappen och höra.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>Jag kommer ihåg när jag inte hade några äpplen kvar så lät det inget!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Och fyra guldmynt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Transcript in Swedish for test group 1

**Group 2**

<table>
<thead>
<tr>
<th></th>
<th>Interviewer</th>
<th>Child 1 - Jesper</th>
<th>Child 2 - Anna</th>
<th>Child 3 - Karin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Har ni sett såna här smådatorer förut?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>ja</td>
<td>Nej</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Du har sett såna förut?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>ja min pappa har</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Nej. Ja man använder en sån penna på skärmen på dom här.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Jesper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Men först tänkte jag bara kolla vad ni heter för nät så jag kommer ihåg det. Vad heter du för nät?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Hur gammal är du?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Anna och jag är sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sex är. Och sen var det? Anna också sex.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td></td>
<td>Anna och jag är sex</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Och du heter?</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Karin och jag är också sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

56
<table>
<thead>
<tr>
<th>10</th>
<th>Bara sexåringar. Vad trevligt.</th>
<th>Fast dom går i förskolan och jag går i ettan, för jag börja ett år för tidigt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Ni kan sånt. Den är? Röd</td>
<td>Röd</td>
</tr>
<tr>
<td>14</td>
<td>Och den är?</td>
<td>Gul</td>
</tr>
<tr>
<td>15</td>
<td>Gul. Och den är?</td>
<td>Grön</td>
</tr>
<tr>
<td>16</td>
<td>Grön. Jättebra.</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Ja det kan du väl få.</td>
<td>Och jag vill ha den gula.</td>
</tr>
<tr>
<td>20</td>
<td>Oj då!</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Ska vi prova? Ett, två, tre, fyra, fem, sex, sju, åtta, nio, tio</td>
<td>Ett, två, tre, fyra, fem, sex, sju, åtta, nio, tio</td>
</tr>
<tr>
<td>23</td>
<td>Du ville ha gul ja. Så tar ni en pennan med rätt färg till er. Så.</td>
<td>Så om inte hade tagit rätt färg hade det inte fungerat då?</td>
</tr>
<tr>
<td>24</td>
<td>Jo det fungerar, men det är tänkt att det är den pennan som tillhör den gula. Om ni lägger datorn där så ska jag visa lite hur det fungerar. Det finns knappar här nere.</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Kan du räkna hur många äpplen du har? Du kollar om det stämmer, ja.</td>
<td>Fem</td>
</tr>
<tr>
<td>Lín</td>
<td>Text</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Där?</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Nej en bit ifrån.</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Ja</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Sen hör man ljud också när man släpper. Ja just ja den...</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Den är plockad så du måste släppa den. Man ser att den är lite ljusare så man måste släppa ner den. Aha</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Ja</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Din pennan är grön just nu.</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Och din är blå och din är gul.</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Men om du tar din pennan där nere. Om du för din pennan dit, till den där gula knappen. Gör det på hennes</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Och du arbetar med hennes. Sen kan du prova din blå. [skrattar] [provar att föra pennan till gröns knapp]</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Så den färgen på pennan här det är den som får arbeta med skärmnen.</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Så, ska vi prova om ni två först om du ska sälja ett äpple till henne. Då får du ge henne ett guldmynt först.</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Ja vi kollar det sen.</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Om du plockar ett guldmynt. Plocka ett guldmynt på.</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Nu måste du ge ett äpple tillbaks till henne, då får du göra pennan gul först. Mmm</td>
<td></td>
</tr>
</tbody>
</table>


52 Ska Jesper också få kolla in en gång nu. Du har ju massor av äpplen så du kan ju sälja ett äpple till Anna.  

53 Jaha men nu är det ju grönt.  


55 Så får du göra pennan blå där.  

56 Nu får du ge honom ett guldmynt. Men du måste göra grön först.  

57 Så nu är den grön.  


59 Ska du prova att köpa nu? [Jesper] Ja  

60 Så kan ju du köpa av honom? [Karin] Ja  

61 Allt på en gång, ska ni prova det? Mmm  


64 Så ska hon få ett guldmynt, så gör pennan blå först. Sen får du släppa den här näanstans.  

65 Hur många äpplen har ni nu? [släpper] Nu ska ni sälja till mig!  

66 Hur många äpplen har du? [plockar] Tre  

67 Hur många? Fem [räknar] En två tre fyra fem [räknar]  

68 Man kan ju trycka på den knappen också. [trycker på knappen]  


71 Så och så släpper du den någonstans på skärmen.  

72 Så får hon ge dig. Du måste göra pennan  

73 ...
| 74 | Så. Sen kan du gå till henne och göra gul. Så | [släpper] |
| 75 | Nu har du två guldmyn্ট i alla fall. [Anna] | Nu ska jag sälja ett till [lösar plocka] |
| 76 | Du måste göra till grön penna igen, det är lite jobbigt. Skär du till Jesper då? | Aha [plockar] |
| 77 | Då måste du göra grön penna först. | [släpper] |
| 78 | Så. Får hon ett guldmyn্ট av dig nu? | [plockar] |
| 80 | Så får du släppa den på skärmen. | [släpper] |
| 81 | Så! Nu börjar ni ju kunna det där. | Nu vill jag sälja till hon [Karin] |
| 82 | Skär du sälja ett äpple till henne? | [plockar och släpper] |
| 84 | Flera äpplen. Man kan göra så att skärmen blir full. | [plockar och släpper] |
| 85 | Ta det lite lugnt! Skär vi få ännu mer äpplen. Om man kommer upp i åtta så säger datorn nånting. | Haha [skärmen blir full] Du har åtta äpplen. [plockar och släpper] |
| 86 | Får inte plats med mer äpplen den då, då är det åtta äpplen. | Nu ska du |
| 87 | Ja det fungerar ju! | [plockar och släpper] |
| 88 | Gör hon nått nu? Du får ge mig ett guldmyn্ট1 | [plockar och släpper] |
| 89 | Fungerar den inte? Jo nu.. | [plockar och släpper] |
| 91 | Tycker du det var svårt det här? [Jesper] | Nej [plockar] |
| 92 | Nej först jag, nu måste du ta! Nu får du göra min blå. | Tack! Så nu får jag göra [plockar och släpper] |
| 93 | Var det roligt? Så sätt er i soffan. Var det kul? | Ja | Det var ju roligt det dära! | Ja |
| 94 | Tyckte ni verkligen det? Var det inte svårt? | Ja Nää |
| 95 | Så ni säger inte bara så för att jag sitter här? | Det var roligare när vi fick prova på själva. |
| 96 | Jaja ni ville bara plocka äpplen som ni vill. Är det roligare? | ja |
| 97 | Men man kanske kan lära sig o räkna genom att titta på skämen och köpa och sälja äpplen | ja |
| 99 | Men ni var ju bara tre så det räckte ju med tre datorer. | ja |
| 100 | Ni höll inte datorerna. De kanske var ganska tunga fast egentligen ska man kunna hålla dom i handen. | [reser sig och lyfter en dator] [reser sig och lyfter en dator] Får jag pröva! [reser sig och lyfter en dator] |
| 101 | Är den inte tung? | Den var inte tung! |
| 102 | Var det lätt att förstå att man kunde plocka med pennan? | [trycker på guldmynts knappen] Tre guldmynt har jag! |
| 103 | Om ni lägger ner de där, jag ska bara fråga er en sak. | Jag har fyra äpplen. Har du fyra äpplen. Jag får kolla! |
| 104 | Var det lättast att räkna på skärmen hur många äpplen det var eller att trycka på den där knappen? | [räknar på skärmen] [räknar på skärmen] Jag tycker det var roligt med knappen, men det var lättast med o räkna. |
| 105 | Hallå lyssnar ni på mig? | Ja De hörde inte.. |
| 106 | När ni skulle räkna äpplen, tryckte ni på knappen där då eller räkna ni för hand så? | 
| 107 | Om du vill veta hur många äpplen du har där, hur gör du då? | [räknar på skärmen] Ett, två, tre, fyra, fem, sex, sju! |
| 108 | Så om du vill kontrollera det kan du ju trycka där. | [trycker på äppleknappen] “Sju äpplen” |
| 109 | Ja det stämde ju! | Och en två tre [räknar guldmynt] [tittar på Annas skärm] |
| 110 | Tänkte ni på att det fanns... | Guldmynt och Äpple Jag vet jag ger det till dig!! [vänder sig mot karin] Nej |
| 111 | Hallå lyssna på mig nu. Här nere i hörnan står det ju nänting. Kan ni läsa vad det står där? | 
| 113 | Fast det kanske är lite svårare att läsa där nere.. | Nä det är lättare! |
| 114 | Är det lättare..mm | Fast jag går i ettan.. |
| 115 | Du har lärt dig räkna då. | 
| 116 | Jamen det fungerade ju jättebra! |
Table 5. Transcript in Swedish for test group 2

Group 3

<table>
<thead>
<tr>
<th></th>
<th>Interviewer</th>
<th>Gul – Ella</th>
<th>Grön – Isabella</th>
<th>Blå – David</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Jag tänkte först kolla vad ni heter för nått, så skriver jag ner det här. Heter du Ella?</td>
<td>Mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Hur gammal var du?</td>
<td>Sex och ett halvt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Är du också sex och ett halvt?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Och vad heter du?</td>
<td>Sju</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Och du är sju år, och vad heter du?</td>
<td>David</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Jättebra! Jag tänkte ni kan väl färger och sånt hära. Det är blå, det är grön och det är gul.</td>
<td>Ja</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Nej det är inga riktiga bläckpennor utan det är såna pennor man har på de här datorerna.</td>
<td>Det är bläckpennor!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Sen tänkte jag fråga om ni kan räkna till tio?</td>
<td>Ja</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Ett, två, tre, fyra, fem, sex, sju, åtta, nio, tio</td>
<td>Ett, två, tre, fyra, fem, sex, sju, åtta, nio, tio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Ja ni kan ju räkna jättebra. Har ni kunnat det länge?</td>
<td>Jaaa! Jag kunde tills och med när jag var ett år.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Ett är? Ojooj</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Om ni kan räkna hur många äpplen ni har. Hur många äpplen hade du?</td>
<td>Fem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Och hur många har du? Det ser du direkt eller?</td>
<td>Tre</td>
<td>Ja</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Och hur många hade du?</td>
<td></td>
<td>Fem</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Man kan också kolla genom att trycka på knappen med det lilla äpplet där nere så kan man hörta hur många äpplen man har.</td>
<td>[trycker på knappen]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Oj nu blev det alla på en gång!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Om vi provar en gång i ordning.</td>
<td>“Tre äpplen”</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Och du har? Prova att trycka. "Fem äpplen" [svagt ljud]

Oj den låt lite lägre. [trycker på guldmyns knappen] “Två guldmyn”

Två guldmyn. Där kan man trycka för att höra guldmyn.

Eller kan ni läsa siffror så kan man se det där hur många man har. Tre äpplen och fyra guldmyn [räknade Ellas]. Men det kanske är lättare att räkna för hand så.


Två guldmyn. Där kan man trycka också och släpper någonstans.

Det var inte så svårt, eller var det? Det fattade ni ganska snabbt hur man plockade saker.


Och det gör man genom att trycka där nere med den pennan. Så blir det gult. [provar att plocka]

Vänta nu får hon plocka nått av dig.. Då måste du göra den grön igen. Då får du ta pennan där nere. [släpper] [plockar och släpper]


Om du köper av... [lägger ner pennorna]

Jag vill ha tillbaks mina äpplen nu! [plockar tillbaks]

Ok ska ni två prova att köpa av varandra då?

Jag tänker köpa av dig.

Har du tagit.. vad har du tagit för nått då?

Det går ju inte. [problem att plocka]


Men du har ju gul penn.. men den är grön här borta.. så då måste du göra den grön först.

Ja då tar jag ett guldmyn här

Det här är blå penn. Du kan sälja med mig.
Så kan ni två prova en gång. Du har ju massor av äpplen. [plockar av david] Istället. om du vill. Fem äpplen!

Nä nu är den.. nå du måste ha samma färg på pennan. [släpper] hihi Fyra äpplen har jag! Jag ger bort..

Om vi provar att ni gör samma färg på pennan. Ok nu har alla färg.. [plockar av ella] alla har gul penna markerad]

Ja vad snäll du är så får han lite äpplen också. [plockar äpplen till david] Jag vill ha ett till!! hehe

Ta det lugnt inte bråka nu! Nej [försöker stoppa isabella] [plockar av ella] jag vill ha några! [plockar av ella]

Nu vill jag veta hur många äpplen ni har? Jag har... sju äpplen har jag. Nej!! [plockar ett äpple av isabella] Haha

Då vill jag att alla ska försöka få fyra äpplen.. Mm då får du ge bort några. [plockar av ella] Jag har sju Tysta! [trycker på äppel & guldmynknapp] "Ett äpple" "Tre guldmyn" [trycker på äppel & guldknapp] jag har fyra

Ska vi prova en annan sak. Får jag låna era pennor.. så tar vi fram de här pennorna istället. [plockar ut standard stylus till alla]

Nu vill jag att ni ska få fyra äpplen. [plockar ett av david] Sju Ska ni prova en annan sak. Får jag låna era pennor.. så tar vi fram de här pennorna istället. [plockar ut standard stylus till alla]

Nu har du för många äpplen. Så nu måste du ge några. [plockar av david] Ett äpple Sju


Om ni vill kolla här hur många äpplen ni har. [trycker äpple knapp] Nu tar jag ett guldmyn från någon.

Hur ser du det? [plockar av Isabella] Sluta Ella du är dum! Jag har fem!

Hur många äpplen har du Isabella? [plockar av david] Fyra

Ella hur många har du? Du räknar på skärmen.. Fem.

Ska du kolla om det stämmer? [trycker äpple knapp] [plockar från Ella]
<p>| 6  | Ta det lugnt! Oj nu har alla blå pennan... ta inte så hårt på skärmen. | Om du får alla mina äpplen så får jag alla dina guldmynt? |
| 6  | Får inte plats med mer säger den då. Då får man inte plats med mer äpplen. Då kan hon bara få guldmynt istället. | Du ska få alla mina äpplen så får jag alla dina guldmynt! |
| 6  | Nåi jag tror vi ska göra färdigt det här. Nu har ni provat på. | [skärmen full] |
| 7  | Så om ni sätter er i soffan så ska jag fråga er lite. Sen kan ni titta lite mer. Så David ska du sätta dig.. | [plockar mellan varandra] |
| 7  | Ni provade och plocka mellan allihop tror jag. | Men jag vill inte bli av med alla mina guldmynt! |
| 7  | Och sen kunde man räkna hur många äpplen det var på skärmen eller så kunde man trycka på den där knappen. Vad gjorde ni för att räkna? Vad var enklast? | Jag gjorde lite olika. |
| 7  | Det var kul att höra rösten ibland kanske. | Jag fick inte plats med alla mina.. |
| 6  | Det var ganska svårt va när man skulle plocka från varandras? | Men mig gedde du! |
| 7  | Jo lite gav du väl. | Jag tog av dig! Nåa inget.. |
| 8  | Ni provade och plocka mellan allihop tror jag. | Och väd står det här då? |
| 7  | Oj då, var du sån! Vilken snåljåp. Det här med siffrorna som stod här nere i hörnet. Här nere stod det ju... kan ni läsa siffrorna? | Sju |
| 8  | Vad står det här då? | Sju Fem |
| 8  | Och vad står det på den? | Fyb Fem |
| 8  | Men det kanske är enklare att räkna för hand? | [tar fram sista datorn] |</p>
<table>
<thead>
<tr>
<th></th>
<th>Ja det finns många olika sätt</th>
<th>Jag kan trycka där! [trycker på äppelknappen]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Oj nu börjar batterierna ta slut..</td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Transcript in Swedish for test group 3
Computer-supported collaboration using Pick-and-Drop interaction on handheld computers

Henryk Gelius

Abstract
This study investigates a new interaction technique for collaboration on handheld computers called Pick-and-Drop. The technique is an extension of the popular Drag-and-Drop method used in many graphical interfaces today, but with Pick-and-Drop on-screen objects can be picked from one screen with a pen and dropped onto another. The aim of the study is to answer whether Pick-and-Drop promote collaboration among children by letting them focus more on other users and the task at hand than on the computer interaction. The study also investigates in what way collaborative situations can benefit from Pick-and-Drop. A prototype Pick-and-Drop system was implemented on four customized handheld computers equipped with wireless network communication. The prototype allowed spontaneous collaboration using ad-hoc networks and peer-to-peer communication. Radio Frequency Identification (RFID) tags were used to identify the pens when picking and dropping objects from the screen. Ten children aged 6-7 years old participated in the study at an after-school recreational centre. They tried Pick-and-Drop by playing a collaborative game of buying and selling apples using golden coins represented as icons on the screen. The test was video filmed for later analysis. The study showed that Pick-and-Drop offers effective collaborative interaction based on a mix of turn taking and concurrent interaction. Users do not have to switch focus when using an application or sharing data as the interaction style stays the same. There was an interesting difference in control over the interaction when users shared objects by “giving” or by “taking”. Users stayed in better control when they shared objects through giving.

Keyword
Pick-and-drop, collaboration, CSCL, interaction, children