Designing for Peer Learning : Mathematics, Games and Peer Groups in Leisure-time Centers

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Constrained by national tests and the mathematics curriculum, teachers have problems finding time for exploratory and hands-on mathematical activities, especially so in classes with a reduced pace of progression, for example because of a large proportion of second-language learners. Could the leisure-time center, where time is not earmarked, provide such opportunities? The conclusion of this thesis is that this can be done, on the condition that designed activities build on the central premise of the leisure-time center: children have the right to choose which activities to engage with. The thesis is interdisciplinary, combining design research, situated cognition/embodied interaction, and pedagogy. The empirical material comes from a design project conducted in collaboration with the Rook, a multicultural school with an integrated leisure-time center. The participating children were 7-9 years old. The games studied were card and board games, especially combinatorial mathematics games (Set and Nim).

The situated and embodied approach towards design is reflected in the analysis, which approaches visual artifacts as parts of multimodal communicative scenes with many co-present participants engaged in playing games or solving problems. It is shown that children learn the game through observation and participation, either as players or in non-playing roles. For many games, rules are written in a format that is inaccessible to children. One of the design tasks in the project has been to develop secondary artifacts related to games: graphic guides, conceptual maps, and paper-based exercises that can be used by children without adult support. The premise of the learners' right to choose has many consequences for the design of learning activities. One is that motivation changes from being a property of the learner to a property of the activity. In order to highlight this difference, this thesis proposes the notions of *learnability* and *learnworthiness* to describe those aspects of an activity and its context which make it motivating from the learner's perspective. The thesis concludes with a discussion of how design can increase the learnability and learnworthiness of a learning activity.

Watching the activity being practiced is the most important resource for potential participants to determine its learnability and learnworthiness. The qualities determining the learnworthiness of an activity are reciprocity, mastery, and the potential for closure. Watching a peer successfully solving a task increases the learnability for the observers as well. If problem-solvers think aloud and use their hands to move or point at cards, collaboration and learning by observers is facilitated. Providing games with non-competitive side activities creates opportunities for deliberate practice, and offers a safe entry for children who are reluctant to engage as players.

Key words Leisure-time centers, mathematics, embodied interaction, design research, motivation, observational learning

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Preface

The work described here started around 2000 in the Narrativity and Communication studio, where I was fortunate enough to be hired as an artistic researcher. The research studio, a collaboration between the newly started School of Art and Communication (K3) of Malmö University and the Interactive Institute, was dedicated to exploring new kinds of narrative in digital media. We were interested in how new technologies could be used for a variety of purposes, among them play and learning. But what we witnessed, at several occasions, was a conflict between our intentions as designers and the actions and expectations of children playing with our prototypes. Especially when there was a group of children, the design could rarely keep in pace with their plans and intentions. This dissertation continues the exploration of the tension between the intentions of children and those of designers (or, for that sake, teachers), and how to make space for both.

This journey has taken me through a number of different research environments. The Interactive Institute and K3 have already been mentioned. For the last six years I have had my base at the department of Philosophy at Lund University, in the Cognitive Science section, and in the Linnéus research environment Thinking in Time – Cognition, Communication and Learning. The span between these research environments is important, and my trajectory as a researcher has been shaped by the need to be interdisciplinary "in person", which is quite different from being part of an interdisciplinary research environment. I would not have arrived at the result presented here without the continuous friction between research approaches.

This work would not have been possible without the contributions of many important people that I want to thank. First, my two supervisors, Peter Gärdenfors and Per Linde: I have enjoyed having both of you as conversational partners for the last few years, and many of the themes and threads in this thesis started in our conversations. Thanks for your patience and reading efforts invested in many subsequent versions of this text during the last two years. Former supervisors Mikael Jakobsson and Robert Ramberg, you have had an important part in giving feedback and suggestions at earlier stages of this project. Researchers and colleagues in Lund: Ingar Brinck, Andreas Falck, Maria Graziano, Emily Grenner, Marianne Gullberg, Agneta Gulz, Jana Holsanova, Roger Johansson, Viktoria Johansson, Martin Jönsson, Peter Kitzing, Maria Larsson, Ia Maurin, Jens Nirme, Birgitta Sahlén, Björn Sjödén, Betty Tärning, Annika Wallin, and many others. K3/Interactive Institute, present and former co-researchers and colleagues: Mette Agger Eriksen, Thomas Binder, Christel

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One of the important lessons learned from the K3 research environment is to hold on to and build long-term relationships with the people and institutions where the research is set. The Rook (the name is fictional) has been my hosting school and leisure-time center throughout the PhD period. The generosity of children and teachers at the Rook has been invaluable, and it has been fun to hang out with all of you. Speaking of leisure-time centers: Thanks to "fritten" Løjtegårdsvej 60, for valuable discussions on the research issues, and for being such an important, safe and fun place for my children Otto and Viggo during the long days of thesis writing.

For funding, I gratefully acknowledge the support from Malmö University, and from the Linnaeus Centre Thinking in Time: Cognition, Communication, and Learning, financed by the Swedish Research Council, grant no. 349-2007-8695. Additional funding has been provided by the foundations of Erik Philip-Sörensen and Uno Otterstedt.

Finally: Viggo, Otto and Thomas, you are the best family I could ever have aspired for.

This book is dedicated to my mother Ingegerd Harvard. During most of her adult life (and mine) she has combined design and research in her work designing play equipment for children's outdoor activities: I follow in her path.

1. Learners with a choice

Figure 1-1. Tony and Jenny play The Lost Diamond (20110322_LD).

In comparison with many other countries, Swedish school children spend relatively few hours per day in school. On the other hand, many of them attend leisure-time centers. In 2014, 83% of children between 6-9 years of age were enrolled in a leisure-time center.[1] Leisure-time centers have a double agenda: they are places for recreation, and are included among the educational institutions of childhood which are regulated by the national curriculum.

This opens up for the first goal of this thesis, to explore *how to design learning activities for settings in which children have the right to choose what they want to do*. This particular condition in not unique to leisure-time centers. In school – and in higher education – learners are also continuously confronted with choices about what to learn and what to engage with, forced to consider what the best options are: "Indeed, a major mission in education is to ask 'Why math rather than billiards?', 'Why spend effort on homework and not baseball?', 'Why learn more when I know enough to pass?' " (Hattie 2009:47). I will argue that the premise that learners are entitled to choose has consequences for how to address issues of motivation, as motivation changes from being a property of the learner to a property of the activity. When people can freely choose what they want to do, we assume that they are motivated by

[1] Source: Skolverket; http://www.skolverket.se/statistik-och-utvardering/statistik-i-tabeller/fritidshem/ (accessed 2015-09-27).

the activity itself. But which aspects of an activity make it motivating for a learner, and what is involved in judging the "learnworthiness" of an activity? These are the kinds of questions that will be addressed in this thesis.

In a learner's choice of activity, many aspects come into play. "While teachers and adult society in general may value certain types of education and academic performance, the individual child must balance this against other societal and peer pressures" (Austin 2002:162). This observation leads to a related topic: peer learning. In this book, the concept of peer learning refers to spontaneous learning processes in groups of children who meet regularly. These learning processes range between informal, unintentional learning and self-directed, intentional learning.[2]

A more specific issue concerning the contributions of peers to learning is *how the peer group influences motivation* during the process of evaluating potential activities involving an investment of time and effort. From the perspective of design, the interest in understanding peer influence on motivation is not an end in itself, but instrumental to the design process: it can be used as the starting point for designing learning activities that better reflect the social dynamics and learning patterns in groups of children.

In graphic design and visual communication, it is customary to describe communication using the transmission model (Shannon & Weaver, 1949). According to this model, visual artifacts are the medium through which a sender (in graphic design: the designer or the client) conveys messages to receivers. However, this model falls short in accounting for the complex interactions in a group of children engaged in a joint learning task, in which participants communicate with each other while interpreting and using visual artifacts. For this kind of setting, there is a need for communication models which include the interaction between many participants and in which the main axis of communication is *between* participants, not from designers to participants. This is therefore the second goal of this thesis, to explore *how visual artifacts are used in settings with many participants.* Cognitive scientists have explored how humans use the surrounding environment for facilitating mental tasks, both the interplay between an indivudual and an artifact, and in broader contexts in which many people, cultural traditions, and social and material environments play a part. Both these areas contribute important insights regarding the use of visual artifacts. However, it is also interesting to look at more specialized settings in which only a few people are engaged in an activity involving visual artifacts. Gesture studies and research in embodied interaction provide a framework for studying this particular kind of scene.

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[2] Peer learning here is used to mean informal learning in children's peer groups. Within pedagogy, there exists a different understanding of peer learning (in Swedish, *barns samlärande*) referring to classroom learning and teacher-initiated practices (Williams et al. 2001).

Mathematics and games at the leisure-time center

The research/design project Ramsamsam, reported here, dealt with the design of mathematical games and problem-solving activities for a leisure-time center for children age 7-9. The project was a collaboration with the The Rook, a primary school with an integrated leisure-time center. I spent time at the school during two periods, in 2011 and in 2013, bringing with me prototypes for games and other activities, and taking part in the routines and activities of the leisure-time center. Some of the children in the study participated both in 2011 and 2013, in their first and third years of school.

A majority of the children at the Rook have immigrant backgrounds, and Swedish is most often their second language. Learning mathematics was a challenge for many of the children, and keeping pace with the national mathematics curriculum was a challenge for their teachers. In short, there was a recognized need for learning interventions in mathematics, beyond the general usefulness of engaging children in extra-curricular math activities. My designs and my field studies have both been shaped by the specific situation and local culture at the Rook, and many of my aims have been formulated in response to discussions with teachers and children. This is also true concerning the pedagogical aim for the design: to develop games and mathematical activities which make children *look for* mathematical relationships, and *talk about them* with peers, as well as to provide players with successful *experiences* in solving mathematical problems.

Research questions

How can we – as designers and educators – resolve the dilemma of designing and enacting learning activities for settings in which children are are not required to engage with the proposed activities? This is the main research question of the thesis.

> **How can we design for peer learning**, in the sense of designing learning activities intended for settings with groups of children, in which children have the right to choose between activities?

I will approach this question from two perspectives. The first is how visual artifacts are used for communication and coordination in children's peer groups, and more precisely, how they are used within the particular context of playing the card game Set.

> **Communication and the use of visual artifacts:** how do participants communicate during joint activity such as playing a game, and what is the role of visual artifacts for communication?

The analysis is based on video-recorded episodes of children playing Set. There are several reasons behind the choice of these particular episodes from the totality of the video recordings, reasons which I will address later. The second perspective is how games and activities are learned in the LTC, and how peer groups influence learning and motivation. Both learning and motivation are approached as situated, with a focus on the dynamics of the concrete setting and circumstances, and the unfolding interaction between participants.

> **Learning:** How was the activity/game learned, and what role did peers play in the learning process?
>
> **Motivation:** What led learners to engage in the activity/game, and what role did peers play in this decision?

This part of the analysis elaborates on the outcome of the first research question, supported with theoretical models from social learning theory, situated learning, and interpretive reproduction. The analysis builds on two graphic visualizations, one of individual participants' trajectories, and another of temporal patterns of participation.

Research approach

This is a work of *design research*, and what this means is further elaborated in chapter 4. I approach the issue of mathematics in the leisure-time center with a focus on the visible and audible interaction between participants and visual artifacts, with special attention to how visual artifacts shape human interaction and how meaning is assigned to them. The strategy for approaching the invisible, unobservable processes of learning and motivation is to instead go through the visible and observable processes of communication, the use of visual artifacts, and mapping trajectories of participation.

This project is multidisciplinary, aiming for a high degree of integration between design research and cognitive science. Within cognitive science, I draw upon *situated cognition* and its more recent offspring *embodied interaction*. In relation to the field of design research, I engage in designing ”paper artifacts” for pedagogical contexts, but I also rely on models, examples, and theories from interaction design. At the end of this thesis, I will discuss the relationship between paper design and digital design and to

what extent the findings of this study can be transferred to design of digital games or learning software.

The analysis of the Ramsamsam is done through visualizations: maps, diagrams, frame grabs and visual narratives articulate the analysis. The role of the visualizations is discussed further in chapter 4.

Concepts and words

There are a number of concepts that have been important for finding a way to capture and analyze the processes in the peer group, and I will use some concepts in a sense that differs from how they are used by other researchers. The most important of these are the paired terms learnworthiness and learnability, which I will use for approaching motivation as qualities in activities as opposed to qualities in learners.

Learnworthiness: a potential learner's evaluation of the benefits of investing time and effort to acquire skills in some activity.

Learnability: the relationship between the investment required and the available resources and support for a potential learner to learn a skill.

Visual artifacts and visual arrangements: visual artifacts are designed objects visualizing some content and making this content "arrangeable": maps, calendars, business cards, bank notes, jigsaw puzzles, board games. Users of visual artifacts regularly produce visual arrangements, for example, by placing playing cards in different formations, or by refolding a map and marking points of interest through pointing or drawing on it.

The Swedish national curriculum uses the word *pupils* for learners from preschool class to 9th grade, whereas the PISA survey refers to *students*, meaning 15-year olds . I will not use the terms pupils or students, but refer to the children in the study as participants and learners depending on the context. This book does not touch on aspects of gender, and in order to avoid unintended gender generalizations I will mostly refer to partipants as *children,* without specifying their gender, and use the pronoun *her* in cases where the identity of the children is not specified.

Following the national curriculum (Skolverket 2011), I will use the English translation *leisure-time center* (LTC), for the Swedish *fritidshem*. Other translations that have been used earlier are after-school care, after-school program or recreational center, but is seems that leisure-time center is becoming the established English translation. There are some complications since the leisure-time center in my study is co-located with the school. Being in one or the other is not a matter of place but of the time of day. The Swedish National Education Agency figures in several references with its Swedish name, *Skolverket*.

Scope

This study consists of a rather extensive reading of a relatively small set of empirical material, filtered through theories of learning, situated cognition, and embodied interaction. This limits the scope of the conclusions. My aim has been to deliver an explorative and unconventional reading of the empirical material in order to create openings for new and different design solutions.

In discussing the use of visual artifacts, I will be looking at how co-present participants use visual artifacts for communication and coordination in a joint activity: playing the game Set. Use of visual artifacts can also refer to participation in visual media cultures, but these aspects fall outside the limits of my study. Interested readers are recommended to read Sparrman (2002), Änggård (2005), and Kjærs (2005), who discuss children's identity and participation in the visual media culture of the leisure-time center.

The primary target group for this thesis is designers working with learning in educational or leisure settings. The line dividing designers (with the task of developing artifacts) and teachers (with the task of enacting learning activities) is thin, and a lot of the design aspects I discuss involve enactment: teachers are part of the target group. Finally, I also address cognitive scientists with an interest in learning and social cognition.

Overview of the thesis

Chapter 2, **Background of the project.** An introduction to the institution of the leisure-time center, and the field of motivation and mathematics learning. The chapter ends with an introduction to the Ramsamsam project, the empirical work in this thesis.

Chapter 3, **Theory.** The first section of this chapter looks at research in cognitive science about how visual artifacts are used for cognitive and communicative ends, with examples from situated and distributed cognition, gesture studies, and embodied interaction. In the second section, learning theories relevant for the leisure-center setting are introduced: situated learning, social learning theory, and interpretive reproduction.

Chapter 4, **Research approach and method,** gives a brief introduction to design research, and discusses the role of visual displays and visual representations as part of the analysis.

Chapter 5, **The setting,** provides a picture of the institutional and material setting of the Rook, discussing some aspects that are of interest for my studies: leisure-time center activities and mathematics lessons, the local culture of playing games.

Chapter 6, **Design,** presents the prototypes in the Ramsamsam project grouped after the two genres of mathematical manipulatives (2011) and combinatorial mathematics games (2013).

Chapter 7, **The video recordings,** provides a walk-through of the video-recorded episodes of playing games, as a reference to the analysis which follows.

Chapter 8, **Using visual artifacts,** is the first part of the analysis. It is dedicated to the research question of how co-present users communicate and coordinate as they play games, and how the visual artifacts (playing cards in particular) are part of the communication. The analysis is primarily based on the episodes in which children play Set.

Chapter 9, **Peers, learning and motivation,** is the second part of the analysis. The recordings of children playing Set is the basis for the analysis. The chapter starts with two visualizations of trajectories of participation: who played with whom, when, and for how long. This continues into an analysis of how participants learned to play the game, and why they chose to engage in the activity. The chapter ends with an evaluation of the Ramsamsam project.

Chapter 10, **Implications for design,** changes the perspective and looks ahead towards future designs. Based on the analysis from chapters 8 and 9, a number of implications for design and enactment are formulated with the intention to make learning activities learnable and learnworthy from the perspective of potential learners.

Chapter 11, **Discussion,** picks up some of the themes of the thesis: streaming and segregation, applicability for digital design, embodied and situated perspectives on visual communication.

2. Background for the project

Before presenting the project, I will sketch a background picture describing leisure-time centers, mathematics learning and motivation, and second-language learning of mathematics.

The institution of the leisure-time center

The leisure-time center (hence abbreviated LTC) combines three functions: it is a place for children to enjoy their leisure-time, a provider of child care for working parents, and a part of the educational institutions of childhood. According to the Swedish Education Act (2010), municipalities have the responsibility to offer LTC care for all 6-12 year old children in need of supplementary care outside of school hours. 83% of Swedish children age 6 to 9 were enrolled in a LTC in 2014.[3] After the age of 9, fewer children attend LTCs (Skolverket, 2011). The LTC is open before and after the regular school day, and during school holidays. It is often integrated into the school premises, and children will typically be at the leisure-time center together with their classmates.

From a historic perspective, LTCs originated as providers of care and preventors from harm. All parents were given the opportunity to work, and children were protected from potentially negative influences from hanging out in streets and backyards. For a long period, LTCs were related to preschools in their organization, and this may have contributed to the emphasis on play in the daily activities and in steering documents (Haglund, 2009). From around 1990, the administration of LTCs was integrated with the school administration. Since 2011, the activity of the LTC is regulated in the national curriculum. From 2001, teachers in the LTC have the same exam/degree as other teachers. Even though LTCs are today part of the school system, they tend to be overshadowed by it. From 2010 to 2014, the average size of groups at LTCs has increased from 38 to 41 children, and the percentage of teachers without a university

[3] See reference in footnote, page 1.

teacher degree has increased from 51 to 58%.[4] A possible explanation is the strong political impact of "learning," and its consequences for the allocation of resources and money. The LTC does not have the learning discourse, or measurable learning aims, that would allow it to compete with schools for economic resources.

Leisure-time centers exist on roughly similar terms in all the Nordic countries. In Sweden and Denmark, leisure-time centers are organizationally integrated with schools, whereas the corresponding institutions in Norway and Finland are not (Foss 2011; Hedström 2012). The school reform in Denmark in 2013 introduced longer school days for all children, and this was partially achieved by introducing "LTC-like" activities and LTC teachers as part of the compulsory school day (EMU, 2015).

Learning in the LTC is not governed by specific educational aims. The Education Act, as cited above, uses open-ended terms like "meaningful" and "holistic".

> The leisure-time center shoud stimulate pupils' development and provide them with meaningful recreational activities. The education in the leisure-time center should be grounded in a holistic view of the pupil and the pupil's own needs. The leisure-time center should encourage a rich array of contacts and promote social companionship (The Education Act, 2010, chapter14 § 2, translation by the author).

Furthermore, it refers to pupils' development instead of their learning. Learning in the LTC, according to Jensen (2011), is mainly informal. It is implicit and procedural, and not regulated by curricula or learning aims decided in advance. In addition, it reflects the intentions of the learner/group of learners, and is often a secondary effect of some other aim. There is, however, a normative basis for the otherwise informal learning processes in the LTC (ibid.). All are allowed – in principle - to participate on equal terms, even if this is not always achieved in practice. Also, the norms of equity in the LTC allow learners to be openly critical of the opinions of other participants (ibid., p.133-134).

Bardon describes learning in the leisure-time center as based on care and socialization (Bardon 2008). She emphasizes how teachers and children in the LTC together create a local culture, to which all are committed and entitled to feel ownership for. Children in the upper grades are a resource for the enculturation of younger children starting in the LTC (ibid.). Larsson (2013) studied the everyday routines in the LTC from the perspective of opportunities for mathematics learning. She found many activities where the mathematical content could be highlighted; however, most of these were not followed up because of a shortage of teachers. When teachers are few in number, they tend to hover above all children as a single group instead of engaging in the activities of smaller groups.

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[4] Source: Skolverket; http://www.jmftal.artisan.se, (accessed 2015-10-02).

LTCs are important sites for children's creation of and participation in peer cultures (Corsaro 2011). In the LTC children form friendships, they are entitled to decide what to do and with whom. Evaldsson (1993) describes how children in the LTC engage in activities, learn through observation, negotiate rules, adapt to each other, relate to norms, and develop their skills as participants in both smaller and larger groups of peers. The picture she offers, based on participant observation studies in two LTCs, is that of a complex social structure in which participants orient themselves in relationship to others, and in which looking at what others do is a central activity. One important aspect of peer cultures of children is visual culture. Through pictures on clothes, tattoos, drawing and coloring pictures, games, media, illustrations, and other visual objects children negotiate issues of gender and identity (Sparrman 2002). Board games are one of the categories of "pictorial objects" that are part of children's visual cultures in preschool and LTC (Sparrman 2002; Änggård 2005).

Groups and cultures

Steering documents for learning in the LTC place an emphasis on group interaction both as the format for and the outcome of learning. But what is a group? A relevant distinction from phenomenology and subjectivity research is that *institutional groups* (for example all the children in a school class or all inhabitants in the same municipality) are defined as groups in which criteria for membership is established from the outside, while *informal groups* are defined as those groups which emerge when persons engage and identify with each other.

The children in the LTC are, inarguably, an institutional group. Cultivating friendships is important for children and they invest time and effort in this (Corsaro 2011; Evaldsson 1993; Änggård 2005; Sparrman 2002). Many informal groups emerge within institutional groups, based on the participants' affinities or in the joint activities they engage in. Children in the LTC engage in activities in various groupings, often involving two to ten children. There is no moment in which all children in the LTC act as one coherent group, in the way school children in certain situations have to act as a school-class (Jensen 2011).

Related to peer groups is the concept of *peer culture,* which is defined as "a stable set of activities or routines, artifacts, vales, and concerns that children produce and share in interaction with peers" (Corsaro 2011:21). Peer cultures are different from peer groups since the culture is not composed of the participating children but of the cultural products these children use and create. This distinction is hard to maintain, though. In Corsaro's own texts peer culture is sometimes referred to as something produced by children, at other times as an "arena" where children negotiate and make sense of observed cultural goods from the surrounding adult world.

Mathematics learning under pressure

During recent years, PISA surveys have reported on an increasing number of children passing through Swedish compulsory school without reaching a basic level of mathematical skills, as defined by the PISA assessment criteria (OECD 2014, 2015). School changes with society, and is influenced by a series of societal processes: democratization, individualisation, internationalization and marketization (Tallberg Broman 2011:10). Both in-school and out-of school factors contribute to the educational achievements of school.

In a globalized society, Swedish schools faces the task of teaching children who possess little or no knowledge of Swedish (Tallberg Broman et al. 2002:162). Even if mathematics as a topic is not confined to a specific language, learning mathematics through the medium of a second language entails extra challenges for learners and teachers. Research shows that it takes many years of practice in order to use a new language in an academic context, which typically implies decontextualized use and many specialized concepts (ibid.). In a study of Year 9 national tests in mathematics, Petersson (2012) shows that second-language learners are disadvantaged in those parts of the test that require extensive reading, whereas learners' achievements are at the same level in the parts dealing with number sense. With respect to language, it is both specialized mathematical concepts and open-ended expressions that create difficulties: *ungefär, knappt, drygt, lite längre än* (in English: approximately, hardly, somewhat more than, a little longer than)(Tallberg Broman et al. 2002:163).

Cummins (1998) argues that second-language learning is in itself not a problem, once teaching methods and learning environments are adapted to second-language learners. Second language learners will habitually need to reference both their languages for learning (Cummins, 1998). In order to facilitate the accessability of both languages for learners, it is important that both languages are present in the learning environment, and that learners' first language is met with respect. Learners are also helped by redundancy in order to map between languages. Cummins (ibid.) lists a number of concrete proposals for supporting second-language learners, and the list below is an edited version of his list with focus on the points that are relevant for the age group and for design:

- Activating students' prior knowledge and **building background knowledge** (through the L1 where necessary)
- Modifying instruction to build sufficient **redundancy** into the instruction (e.g. through paraphrasing, repetition, demonstration, gestures etc.)
- Use of **graphic organizers** to transmit conceptual content
- **Hands-on activities** in content areas such as science, mathematics, and social studies

- **Cooperative learning** and other forms of project work that encourage students to generate new knowledge rather than just consume information.

The recommendations of Cummins reflect an inclusive approach, in which learners are not treated as the cause of a problem, and in which the forms of teaching and learning have to meet the requirements and skills of learners.

Learning in small, heterogenous groups (which I interpret as groups consisting of both native speakers and second language learners) is fruitful, and allows participants to share language and build knowledge together (Tallberg Broman et al. 2002:163).

Curricular pressures

Mathematics is the school subject with the second highest number of hours (after Swedish) throughout compulsory school, 1020 hours in all.[5] Learners' skills are tested in national tests in grades 3, 6 and 9. However, the attention to mathematics, the structure of tests and surveys and the curriculum also imposes constraints on teachers' pedagogical practice (Meaney & Lange, 2012). In relation to the curriculum and the task of preparing learners for national tests and surveys, the time for teaching mathematics is very limited, especially so in classes in which the tempo is slower than average. Classes with many second-language learners may typically be in this category since the forms for teaching and learning are not adapted to the needs of this group of learners. Cooperative learning, practical labs, and hands-on mathematical activities demand more time than standard classroom teaching. This is a catch-22 situation since the slow learners, who are likely to have a low level of motivation and belief in their own potential as mathematical thinkers, are the ones who would benefit the most from hands-on or laborative entry paths into mathematics. Stenhag (2010) argues that mathematics becomes important because of the attention and time dedicated to it in the curriculum: "If mathematics is given a lot of place in school, the topic will become important as a consequence of this, regardless of its intrinsic value" (Stenhag 2010:22, in my translation). This suggests an inversed proportionality, in which extra resources dedicated to support the teaching and learning of mathematics are less *reflecting* the importance of mathematics than *creating* it, and in the end raising the demands on learners' and teachers' combined achievements instead of – or alongside with - making the subject of mathematics more achievable.

[5] Source: Skolverket; http://www.skolverket.se/laroplaner-amnen-och-kurser/grundskoleutbildning/grundskola/timplan/timplan-for-grundskolan-1.159242 (accessed 2015-09-29).

Motivation and mathematics

In recent research, motivation is described as a combination of three components: *beliefs* about one's own skills (including self-concept and self-efficacy), *attitudes* to the topic of learning, and *emotions*. Emotions are short-lived, whereas attitudes and beliefs form over time (Hannula 2012). During the first years in school, motivation is malleable. Later it crystallizes into a stable pattern. Since persons tend to engage with activities they think that they are good at (self-efficacy), self-concept and self-efficacy are reinforced over time.

Negative beliefs and negative attitudes towards mathematics often go hand in hand (ibid.), and learners who fall behind "develop sophisticated defences to cope with failure" (Mighton 2003:43). Giota states that demotivation is more than a matter of neglect or accident, but a strategy used by learners in order to avoid the risk of losing face or appearing stupid (Giota 2002). The topic of mathematics is still seen by many as a sorting tool for higher education, a system that intentionally produces high- and low-achievers (Stenhag 2010). Children not only learn math during mathematics lessons, they also learn "about their own performance in relation to the educational aims of school" (ibid., p.22, in my translation).

Motivation used to be described as intrinsic (driven by inner interest) or extrinsic (driven by external rewards or punishments). Today it is more common to discuss learners' motivational patterns as oriented towards performance or towards mastery (Dweck & Legget 1986, in Giota 2001:41). A performance-oriented learner is interested in achieving a good result and may for this reason avoid difficult tasks, as the chance of succeeding in these is lower. The mastery-oriented learner, on the other hand, seeks out difficulties in order to advance her understanding. The difference in orientation is assumed to be related to the explanatory models of the learner: learners who believe that mathematical talent is innate have no reason to invest effort into learning. For learners who make the connection between effort and achievement it makes sense to work hard. In a long-term perspective, mastery-orientation yields better results: "The idea that higher achievement is a direct result of one's efforts and interest is critical to success" (EC 2011:96, with reference to Hattie 2009).

Motivation: irreversible or contextual?

Most research on motivation approaches it as a psychological disposition of the learner (Hannula 2012), and often as an irreversible process of personal dispositions crystallizing into stable patterns. However, there are researchers who challenge the notion of motivation as irreversible and psychological, and instead propose a picture of motivation as situated and changing. Andersson and Valero (Andersson 2011) have shown that mathematics learners change their identity narratives in relation to

recent experiences of mathematics learning, and available examples of identity narratives. ”Identities are not always as consistent as they appear to be” (Andersson 2011:205), and identity narratives are updated and changed according to new needs or life events.

Emotions are in themselves short-lived but they may have long-term effects on learners' beliefs and attitudes towards mathematics, according to Liljedahl (2005). He has looked at the effect of AHA-experiences on adult mathematics learners. AHA-experiences are according to Liljedahl, essentially emotional: the release of tension when passing from ”stuck” to ”unstuck.” The leap in understanding may be small: “unremarkable and in many cases indistinguishable from simply having learned something” (Liljedahl 2005:226), but this does not prevent the AHA-experience from having a lasting positive impact on a learner's self-concept and attitude to mathematics.

> It was clear that there was an experience of some importance, but that importance was not played out at the level of mathematical understanding. That is, the power of the experence lay in the experience of an answer or an idea arriving in an untimely and unanticipated manner and not in the answer or idea itself (ibid., p. 226).

Similarly, Gärdenfors describes AHA-experiences as a combined feeling of success and relief: “After wrestling with a resisting and complex material, as all pieces fall into place, frustration and tension go away” (Gärdenfors 2010:90). Liljedahl raises the question whether AHA-experiences can be ”orchestrated” for learners, but comes to the conclusion that they are too dependent on chance: the environment for AHA-expericences may be orchestrated, but not the experience in itself (Liljedahl 2005:232). I will follow up on this in the analysis of motivation, looking at when and why Set players smile (chapter 9).

In 1966 Jerome Bruner published the essay ”The Will to Learn” (Bruner 1966, see also Gärdenfors 2010:86 for a discussion), arguing for children as endowed with the will to learn, driven by a number of ”natural energies”:

- Curiousity
- Closure. The activity provides “a sense of accomplishment”
- Achieving competence
- Getting the approval of the relevant “reference group”
- Identification with, and emulation of, relevant competence models
- Reciprocity: doing things together with other persons (Bruner 1966)

In spite of Bruner's description of the will to learn as "an intrinsic motive, one that finds both its source and its reward in its own exercise" (ibid.), it is notable that four of the six points which he proposes have a direct reference to the social context of learning: getting the approval of others, reciprocity, emulating role models, achieving competence.

The only point that relates to the activity per se is that of "providing a sense of accomplishment." Coincidentally, the participants in Liljehdahl's study of AHA-experiences refer to these moments in the same terms, as providing sense of accomplishment (Liljedahl 2005:230). I will get back to this list since it takes the perspective of learnworthiness, approaching motivation as a quality of certain activities and their social context.

Educational aims and learning goals

I will end this section on motivation in relation to mathematics learning from the angle of *educational aims* and *personal learning goals*. Educational aims are formulated by educational institutions or schools, and they are at the outset irrelevant or indifferent to learners. A condition for learning is that learners appropriate educational aims, re-interpreting and transforming them into personally relevant learning goals. In order for this process to happen, educational aims have to be perceived as meaningful, relevant, and achievable by learners.

Goals that appear inaccessible to learners are ignored or treated as irrelevant (Hannula 2012). Children need support both from school and from their families in figuring out educational aims and what they are expected to do with them (Hattie 2009). If school does not offer sufficient support for learners in personalizing learning goals, the family background and educational level of parents will have a strong impact on a learner's chances to be successful in school, which is further reinforced by self-preserving strategies (Giota 2002).

One strategy for making the connection between personal goals and educational aims is to approach mathematics from everyday and real-life scenarios, connecting it to learners' experiences outside of the classroom (Cummins 1998; EC 2011; see also Tomlin 2002 for a critique of the everyday/real life approach to mathematics). An argument that can be held against the everyday approach is that many self-directed learners are motivated by the need to escape the everyday or create alternatives to it.[6]

[6] I do not have a scholarly reference for this point. It is based on conversations with friends and students about engaging in long-standing individual learning projects during childhood and adolesence, within non-everyday fields of interest like WWII aircrafts, musical theory, extinct languages, sorcery, manga drawing etc.

Giota (2002:285) mentions the importance of considering the learners' entire life-situation, including pressure from peers and family. Teachers have to reach out to learners' inner worlds, taking their perspectives and meeting them with respect (Ford, in Giota 2002). In addition, it is important that learners feel safe and appreciated, and that the environment allow mistakes and encourage experimentation.

> To develop intrinsic motivation, mathematics teaching and learning must take place in a supportive learning environment where students are encouraged to communicate their understanding of the tasks and where their ideas are valued and appreciated. Such an environment supports students' self-concept, their self-efficacy and their enjoyment of mathematics as they discuss and share their understanding with their peers. (Mueller et al., 2011, in EC 2011:98)

Similar arguments are made by Sfard (2008), Cummins (1998) and Tallberg Broman et al. (2002). A closing reflection on the theme of mathematics and motivation is the importance of offering opportunities for math learners to be successful and smart, and avoid situations in which learners fail for reasons not related to mathematics – for example because they have problems reading and interpreting instructions in a language they do not yet master.

Learnworthiness and learnability

In a formal teaching situation, educational aims are defined at the outset, and learners may understand and endorse these to various degrees. Above I discussed motivation in a school setting, and the importance of learners appropriating and transforming educational aims into personal learning goal as a prerequisite for both motivation and learning. However, the setting of the LTC is different. There are no explicit educational aims, but rather a collection of activities are on hand for children to choose between. The question of motivation, hence, becomes less about being motivated or not, but about what children are being motivated by.

Certainly, there is a difference in the degree of commitment between adopting a learning goal as discussed in the previous section, and deciding to engage with an activity, as I will discuss in the following. However, less committed forms of engagement merit being taken seriously as they are likely to be part of the process of formulating personal learning aims.

I use the two notions of *learnability* and *learnworthiness* as a means to conceptualize motivation as qualities of activities that make them interesting to engage with, from the perspective of a potential learner. This can be expressed as a hypothesis: *For a learner to engage in an activity or with a piece of knowledge, the activity/knowledge must be percieved as learnable and learnworthy.*

The notion of learnworthiness was introduced in an essay by Austin (2002), applying group socialization theory (Rich Harris 1995) for understanding learners' deliberations within professional education in pharmacology.[7] Austin describes learners, children as well as adults, as continuously involved in weighing the benefits and disadvantages of different learning activities against each other. Educational performance has to be balanced against other pressures from society, family, and peers in an ongoing *learnworthiness calculus*:

> the real-life *learnworthiness calculus* that appears to be so commonplace and a part of school-aged learning, professional education and post-graduate continuing professional development sheds important insights into the process of learning. It also provides important clues to answer the question of how people learn, by reframing the question of "how do people learn?" towards "how do people determine what is learnworthy?" (Austin, 2002:162)

Austin makes one more point that I want to elaborate on here. What he claims, again with Rich Harris as support, is that the peer group decides what is learnworthy, through a process involving learners throwing "sidelong glances towards their peers and their peer groups, to learn what they deem to be important and learnworthy" (ibid.).

> In effect, peer groups of children act as a jury examining the evidence offered by parents, teachers, siblings, the media, other peer groups, etc., and based upon their own secret and unique peer group dynamics, render judgment as to what is appropriate, acceptable, and normal for other members of that group. Peer groups define what is to be believed, what can be safely ignored, what is real, and what is fake, and ultimately what is learnworthy (Austin 2002:163).

There are many parallels between Austin's description of learning in peer groups and those of Evaldsson (1993), Bardon (2008) and Corsaro (1992, 2011). All three mention the importance of observing peers, an activity that gets extra grounding through Austin's account.

So far, nothing has been said about what makes an activity learnworthy; the content of "learnworthiness" is still a black box. In order to use learnworthiness in my analysis I will use a provisional list of learnworthiness qualitities, based in Bruner (1966): what makes an activity learnworthy from the perspective of children age 7-9 is that it affords *reciprocity*, achieving of *mastery/competence*, *identity-building,* and relevant role-

[7] I any am not aware of other researchers than Austin discussing learnworthiness, but in the field of technology design, Eftring (1999) argues for the notion of *useworthiness* for similar reasons.

models, and finally, the activity affords *closure.*[8] To sum up, I will base my analysis on learning and motivation in the LTC on Austin's notion of learnworthiness, meaning perceived qualities in activities or skills that make them worthwhile of engagement and learning, from the learner's perspective.

Rich Harris' theories about peer influence are controversial (see Vandell 2000 for a critical discussion). The critique however, is mainly concerned with the long-term influence of peer groups on children's personalities. In the setting that I am studying, I will only look at the short-term, situated influences of the peer group – and my judgment is that the theories of Austin and Rich Harris can provide a fruitful perspective on peer learning.

Learnability

I mentioned learnworthiness and *learnability* before. There are two reasons for using the notion of learnability together with learnworthiness in the analysis and the implications for design. The first one is trivial: in order for participants to learn a new activity there has to be sufficient support for learning – live instruction, or opportunities to observe and participate, or guidelines/instructions in print or digital formats. The second reason relates to the flip-side of motivation: disengagement and risk avoidance. Learnability refers to the relationship between the investment needed and the available resources and support for a learner to learn a skill. Put differently, learnability answers to a potential learner's questions about the level of difficulty, the risk of failing, and what support is available for succeeding.

To conclude, we now have a draft for some conceptual tools for dealing with motivational issues in learning settings in which learners choose what to do. *Learnworthiness:* a potential learner's evaluation of the benefits of investing time and effort in acquiring skills in some activity. *Learnability*: the relation between the investment needed and the available resources and support for a potential learner to learn a skill.

As learnability and learnworthiness are defined by learners themselves, they are not available for direct interventions by designers. On the other hand, since the learnworthiness/learnability calculus is based on *perceived* benefits, design can contribute by ensuring that the activity and its qualities are visible to the peer group.

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[8] I have not included *curiosity*, as curiosity is the starting point for finding out about the activity but not a reason for sustained engagement and learning. Also, *approval of the reference group* is subsumed in the point of *reciprocity.* Finally, I will use the notion of "closure" for Bruner's *sense of accomplishment*.

Ramsamsam: mathematics at the leisure-time center

The aim of Ramsamsam is to explore mathematics learning at the leisure-time center from the perspective of design. The project is set in a multicultural school, with many second language learners. The topic of learning is mathematics, approached through the leisure-time center and its local culture.

The Ramsamsam project has two sets of aims: research aims that are the same as the aims of this thesis, and a set of design aims as guides for the choice of and development of learning activities in the project. These were to find and/or design activities that

- invite children to look for mathematical relationships, and to talk about them with peers.
- afford experiences with the potential to contribute to the learner's mathematical knowledge, if contextualized in classroom discourse.
- afford positive experiences of competence and success, to indivual participants and to the group.

According to Sfard (2008) learning mathematics is to become a participant in mathematical discourse – which is formal and literary. My starting point has been that the LTC does not support engaging children in mathematical discourse. This needs the structure of the classroom. The discourse in the LTC is colloquial – with room for some mathematical concepts but not with the discipline connected to mathematical discourse. For this reason, I have envisioned the role of mathematics interventions in the LTC as providing experiences that may be taken up and recontextualized in relation to mathematics teaching post-hoc. The vocabulary used by children in the LTC is not under control of adults or educational aims, but the symbols and graphic elements on playing cards are – and these may be a way to introduce mathematical concepts without interfering with spoken discourse.

The project unfolded in two phases, a first phase in 2011 and a second phase in 2013. During the first round of Ramsamsam, I visited the Rook once a week together with two graphic design students, Niclas Bränström and Sofi Bornheim. For each meeting we prepared prototypes or other design-related activities. The three of us took turns introducing the activities, video-recording and taking notes. With the assistance of the teachers in the leisure-time center we formed two groups of children interested in participating in a "math game project". The teachers also helped us with distributing and collecting forms for informed consent from participants and their parents.

Our activities were set in the classroom of 1A. For each visit, we planned for 45 minutes with each group. At most time, there was some degree of mismatch between who had signed up and who actually participated. The organization in two groups was difficult to maintain as children were coming and going. We ended up with a

group of about ten children that turned up for most of our Tuesday visits. As time went on, our visits were less planned. We spent two hours with our group, using some prototypes and having the time to follow the proposals of the participants.

Some of the most rewarding episodes in 2011 were unplanned: children invited us to play games that they liked, or they explained their games to us. Some of the participants left the group since they had expected using computer games, loosing interest when this was not the case. We engaged in occasional conversations with teachers. We also had some challenging moments where we found ourselves alone with the children, and had to assume teachers' responibilities since no one else was around. In preparing for the second round, this was something that I brought up with the LTC teachers.

Niclas and Sofi focused primarily on the visual aspects of their games, and some of the activities and observations from their work will be described more in detail in the following chapters. The prototypes that I introduced were combinations of mathematical manipulatives and games, intended for use by children in peer groups.

Ramsamsam 2013

In preparing for the 2013 period of field studies, I wanted to set side more time for participant observation, for just being there without imposing activities on participants. The starting point for the design was a conversation with the class teacher, Eva, about language and mathematics. In her experience, some of her second language learners – who by 2013 were almost all the pupils in the class – had difficulties understanding mathematics that were connected to their everyday, colloquial language skills. Many of the children in the class had problems expressing and understanding precise spatial relationships in everyday language: differentiating between on and in, under and behind. Eva's analysis was that these pupils were not enough often confronted with tasks or situations demanding them to communicate with precision about spatial, logical or quantitative relationships.

The issue was not which language they were using, but the engagement in communicative tasks requiring precision about spatial relations. This was reflected in the aims for the 2013 round of design: make children *look for mathematical relationships, and talk about them with peers.* In the design, I settled for the genre of combinatorial mathematical games, "games with hidden information and no chance" (Siegel 2013:1) and mathematical puzzles. There were two practical reasons for this decision: the experiences of using Set in 2011 led to fruitful discussions and children collaborating in searching for sets. Given the research questions I wanted to produce many copies of the prototypes, in order to leave them for children to use as they wanted. I settled for paper – coloring sheets, work sheets and playing cards – as the main prototyping material.

The fieldwork in 2013 was less planned than in 2011, including more non-earmarked time for just being around. As I said earlier, this setup presented difficulties with respect to participants' informed consent. On the other hand, the challenges we had in 2011 with participants resisting the activities proposed by us were not there, since there was no obligation to attend to the games or activities I brought. In the spring semester of third grade, children pass through the national test in mathematics. My field studies took place in the two months leading up to the national tests.

As a summary, I have approached peer learning in the setting of the leisure-time center as a complement to classroom learning, where the insitutional contract and the agency of children provide opportunities to make knowledge relevant in the peer group, to anchor mathematical language and reasoning in the modes of talking and interacting of the peer group, and offering experiences of success.

The Ramsamsam design has mainly been paper-based: coloring sheets, membership cards, playing cards, game boards. Some of the 2011 prototypes were made of MDF board and included marbles. A lot of the design efforts went into designing secondary artifacts (rule sheets, membership cards, graphical maps over games), as help for children to learn and take charge of the activities. In this respect, the design has involved equal parts of graphic design and interaction design concerns.

In previous interaction design research projects I have been working with digital media and digital play environments (Harvard & Løvind 2002; Harvard 2009). Restricting the prototypes to board games and card games does not mean that future designs may not be digital. My decision to work with paper as my main prototyping tool was pragmatic. It allowed me to be in control of the prototyping process, to iterate the design and be able to print new copies as the need arised. The use of paper and cardboard for prototyping purposes is not intended as a limit of what medium the design and analysis may apply to.

Figure 2-2. The video camera is an agent in its own right, shaping the scene by its presence. The screen shots show children playing with the camera (2013).

The challenge of voluntary participation

In preparing for the 2013 field studies, I wanted to include more participant observation, and have my basis in the leisure-time center. One more reason for spending time in the LTC as an observer or participant, without introducing new activities or asking children to engage with a prototype, was getting to know the ecology of artifacts in the LTC. What are the things children and teachers do? What other games are there, and how are they used? Are there games or activities with a potential for mathematical experiences?

An important aspect of the activities, and of the project as a whole, was that participation was voluntary on children's behalf. I said before that my background was studies in designing for play. Play is a voluntary activity, it depends on participants wanting to engage. Another aspect was the Informed Consent form that children and parents had to sign. It stated that participation in the study is voluntary and that all participants have the right to withdraw at any moment. This wording, as applied to the setting of the LTC, may have given rise to other interpretations than the authors of informed consent forms envisioned.

Voluntary participation turned out to be a major challenge to the project. The decision to volunteer in playing math games as a legitimate reason to skip math class is different than the decision to play math games during one' leisure time, instead of playing football or hanging out with friends. The leisure-time center setting required other approaches than design interventions during class. In previous studies, I have often taken out prototypes or concept sketches to groups of children in school or preschool, as a basis for semi-controlled exploration for a limited time, typically 30 minutes (Harvard 2009).

In preparing for the second round of field studies, my ambition was to introduce games that sparked off new peer cultures, games with the potential to take on their own life in the group of children. Even though the prototypes and games that I introduced did not make it that far, I had the opportunity to observe and participate in other activities that were undertaken on the initiative of children: playing UNO, playing Couronne, building with the Marbles Run (see chapter 5), a project that engaged many children for a few weeks. A group of girls launched another project, the pegboard store ("pärlplattebutiken"), which also attracted followers in the group. In short, I will not be able to tell the story of peer appropriation based on my own project, but I can give some observations from the other projects that I had the opportunity to follow in the LTC. If children were to engage in the LTC, the game or activity has to be interesting to them. This simple fact was a challenge to the project, and it has had a lot of influence on the research process and the outcome.

PARTICIPATING CHILDREN IN 2011

1st grade 2011		*2nd grade, 2011*	
Adam	L2	Jenny	L2
Freja	L1	Stella	L1
Molly	L2	Virginia	L2
Richard	L2		
Tony	L2		
Urban	L1		

L1: first language learners
L2: second language learners

PARTICIPATING CHILDREN IN 2013

2nd grade, 2013		*3rd grade, 2013*			
Emma	L2	Adam	L2	John	L2
Jacob	L1	Adina	L2	Joseph	L2
Jessica	L2	Ella	L1	Nick	L2
Leo	L1	Franz	L2	Richard	L2
Lovisa	L2	Gnar	L2	(Freja*	L1)
Nemo	L1				

**Freja is not in the class 3A but in a parallel class.*

Figure 2-3. Participants in 2011 and 2013. Fictional names are used throughout this thesis. I have not included children who are not in the videos. In 2013, Ella was the only L1 learner in the class as Freja had transferred to another class. First or second language learner: based in my appreciation of how the children spoke Swedish/other languages.

The participants

The class I followed was a first grade class 2011, and a third grade in 2013. The class counted around 22 children in 2011, but only 14 in 2013 (see figure 2-3). About one third of the class had Swedish as their first language in 2011, compared to one single child in 2013. The 3A class teacher, Eva, has a background as a Montessori teacher. Her colleague Krister is responsible for planning the mathematics lessons, but the two teachers share the teaching. Krister has his classroom downstairs, in another classroom/LTC department. The teachers Lotta, Pernilla, and Håkan work in the LTC. Besides class teachers and leisure-time center teachers, there are many other types of teachers criss-crossing the open space in order to go to the classrooms or the small rooms: special education teachers and mother language teachers.

As I had my basis in the LTC in 2013, I got to meet and work with children in the second grade as well. I did not have any contact with them in the classroom, but several of them were part of my study in the LTC.

I had my base in the open space, where I took out games and prototypes, arranged the video camera on tripod, played games, or simply waited while observing what was going on. Children and teachers nicknamed me ”speltanten” (the gamelady), which I found a suitable label for my LTC persona: a nerdy person engaging all interested children in strange problem-solving games, or accepting invitations to play other games or participate in other activities. As the gamelady, I did not discuss design with the children participants: I preferred to engage them as users and players, not as lay designers reflecting on issues of visual style or usability.

Figure 2-4. The persona: ”the gamelady” (speltanten) engaged in Embodied Set together with Joseph, Ella and Franz. The setup: a video camera on tripod overlooking one of the tables in the open space.

Ethical aspects and integrity

Research involving children requires that participants' integrity and identity be protected. Informed consent to participate has to be expressly given by parents, preferably also by the children themselves. Participation is voluntary, and participants can choose to interrupt their participation at any moment.

For both rounds of Ramsamsam I prepared posters for the leisure-time center with information about the study, the researchers, and its aim. Forms for informed consent were distributed to children and parents through the teachers. The informed consent papers had a box to tick for agreeing to participate, and another box for declining participation in the study. One parent called back to discuss the study before signing the paper in 2011. The teachers helped to collect the informed consent papers. As we carried out our field studies, we brought the group of participants to the classroom, where we arranged prototypes and other activities.

In 2013 the setup was more informal, and the procedure for acquiring informed consent and restricting participation to those children who had answered was more difficult. Some families filled in the papers, accepted that their child participate, and sent it back to the teacher. Three families declined participation. Most families did not answer, but thanks to the efforts of the teachers the informed consent papers were eventually filled out. However, even children from families who had not answered and children from families declining to participate in the study wanted to participate playing games in the LTC. I found it more important to be consistent as the Gamelady, inviting all children to participate, than being consistent with the informed consent papers. When non-participants joined, I arranged to point the camera away from them, or to skip the video recordings.

The informed consent included showing photos in research-related contexts, on condition that all participants are anonymized, but not showing video-recordings. All children, teachers and the school are given fictive names, and faces are anonymized in the photos used in this book. I have given earlier versions of this manuscript to the teachers at the Rook for consultation. There are a few anonymized video clips that I have prepared for research presentations and talks. These have been sent to the children and families in question for approval.

The documentation of the field studies consists of a field diary, design sketches and prototypes, and video recordings of episodes of play. With a few exceptions, I used the video camera only for the sessions when children played Set, SOS or Nim, and not for documentation of the daily routines in the LTC.

Figure 2-5. The setup in 2011: participating children and researchers had their base in the classroom, splitting up between the groups of tables. In this picture, Tony, Richard and Adam play pinball after trying out one of the Ramsamsam prototypes (visible at the left corner of the table).

3. Theory

The setting which I explore in this thesis is a group of children engaged in gameplay or problem-solving activities, involving visual artifacts. In this chapter I will present two theoretical perspectives on this "target setting." The first perspective is cognitive, in a broad sense, and deals with the use of visual artifacts for individual feedback, communication, and coordination of a joint activity. The second perspective is pedagogical, and discusses some theories of learning which can be used for understanding and designing within this setting. A common denominator of both perspectives is visibility: visual artifacts, visible hands and bodies, observational learning.

Using visual artifacts

The question that I will set out to answer in this first part of the theory chapter is as follows: What can be learned from research in situated cognition, distributed cognition, gesture studies, and embodied interaction about how visual artifacts are used and how meaning is attributed to them by co-present participants engaged in joint activities in which the artifacts play a part?

I will approach the question step by step, starting with situated cognition and research in how the *visual and material gestalt of artifacts* influence how they are used in cognitively demanding tasks. In the second step, I will add a layer to the visual artifacts: *hands.* In nearly all contexts where visual artifacts are used, hands are part of the visual scene, both one's own hands and hands of others. In the third step, I will add another layer, including whole *bodies* in the visual scene, and discuss how the *spatial structures articulated by visual artifacts* organize human interaction, from talk and gaze up to the level of entire bodies.

The final section deals with *common ground*: the shared knowledge accumulating during a conversation, and the long-term accumulation of cultural products and traces in human-made environments.

Cognitive aspects of designed artifacts

Situated cognition emphasizes "the role of the environment, the context, the social and cultural setting, and the situations in which actors find themselves" (Norman 1993:1). It started started as a continuation of – and a counter-reaction to - earlier research in cognitive science, in which cognition was understood as mental computations produced by a brain, resembling a computer processor. One theme in situated cognition is the interplay between designed artifacts and human problem-solvers.[9] As human information-processing abilities are limited, problem-solvers have to develop strategies to overcome limitations of attention and working memory. Such strategies often involve offloading mental tasks onto the material environment. Examples of this are writing, drawing, placing things that have to be remembered in places where they are seen, facilitating counting by using an abacus or a calculator, using clocks to keep track of time, and so forth. Offloading mental tasks onto the environment is an everyday behavior and it is reflected in everyday artifacts and in the designed environment (Norman 1988; Svensk 2001; de Léon 2003).

Mathematical and combinatorial games have often been used in studies of mental off-loading, probably because they present tasks that are mentally taxing but without real-life ambiguities; it is easy to measure the outcome. One of these games is Towers of Hanoi, and it consists of moving discs of different sizes between three rods. The game starts with a "tower" with smaller discs on top of bigger, and the aim is to move the tower to another rod. Only one disc at a time may be moved, and a larger disc may never be placed on top of a smaller one. With three discs and three rods, the game is challenging but achievable for children age 6-12. With four discs and three rods it is difficult to solve even for adults (Goldin-Meadow 2003:173).

The mental problem-solving strategies deployed for solving the Towers of Hanoi game were discussed already by Simon and Newell (1972), but in a follow up study (Zhang & Norman 1994), three different designs of the game were compared in order to shed light on how the visual and material gestalt influences problem-solving (see figure 3-1). Besides the original design of the game with rods and discs, the study presented one version in which players had to build towers by placing larger cups on top of smaller cups, and another in which balls were put in bowls. Even though the task was identical from a computational point of view, the different material realizations had significant effects on the level of difficulty. The cup version was easiest to use, whereas the balls in the bowls were the most difficult, judged by how successful the test persons were in solving the puzzle.

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[9] In the learning section of this chapter I will come back to another part of situated cognition through the work of Lave, Rogoff and others on situated learning.

The explanation of Zhang and Norman is that a task is easier if the design takes its starting point in well-known cultural or material constraints, since the problem-solver does not have to pay attention to these. In the case above, anyone knows that in order to build a tower from cups, bigger cups should be placed on top of smaller. But there are no corresponding learned principles about the order balls should be placed in in bowls. Therefore a part of working memory has to be assigned to remembering the rule, with the consequence that fewer resources are left for solving the task.

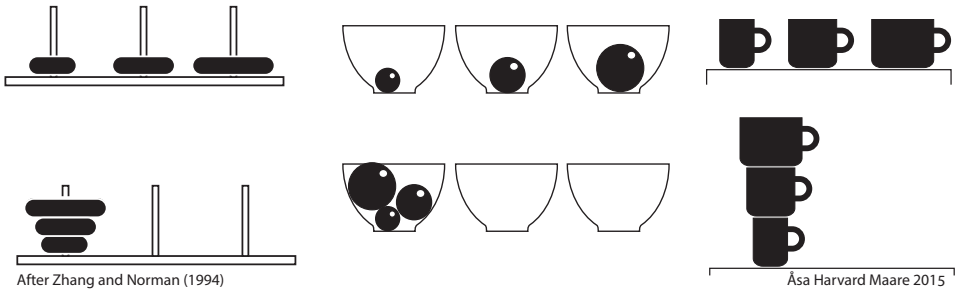

Figure 3-1. The different realizations of the Tower of Hanoi game compared in the study and Norman (1994). For the sake of comparison, all three versions were constructed around the idea of placing larger objects on top of smaller objects.

This study and similar ones led Norman to formulate a number of design principles for "transforming difficult tasks into simple ones." The first five principles are as follows: "Use both information in the world and knowledge in the head. Make things visible[…]. Simplify the structure of tasks. Get the mappings right. Exploit the power of constraints, both natural and artificial" (Norman 1988:188).

Even though the above list is based on studies of all sorts of everyday objects, there is a second context of importance: this is input into the nascent field of user-centered design, and the principles are written with the design of computer interfaces in mind. The methodology used by Norman and his fellow researchers comes from experimental psychology, comparing individual test persons in controlled lab environments. As a consequence, there are a number of issues not addressed, for example cultural differences between problem-solvers or the effect of group interaction. The perspective is that of adapting design to people, not taking account of the sophisticated ways in which people adapt themselves to their designed environment. But the list as such also has some important qualities as a design tool: it is concrete, related to practice, and it consists of easily remembered rules-of-thumb. It also has some fundamental qualities related to design research, which I will come back to in chapter 4.

Visual artifacts and visible hands

Hands can be used for making cognitive tasks easier: a cook arranges ingredients and tools on the kitchen table in the order they will be used for preparing a dish, sparing herself the effort of keeping the different steps of the recipe in her mind (de Léon 2003). Drawing students learn to use hands and a pen as a visual overlay, holding them in front of the object they are drawing while looking with only one eye, as a help for measuring angles and proportions. Both of these are examples of *epistemic actions* (Kirsh & Maglio 1994), undertaken not because of a direct functional result but because the task at hand (cooking or drawing) is facilitated through the visual arrangements of objects and hands.

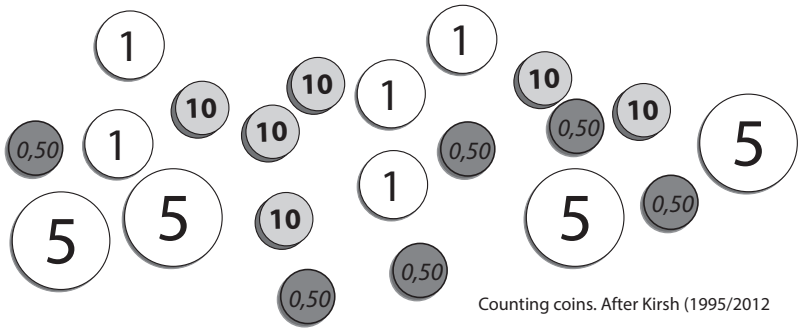

Figure 3-2. An example of the style of the task in which research persons had to count coins with or without hands, in Kirsh's study on complementary strategies (Kirsh 2012).

"Intelligent creatures amplify their cognitive abilities by adapting their environments of action to environments where they can get the best results from their limited cognitive resources" Kirsh argues (2012) and for humans, hands have a central role for doing so. In a study of counting strategies, research persons were asked to count a number of coins of different values (ibid.). The visual presentation of the task was a photo of coins spread out in a random pattern (similar to that in Figure 4-3). In one condition, research persons were allowed to use hands for pointing or counting, in the other condition they were unable to use hands. The hands-off group counted slower, and made more mistakes compared to the hands-on group. After a number of trials some of the hands-off persons had elaborated compensatory strategies which helped them to count, but still not as fast and reliably as the hands-on group (ibid.). This study points to one aspect of hand use: as a visual overlay providing structure to a complex scene.

Another aspect of using hands in combination with visual representations is described by Hutchins (2008) with reference to a number of studies in which a person uses her hands in combination with a visual display: an architect moving fingers over an

architectural plan, a child moving a doll in a doll's house, a scientist visualizing brain damage by translating a diagram into a shape. Hutchins describes his examples as combining two kinds of seeing: "Each makes use of a rich culturally elaborated static medium (doll house, control panel, molecular diagram, brain image, naviga- tion chart and architect's rendering). The static medium is both seen as a thing in itself and seen as the thing it represents. One's own body is simultaneously seen and seen as something quite different from a body. The dynamic relation of the body to culturally meaningful objects allows the body to be seen as some dynamic aspect of the domain that is represented by the objects" (Hutchins, 2008:2014).

If teachers use appropriate gestures, learners understand better. This is the premise for studies conducted by Goldin-Meadow (2003) in which teachers are instructed as to which gestures to use while explaining a mathematical problem. Goldin-Meadow discusses gesture as a visual representational format along with diagrams, written text, and physical models, a symbolic system that teachers may use for conveying mathematical relationships. As a format of visual representation, gestures have the disadvantage of being ephemeral, but the advantage of being highly integrated and timed with spoken words (ibid., p.112). In this account, the hands *are* the visual representation, and the focus is on the interplay between hand gestures and talk, but not between hand gestures and non-human visual artifacts.

From an emboded interaction perspective, Streeck (2011) approaches the border between moving hands and visual representation: if a gesturer has a pen and a paper, the gesture may leave a trace and become enduring. This does not change the timing of the gesture that produced the drawing. What makes drawings, symbolic inscriptions, and arrangements of visual artifacts into something else than gesture is that they remain and may be used again: "Because they remain on the scene after the moment in which they are produced, inscriptions and 'monuments' such as piles, stacks or arrangements of objects can become targets or components of further symbolic acts" (ibid., p. 77).

The four examples of using hands presented here describe different relationships between the hands and visual artifacts: as overlays, as an animation toool, as a visual representation system, and finally, hands as producers of enduring graphical inscriptions given the presence of pen and paper. Only the last example, that of Streeck, discusses hand movements (and the resulting graphic marks) as contributions to common ground.

In gesture studies, gestures are defined as "symbolic movements related to ongoing talk and to the expressive effort or intention" (Gullberg 2006:104), and are thereby distinguished from hand movements in general (functional movements, for example) that "are not communicatively irrelevant but […] not typically part of the message the speaker intends to convey" (ibid.). This distinction is, from the perspective taken in my text, too narrow since it would exclude the hand movements of the cook, the drawing student, the architect (Hutchins 2008) and the person counting coins

(Kirsch 2012), unless the hand movements were produced as part of explaining their actions to somebody. The example by Streeck is the best fit for my target setting, since it encompasses both persons, environment, visual artifacts and talk. In the following section I will continue with some more examples of research in embodied interaction, and widen the scope to also include entire bodies in the visual scene.

To summarize what these studies tell us about hand use: hands are used as a visual tool for looking at images in various ways, intended sometimes for the person herself and sometimes for the other participants. The ephemeral hand movements, and the enduring products of those movements, are both part of the accumulating common ground of the activity.

Graphic fields and visible bodies

Researchers in embodied interaction "insist that embodied interaction *in the material world*, which includes material objects and environments in the process of meaning making and action formation, is primary" (Streeck, LeBaron, Goodwin 2011:9). The object of study in embodied interaction is groups of people engaged in joint activities. If the continuity between bodies and environment is one characteristic of embodied interaction, another characteristic trait is temporality: action unfolds from moment to moment, and what is studied is the "formation of action sequences" (ibid).

As the scale changes from hand-sized visual artifacts to settings involving entire human bodies, the perspective on visual artifacts changes too. In a study of children playing hopscotch, Goodwin describes how the chalk drawing of the hopskotch grid creates a graphic field within which participants act (Goodwin 2000a). The hopscotch grid does not represent anything, but it provides a framework for classes of actions, building on the deployment of the structure in "conjunction with other relevant meaning-making practices, such as the game-relevant body of an actor jumping through the hopskotch grid" (ibid., p.1516). In another example, the context is archeologists analyzing colors, and the graphic grid is provided by a visual tool, the Munsell chart. Archeologists use the Munsell chart as part of their professional practice, and its use is integrated with how they talk, with gestures, and the use of other tools like trowels (ibid.).

In order for a joint activity to happen, participants must maintain a mutual orientation. The visible product of this has been referred to as an ecological huddle (Goffman 1964, in Streeck, LeBaron, Goodwin 2011:2) a F-formation (Kendon 1990, in Streeck et al. 2011:2) If one participant turns away, disregarding the attention of the other participant, there is no mutual orientation and the participation framework falls apart. However, mutual orientation is readable both for participants and for other present, non-participant persons: "The visible bodies of participants provide systematic, changing displays about relevant action and orientation" (Goodwin 2000b:157).

Both hopskotch grid and Munsell chart are examples of hybrid systems of semiotic resources (ibid.), serving the purpose of guiding action. The graphic field of the hopskotch grid – or of the table with playing cards in different formations (see chapter 8) – is used in conjunction with relevant body positions, actions, and talk. The visual artifacts may have representational properties, but more important are their organizational properties and how they are embedded in the organization of human practice (Goodwin 2000a).

Visual artifacts are never perceived in isolation, but as parts of joint activities in which they contribute to producing action, together with visible bodies and environmental resources of various kinds. People engaging in joint activities need to uphold mutual orientation and joint focus. In doing so, they continuously inform each other, and other non-participants, about the status of the activity and their commitment to it.

Common ground and repositories of culture

A theoretical notion which may help explain the different expressions of how visual artifacts are used is that of common ground. Common ground consists of shared references between participants involved in a joint activity, for example conversation. According to Herbert Clark, joint activities accumulate common ground (Clark 1996:43). The common ground consists of recently used words, expressions, references, gestures, etc., and it is available for re-use by partners. Common ground is implied by Streeck in his account of visual arrangements remaining on the scene, and thus remaining available for re-use. The reason for re-using may be economical – sparing the participant the cognitive effort of searching for *other* words or expressions – but the effect of sharing words, attitudes, expressions, etc. extends beyond saving effort: conversational partners using the same words tend to be perceived as sympathetic (Chartrand & Bargh 1999). As conversational partners align low-level lexical or phonological features (tone of voice, tempo, or choice of words) this facilitates alignment of high-level features, semantic representations, and situation models (Pickering & Garrod 2004:174). In short, as people interact, everything they do is collected into an accumulating repository of uttered words, performed actions, and displayed gestures, open for re-use by others. Their availability is an effect of priming (recent use), but the usefulness of the bits and pieces of common ground is also related to them being shared with other participants.

Common ground is normally used for the shared knowledge produced within a joint activity or conversation, but the concept can be upscaled, at which point we usually refer to it as ”culture.” In a comment to Andy Clark’s Principle of Ecological Assembly -- which is formulated: ‘‘the canny cognizer tends to recruit, on the spot, whatever mix of problem-solving resources will yield an acceptable result with a minimum of effort” (Clark 2008, in Hutchins 2011) -- Hutchins adds that the

environment providing these problem-solving resources in fact consists ”almost entirely of products of previous cultural activity” (ibid.).

> The ecological assemblies of human cognition make pervasive use of cultural products. These are always, initially, and often subsequently, assembled on the spot in ongoing cultural practices (Hutchins 2011:445).

Interacting partners create common ground, and over time, the residues of human action accumulate into culture – creating the framework for humans to act, and providing the resources for accomplishing joint projects. With this, I will leave the cognitive aspects of children in groups using visual artifacts, and turn to the learning aspects.

Learning through observation and participation

Many theories of learning carry, implicitly or explicitly, the imprint of school and formal education, and are for this reason difficult to apply to contexts of informal and leisurely learning. In this section I will present learning theories with the potential to explain aspects of the LTC as a learning environment.

Situated learning

Situated learning theory is based in cognitive science, anthropology, psychology, and sociology. It started with the ethnographic studies of Lave (1988) about everyday mathematics in the grocery store and other places: how JPFs (Just Plain Folks) calculate what to buy or how much things would cost, using methods that had little to do with those taught in school. The findings and learning approach by Lave, Scribner, Suchman, and others inspired educational researchers to call for a new approach to education, with an emphasis on authentic activities, apprenticeship, and collaborative learning (Brown et al. 1989). In the early texts, a situated learning pedagogy was proposed under the name of ”cognitive apprenticeship.” Today, the central notion in situated learning is participation. Learning is described as ”increasing participation in communities of practice (Lave & Wenger 1991:49), ”transformation of participation” (Rogoff 1996), ”trajectories of participation” (Melander 2009), and learning mathematics as becoming “a participant in mathematical discourse” (Sfard 2008).

In this account, I will focus on two models for situated learning, that of communities of practice (Lave & Wenger 1991), and a model proposed by Rogoff and Paradise (Rogoff 1996; Paradise & Rogoff 2009) on children’s situated learning in the family context.

Following is the main outline formulated by Lave and Wenger (1991): Members of a professional community, or *community of practice*, do jointly hold, develop and transmit a body of skills and knowledge that is of value to the wider society. A community of practice is sustained as new participants join, and over time learn to be full participants. The learning process, from novice to expert participant, happens through *legitimate peripheral participation*. The legitimacy consists in newcomers being accepted by central members, and being allowed to contribute to the community through small errends or peripheral tasks. As a novice becomes more skilled she is offered more central and complex tasks. Learning is inseparable from moving in social space: as the novice learns more, she moves towards the center of the community, knowing and being known by many other members (see figure 3-3).

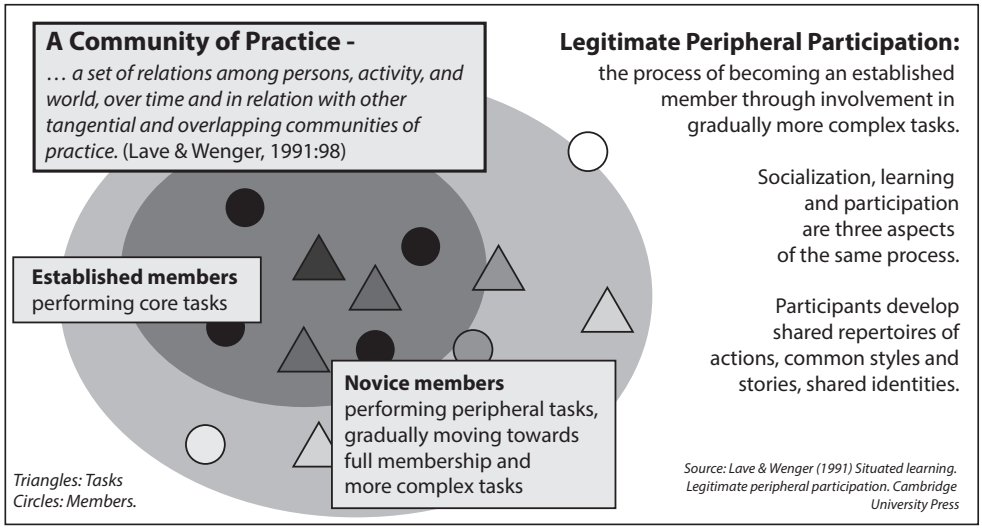

Figure 3-3. Communities of practice, after Lave and Wenger (1991).

The model of communities of practice/legitimate peripheral participation has been taken up by many researchers working with children and learning, in schools, families or at the leisure time center (for example in Klerfelt 2007; Jensen 2011; Corsaro 1992 and Bardon 2008) – in spite of its focus on adult apprenticeship learning. My suspicion is that a major reason for this is the way it is presented, through persuasive visual models and verbal formula. With this, I will continue to the research of Rogoff, which is a little less suggestive in its formulation but a better match for understanding the LTC setting.

Learning through observation and pitching in

The headline above comes from a study by Paradise and Rogoff (2009), and describes how children learn to take part in shared family activities. In their studies, as well as other ethnographic studies of informal learning in children, observation is important. This can be contrasted with Lave and Wenger, who specifically draw a line between observation and participation: ”Newcomers' legitimate peripherality provide them with more than an 'observational' look-out post: it crucially involves participation as a way of learning – of both absorbing and being absorbed in – 'the culture of practice' ” (Lave & Wenger 1991:95).

According to Rogoff, children learn ”through active observation and participation in ongoing community activity with mutuality and support from more skilled community members” (Rogoff et al. 1996: 396-397). Observation is active and requires focus. Paradise and Rogoff cite examples where young children are even *taught* to observe properly, and note the important details from what they see. Borrowing a citation from the anthropoligist Margaret Mead, children's observational learning is referred to as “stealing information” (Paradise & Rogoff 2009).

Some of the Swedish studies on informal learning in the LTC touch on observation as well. Bardon (2008) makes a point of imitation as a learning strategy: choosing whom to ressemble.

> Imitating others is an important part of how children experience the constructing of the world. Children choose to resemble the peers or adults who are important in a specific setting. By being active children make a plan for their own learning (Bardon, 2008:9, in my translation).

Evaldsson's study (1993) focuses on peer-to-peer learning, and she describes how newcomers are asked to observe. A child trying to enter an ongoing activity without first trying to observe and pitch in may be perceived as rude, offending implicit rules of participation in the LTC:

> Particular rules of a game are very rarely made explicit before the children engage in jumping. The children who know the game tell others, who are not initated, just to look at what they do and then copy the movements and the words in the game (Evaldsson 1993:107).

Further, Evaldsson expands the theme of learning through observation to the entire activity system of children spending ”some of their time just going around and looking at what others are doing. In monitoring, they pick up ideas and are able to join in existing activities “ (Evaldsson 1993:80). She refers to this phenomenon as “children floating around” (ibid.), and this theme is one that I will elaborate on in the analysis of learning at the Rook: children wandering the premises without any particular intention.

Peer cultures and interpretive reproduction

The studies of Bardon and Evaldsson is a suitable place to shift over to the next peer learning model, that of peer cultures and interpretive reproduction. This way of understanding children's socialization and development has been developed largely by William Corsaro, a sociologist, and is based in extensive ethnographic studies in children's institutions. Corsaro describes how children, throughout their childhood, create and participate in a series of peer cultures, and that these are important venues for sharing, negotiating and re-interpreting cultural knowledge picked up from the surrounding adult culture. This process is referred to as *interpretive reproduction* (Corsaro, 1992).

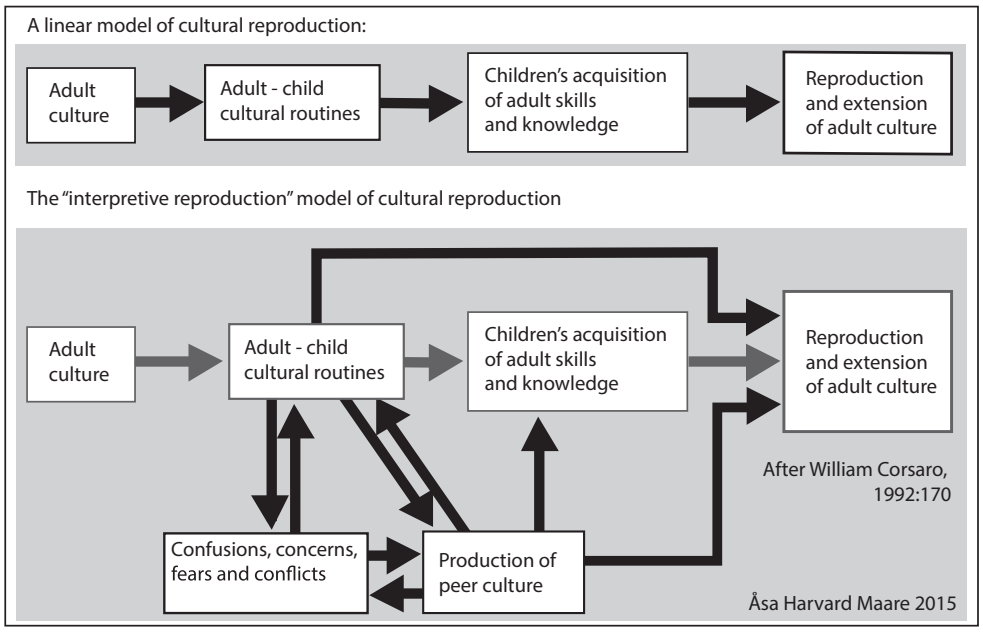

Figure 3-4. This illustration by Corsaro explains the role of peer cultures as sites of cultural production, a secondary stream of learning besides the one children get by participating in adult-child cultural routines (as in parenting, or classroom teaching). Another point made by Corsaro is that peer cultures are innovative, and often contribute to adult culture with new expressions (Corsaro 1992:170).

Peer cultures (see also chapter 1) form in places where children meet on a regular basis. In modern Western societies, this happens in the educational institutions of childhood. From the point of view of peer culture, the function of preschools and schools is to provide children with structures suitable for peer culture development, since today's children are rarely able to use streets or backyards for hanging out with friends.

Interpretive reproduction is more a model for socialization than a model for learning. It has many common traits with situated learning but the scope is different. How children become participants in peer cultures is not discussed or problematized in this model, nor is the learning development from novice to skilled participant. Instead, the process targeted by Corsaro is how children learn by appropriating and re-interpreting goods from the surrounding adult culture. This process is a complex one, influenced by many factors, and one in which children are also participants in adult culture on their own right. Figure 3-4 builds on a graphic overview from Corsaro, (1992:170) but I have split it in two in order to highlight how the interpretive reproduction model differs from a linear model of cultural reproduction, in which influence goes one way, from the old to the young.

For Corsaro, peer cultures are important because they offer a safe place in which children can learn from adults without being directly exposed to them. It is also the place where experiences and frustrations from other social contexts can be formulated and negotiated with the help of other children. Participating in peer cultures is, thus, a matter of belonging and of emotional security.

Routines are central: children express their belonging to, and their understanding of, a peer culture by performing the routines connected to it. Routines are predictable and repetitive, which creates opportunities for participation. Also, routines provide emotional stability, and create a sense of belonging; they are predictable, and they provide frames within which a wide range of sociocultural knowledge can be produced, displayed, and interpreted (Goffman 1974).

Social learning theory

Social learning theory builds on the work of the psychologist Albert Bandura. He argues that learning by example, also called *modelling*, is superior ”under circumstances where mistakes are costly or dangerous” (1971:3). Observing competent models demonstrating the behavior makes it possible for others to perform it without needless trial and error (ibid.). Here, consequently, observation is crucial for learning, and the active and transformative role of observers is emphasized:

> In social learning theory observers function as active agents who transform, classify and organize modeling stimuli into easily remembered schemes rather than quiescent cameras or tape recorders that simpy store isomorphic representations of modeled events (Bandura 1971:21).

In social learning theory, learning through observation and performing a learned behavior are described as two separate processes, each with its context and its set of motivations. The decision to perform a previously learned behavior is causally and temporally decoupled from the observational learning, or coding, of the behavior. In social learning theory, people can learn without any noticeable changes in behavior.

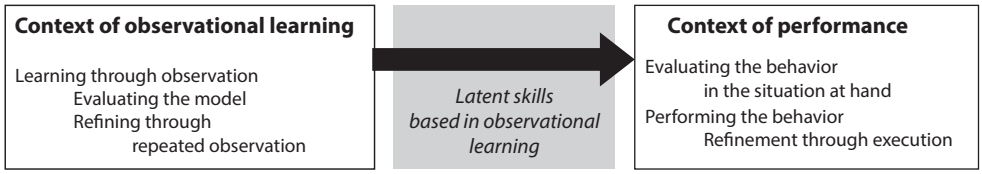

Figure 3-5. In social learning theory, the event of learning a behavior through observation is seen as separate from the event of performing the learned behavior. Bandura's point is that there is in fact learning without any change in behavior – in this schematic image shown as "latent skills" that can be converted into performed skills if needed.

In order to be able to perform an observed behavior, it is an advantage to have seen it many times. The first observation gives the outline, whereas repeated exposure allows the learner to focus her attention on problematic parts and learn them better.

The application of social learning theory has mostly been used for understanding the processes of unwanted learning, of abuse, or crimimal behavior. But there also exists pedagical applications including as a model for sequential skill acquisition (Rijlaarsdam et al. 2008) which is used in the context of teaching children and young people writing skills.[10]

> This model claims that the optimal acquisition of new writing skills takes place through four sequential levels: (i) vicarious observation of actions, considerations and consequences (modelling), followed by (ii) emulation (enacting), (iii) self-directed practice and (iv) self-regulated learning (adapting performance to task conditions, internal and external) (Schunk and Zimmermann, in Rijlaarsdam et al. 2008:67).

Summary

The first half of this theory chapter dealt with situated cognition and embodied interaction, with a focus on how visual artifacts are used together with other communicative channels: speech, gesture and hand movements, and body direction. One of the distinct features of visual artifacts is that they have duration: once positioned, they remain "on stage," accessible to participants and observers engaged in a joint activity.

In the second half of the theory chapter I have reveiwed some learning theories with the potential to shed light on the informal learning processes in children's peer groups from different perspectives. Common to all is the emphasis on participation and social interaction, but when it comes to observation there are differences in the

[10] A follow-up project using the same methodology is underway in the department of Speech Pathology at Lund University.

explanatory models offered by the different theories, especially concerning the role of observational learning, a theme which I will follow up on in the analysis of Ramsamsam.

This has been a short introduction to cognition and visual communication at the level of artifacts, visible hands, and visible bodies: one possibility among many for telling the story of learning and cognition as situated in the material world. There are many other perspectives to take on this story, for example. to further explore the influence of artifacts and technologies on human interaction (Latour 1987; Suchman 1987); the evolutionary backdrop of imitation and observational learning (Tomasello 1999; Boyd & Richerson 2005); or the connections between social behavior and neuroscience (Dijksterhuis & Bargh 2001; Rizzolatti et al. 2001). These perspectives have contributed to the arguments in this thesis, but I have chosen to focus on theories that resonate within the context of children's peer groups, and build an argument stemming more directly from the empirical material of the study.

4. Research approach and method

The research approach in this work is design research, and the methods used are, in the most case, typical for this kind of research: participant observation, collaboration with future users and prototyping as a means to create knowledge. The analysis of the video data draws on other research traditions from interaction analysis and research in embodied interaction. In the first half of this chapter I will give a short introduction to design research in order to situate the project within this tradition, primarily intended as an introduction to readers not familiar with design research. The second part will discuss the video analysis, above all the process of creating two-dimensional static representations from the video data, a process that is interesting both for the representational challenges it offers, and for the way scientific knowledge changes with the format of presentation.

Design research

Design research is shared between several research domains: interaction design, learning and education, architecture and urban planning, industrial design, health care, engineering and business. Design research can be defined by the following five characteristics

- Design research is oriented towards *change*
- *Prototyping* and design are part of the research activities
- Research involves *real-world settings and people*
- The research process is *iterative*
- Design research produces *design knowledge* intended for designers and practitioners

In the following section I will give a short introduction to design research, based on these five points. There are many subdivisions within the field of design research (design-oriented research, design-based research, research-oriented design, design through research, etc.). Although I have avoided going into detail, the approach outlined here is close to that of research through design (Gaver 2012) and design-oriented research (Fällman 2005).

The references that I will use are mainly from interaction design, which has been an important arena for the theoretical and practical development of design research.

Change

Change is inherent in the notion of design, something that already the first generation of design theorists pointed out. ”Everyone designs who devises courses of action aimed at changing existing situations into preferred ones.“ (Simon 1969, in Krippendorff 2006:25). Major themes in contemporary design research include issues of sustainability, urban planning and social innovation. Here, change is addressed at a macro level, as in the following statement by Designfakulteten[11]: ”Design research contributes to ethically and esthetically informed ways of developing the conditions in society.” The orientation towards change can manifest itself either in the direction towards a not yet existing artifact (Westerlund 2009), or in the intention to furnish practitioners with useable knowledge (DBRC 2003). The direction towards change has epistemic consequences as well: by being productive, design research, as activity research, “changes the context of its own activities” (Gaver 2012:940).

Prototyping

Prototyping, sketching and concept development are in part practical design work, but they also belong to the research methods used in design research. Researchers engaging in design work may maintain certain professional aspects of the design process, but will focus primarily on the generation of knowledge. This is often done in combination with more “research-like” methods (ethnographic studies, semiotic analysis, user studies, etc.) This can be contrasted with the field of product development, in which research precedes and feeds into the subsequent design. When the design aim is to generate knowledge, the prerequisites for design change. “[T]he artifact that is developed does not need to encompass all services, functions, and level of completeness that a final ‘product’ would need to embrace. The design-oriented researcher hence works with sketches and prototypes of different kinds, depending on what aspects are investigated” (Fällman 2005).

There are at least two ways of understanding the knowledge-generating effects of prototypes. Prototypes can be *catalysts for social events*, meaning that the generation of knowledge results from the use of the prototype by users or stakeholders. Prototypes

[11] Designfakulteten, a Swedish research initiative involving design schools and design researchers. http://www.designfakulteten.kth.se. (accessed 2015-06-26, in my translation).

can also be understood as *articulations* of potential design solutions (Lawson 2005); research hypotheses (Joseph 2004); or of design knowledge that ”requires articulation, not necessarily in the form of written or spoken words, but in forms that can be appropriated and assessed by others” (Löwgren & Stolterman 2004:2); or of potential design solutions.

In design research, prototypes contribute to narrowing down and defining research questions. The open-ended and explorative approaches of many design research projects risk generating too much data, which becomes a problem for arriving at viable conclusions (Wang & Hannafin 2005; Joseph 2004). Where other researchers define their research questions in relation to published texts, the design researcher can use the design project and its prototypes as a way to arrive at relevant design questions (Joseph 2004).

> Designed artifacts are constructed such that they embody hypotheses about learning phenomena. […]The design researcher creates artifacts that embody these hypotheses and places them in the real world for testing. This perspective effectively narrows the set of potentially relevant research questions. (Joseph 2004).

Biggs suggests that prototypes are objects of desire for involved designers and design researchers. The principal feature of art and design research, according to Biggs, ”is not the employment of a particular method, but the desire or requirement to create artifacts and to present them as parts of the ‘answer’” (Biggs 2002:2). This might seem like an odd argument for prototyping and design research, but I want to include it here since my experience is that it captures the motivation of many designers and design students venturing into research. Creating artifacts is central to the self-understanding and professional ethos of designers in a way that academic writing is often not.

Real people and real-world settings

The next characteristic of design research is the participation of real people and the setting in real-world environments (DBRC 2003). In participatory design, designers (or design researchers) and users work side by side. Users and other stakeholders are invited as co-designers (Agger-Eriksen 2012; Beadouin-Lafon et al. 2002). This is both a way to acknowledge their expertise as members of a profession or organization, and a way to empower them as the future users of the systems or artifacts that are the outcome of the project.

Researching “in the wild”, in existing social settings, will often leave researchers confronted with issues of complexity and uncertainty. According to Schön (1983), the practical knowledge of the designer adapts well to such issues. Schön nurtured the ambition of establishing “an epistemology of practice implicit in the artistic, intuitive

processes which [designers and other] practitioners bring to situations of uncertainty, instability, uniqueness and value conflict" (Schön 1983:49).

On a more down-to-earth level, "real" people seldom behave as expected. "People have a tendency to use artifacts in ways which were not intended and are not controlled by the designer. Mixing artifacts with people also brings the phenomenon of 'now' into play" (Fällman 2005). The "now" of Fällman consists of people's meanings, presumptions, cultural values and beliefs. In having to account for people's opinions, design research finds itself closer to social science than to the natural sciences. Studying artifacts in use means studying the interactions between co-present persons and artifacts, with an eye to how cultural norms and knowledge shape interaction.

The locus of meaning-making

This represents a shift of focus from the designer as a maker of meaning to users as makers of meaning, and from the "now" of the designer at work to the "now" of future users engaging with the artifact. In the words of Dourish,"users, not designers, create and communicate meaning" (2006:170). He proposes that the designer should retain responsibility for the artifact, but abdicate from the responsibility for how future users will use it. Such a stance would "provide designers with a new set of problems and potential solutions. In particular, the designer's attention is now focused on the resources that a design should provide to users in order for them to appropriate the artifact and incorporate it into their practice "(Dourish 2006:173).

Krippendorff (2006) proposes a similar shift from designer to user in product semantics, which he defines as an inquiry into "how people attribute meaning to artifacts and interact with them accordingly," combined with a design methodology focusing on the meanings that artifacts "could acquire for their users and communities of their stakeholders" (Krippendorff and Butter 1989, in Krippendorff 2006:2). It is worth noting that meaning, in this context, is not necessarily verbal or conceptual. Krippendorff outlines several different channels for users' meaning-making, and one of these is how artifacts are used.

The points made by Dourish and Krippendorf can be summarized thus: *the locus of meaning making is where the users are.* Any intentions that the designer may have are meaningless as long as they do not feed into the meaning-making of users. This understanding of meaning-making is central also to the work presented in this thesis.

Ecologies of artifacts

In the previous chapter I touched on the designed environment as a repository of cultural products, with reference to Hutchins (2010). A similar perspective is taken in design research in discussing *ecologies of artifacts*: the literal or figurative presence of all the *other* artifacts that a new thing will be compared with, understood through, and contribute to making obsolete. Krippendorff suggests that users activate their

knowledge of related artifacts in forming their expectations of the new. Using an evolutionary metaphor, he groups artifacts into "species"[12] related through family resemblance, metaphorical connections, or as part of the same setting. The rich network of associative links between artifacts provides users with shortcuts for figuring out the genre and possible uses of a new thing: "its meaning is established through its possible interactions with other artifacts" (Krippendorff, 2006:198). This can also be used by the designer, who may learn about the prospects for a new artifact by observing related artifacts and the cultural practices of which they are a part.

Iteration

The next typical characteristic for design research is iteration: there will typically be many cycles of design, evaluation, theorizing and more design. There is no natural ending point. Iteration can be a way to acknowledge the serendipitous and non-linear aspects of design practice and creative work, in contrast to the linear and rational design processes that were advocated during the 1950s and 1960s (Gedenryd 1998; Koskinen 2011:15). A consequence of an iterative process is that it becomes hard to tell what came first: theory or research questions, conclusions or background.

Design knowledge

The last and most challenging point to explain is the notion of design knowledge. Design knowledge is primarily intended for designers and practitioners (Gaver 2012; DBRC 2003; see also Harvard 2004) and other stakeholders of design processes (Löwgren & Stolterman 2004; Krippendorff, 2006). As an "epistemology of practice" (Schön 1983), the format of design knowledge will have to share features with design practice in order to be applicable. In Human-computer interaction (HCI), the standard format for the outcomes of a design research project is a bullet point list entitled Implications for Design, often written for the purpose of translating the outcomes of a specific design project into de-contextualized, generalized design principles. The recommendations of Norman (1988) cited in the previous chapter can serve as an example (see p. 29).

The humble "implications for design" list may be upgraded to the status of a theory: "sharable theories communicating implications to educational designers" (DBRC 2003). Assigning the status of theory to design implications opens for epistemological

[12] In chapter 6 I will look at some specific interactions between related artifacts, but using the everyday notion of "genre" instead of "species". The function is the same: genres offer potential users a shortcut for forming their expectations about a new thing.

debates. Design theories may well support designers in creating successful designs, but they are not a guarantee for a satisfying result, and thus not falsifiable. This may qualify design theories as unscientific. Gaver stands up to defend design research and its theories by suggesting that "the theory produced from design practice tends to underspecify practice and to be generative in nature" and that it should be appreciated "for its proliferation of new realities, and its theory considered as annotation of the artefacts that are its fundamental achievement" (Gaver, 2012:941).

Gaver thus proposes annotated artifacts as a format for articulating design knowledge. This has been operationalized in the format of the *annotated portfolio* (ibid.). What the prototype on its own cannot communicate is filled in with commentaries and accounts of use, written in order to preserve ethnographic detail and information about context. This combination provides a richer and more useful knowledge than through the artifacts in isolation. A related way to conceive of the relation between prototype and knowledge is through a *repertoire*: through experience, the designer acquires a repertoire of things she knows how to do (Schön 1983).

Another way of conceiving of prototyping as knowledge generation is through the construction of a design space: "a representation of all possible solutions [,] the design space provides a conceptual tool representing what the design work is all about. It serves as something to aim ones intention at during the whole design process." (Westerlund 2005). Westerlund describes the prototypes and sketches as gestures towards the "not-yet-existing product." Conceptualizing the process as the construction of a design space is among other things a strategy for not zooming in on one solution too early in the process. Prototypes are created not with the intent to focus onto a solution, but as a strategy for expanding the space of possible solutions. A sketch or a prototype represents a point in a design space, where it is connected to other points through similarity or divergence. The salient point is that there should be many prototypes and many reference points in order to visualize the design space of possible solutions to a particular design problem.

Finally, the issue at stake is whether design theories are contingent on the concrete design projects within which they emerge, if they can be decontextualized into general recommendations, or if there are instead intermediate solutions with some degree of generalizability in combination with some contextual anchoring. Most design researchers seem to acknowledge the importance of maintaining the connection to the original context of the design recommendations, by offering "detailed accounts of use" (Fällman 2005; DBRC 2003). These may consist of thick, descriptive datasets, used as a base for analysis and consensus-building among the professionals targeted in the research (DBRC, 2003). Similarly, in participatory design it is a common approach to recycle ethnographic documentation in design workshops, where it is looked at and discussed in groups with participants from various backgrounds.

Applied to Ramsamsam

This was a brief introduction to design research, and I want to conclude it by pointing to how it comes into play in this thesis. The real people and real-life settings have been introduced briefly in chapter 2, and a more extensive description follows in chapter 5. The design work is presented in chapter 6. The outcome, in terms of design knowledge, is presented in chapter 10. The entire process has been iterative, and one of the difficulties in writing this thesis has been to draw the line between "background" and "outcome": every iteration is the outcome of the previous iteration and at the same time the background of the next. The timeline established in the thesis is a post-hoc construction and there are some inconsistencies related to this.

Design and enactment

The concept of *enactment* comes from design-based research in the learning sciences. DBRC (2003) proposes to make a distinction between design as an activity done by designers or educators, off-line, when planning for and preparing learning activities, and enactment as the online process of introducing and staging activities with a particular group of learners in a particular setting. Enactment is not done by the teacher in isolation, but is a product of the combined contributions of teachers, learners, and contextual factors. Identical designs can yield wildly different outcomes depending on enactment – and it is therefore important to document both in design research.

The distinction between design and enactment is modelled on the job of teachers (and design-based learning researchers) who alternate between the tasks of planning/ designing and the task of interacting with learners. I have, however, found it relevant also for "artifact designers" such as myself, as it articulates the difference between being off-line, in the studio, and interacting with prototypes together with "real people" in authentic settings. As I enter the leisure-time center with my equipment, video camera, prototypes, games etc., I become a part of the scene that I study. The advantage of this is that I can profit of being co-present: I can talk, explain, change my mind, react to other participants. The disadvantage is that the enactment is likely to be more important than the prototype *per se* for the outcome of the intervention. The proposal of the DBRC is that design-based research methods should "document and connect processes of enactment to outcomes of interest" in order to capture and communicate "how designs function in authentic settings" (DBRC, 2003:5), a proposal which I have found relevant and which has served as a guideline for how to report on the experiences from the field.

Visual arguments

Using video has been an important part of the research process, together with research methods related to design research (participant observation, prototyping). Using video in learning research is in itself a field of research (see for example Jordan & Hendersson 1995; Powell & Maher 2003; Koschmann et al. 2007; Derry et al. 2010). In the following section, I will focus on one specific aspect of video research: the transformation from video-recorded episodes of human interaction into two-dimensional, static graphic displays.

Visual displays present many advantages to the researcher. They are mobile, flat, immutable, scalable, reproducible, recombinable and superimposable. They can be inserted into texts, and merged with geometry (Latour 1986:19-20). They give the scientist the important advantage of *showing* instead of just telling:

> "You doubt of what I say? I'll show you." And, without moving more than a few inches, I unfold in front of your eyes figures, diagrams, plates, texts, silhouettes, and then and there present things that are far away and with which some sort of two-way connection has now been established (Latour 1986:13).

So what are these visual displays within embodied interaction and neighbouring fields? (For design research, this question has been addressed earlier in this chapter, in the sections on prototyping and design knowledge, p. 42). In Conversational Analysis, the "visible, gazing body, and the orientation of participants toward each other as they co-produce states of talk is central" (Goodwin 2000a:162). The visual displays produced with this focus are often transcriptions of dialogue with supplementary visual information through frame grabs or drawings based on these, see for example Björk Willen (2007) and Melander (2009). The ethnomethodological approach focuses less on talk and bodies and more on "images, diagrams, graphs and other visual practices used by scientists to construct the crucial visual working environments of their disciplines"[13] (Goodwin 2000b:162). The visual representations produced in such studies contain transcribed speech, but it is often deconstructed into multi-layered diagrams of visible bodies, talk, gaze, gesture, intonation or other aspects. The collection of diagrams and visualizations of two girls playing hopskotch in Goodwin (2000a), originally from Harness Goodwin (1985), is a good example. Another is Steffensen's cognitive event analysis of two office clerks solving a problem with a faulty invoice (2013). This episode is rendered and analyzed through several different visualizations and diagrams: frame grabs with graphic

[13] It should be added that there are also ethnomethodological studies of non-scientists: salespersons, family members, auctioneers and office clerks. The anthology Embodied Interaction (2011) offers many interesting examples.

overlays describing the setting, diagrams of speech and joint attention, photos of the invoice that is at the source of the episode. As in the previous example, the timeline has been broken up, and starts in the middle at the pivotal moment of agreeing what to do with the invoice.

The rich array of contextual information and different visualizations in Steffensen's analysis refers to the principle of ecological assemblies (see p. 33). As problem-solvers use "whatever mix of problem-solving resources [that] will yield an acceptable result," Steffensen argues, "there is no apriori way of delineating what ought [to be] investigated as contributing to the emergence of a solution" (Steffensen 2013:218). Consequently, the episode is rendered in many layers unfolding around the pivotal moment. But this is not the whole picture. Non-situated elements "including sociocultural resources, verbal patterns, narratives, memorised procedures, and autobiographical memory" (ibid.) may also contribute to the interaction within the episode under scrutiny. This presents the situated analyst with a problem: how can she account for the non-situated elements in analyzing a communicative scene? The question raised by Steffensen is also relevant for the other examples discussed here, including my own study. The solution proposed in design research, and adopted in Ramsamsam, is to combine detail with overview and to provide an ethnographic account of the setting together with in-depth analysis of selected episodes. The analysis here is T-shaped, combining parts that are broad and descriptive (chapter 5) with in-depth analysis of short events (chapter 8).

Another issue in translating moving images into static displays is how to represent movement. Goodwin (2000a) and Melander (2009) use arrows. I have opted for another strategy, using sequences of frame grabs instead of single images. The aim is not to capture the outline of specific movements, but to provide an understanding of the patterns and scope of participants' movements.

An important part of the visual environment in which the visual displays have been produced is the interface of the ELAN software[14], which I have used for browsing and annotating the video data. In ELAN, video clips may be commented coded in many superimposed tracks (or "tiers"), ressembling a musical score. The unit in ELAN is not points in time but segments of the video data. In this way, I have had tools for identifying segments with participants finding sets, smiling, joining or leaving the activity. These segments can be exported as lists of entry and exit points for further analysis in Excel or a statistics software. I have, however, mainly used ELAN as a browsing tool, enabling me to compare many instances of similar behavior.

[14] https://tla.mpi.nl/tools/tla-tools/elan/ (accessed 2015-10-09).

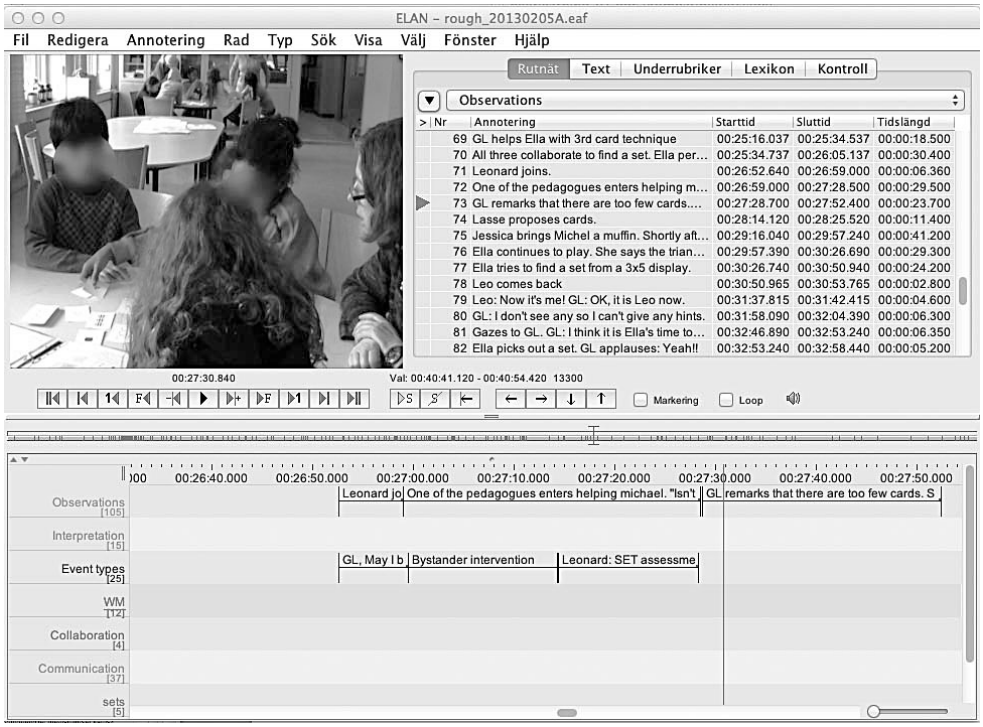

Figure 4-1. Looking at and annotating videos through the ELAN interface.

As in the cognitive event analysis of Steffensen, I have produced many different visualizations with different degree of detail, often of the same episodes (see chapter 8). Some of them have been produced not to demonstrate a particular point but rather as visual explorations of the data material, leading either to some interesting discoveries or to nothing special. This method led to my finding about the large number of observers at the leisure-time center, and the absence of casual observers during lesson time (figure 9-2).

The two representations of participation over time in the beginning of chapter 9 are more or less direct applications of formats for data visualizations described by Tufte (in Grady 2006). The format of *small multiples* (figure 9-2) permits ”viewers to visualize variation and change by comparing two or more sets of data displayed on a similar template” (Grady 2006:237). Tufte advocates non-naturalistic approaches, mixing spatial data with statistics, or creating spatiotemporal overlays. *Visual narratives* combine spatial and temporal dimensions – often an eclectic mix of visible and non-visible data. Figure 9-1 is an attempt at creating a mixed visual narrative.

There are several perspectives that can be taken on visual displays as parts of research. Researchers in Science and Technology Studies – one of them is Bruno Latour, whom I cited earlier in this section – have studied how researchers transform living tissue

into visual displays: ”Bleeding and screaming rats are quickly dispatched. What is extracted from them is a tiny set of figures” (Latour 1986:15).

> Manifestly, what scientists laboriously piece together, pick up in their hands, measure, show to one another, argue about, and circulate to others in their communities are not “natural objects” independent of cultural processes and literary forms. They are extracts, “tissue cultures,” and residues impressed within graphic matrices; ordered, shaped, and filtered samples; carefully aligned photographic traces and chart recordings; and verbal accounts (Woolgar & Lynch 1990, in Goodwin 2000a:8).

Edward Tufte, on the other hand, is more concerned with the transformations of textual data into visual: ”a wide array of graphic displays can be used to make different kinds of points or arguments more effectively, clearly, and in less space than is needed in either exclusively verbal or written communication (Tufte, in Grady 2006:224).

The visual format is not only a way to present research findings, but a way to arrive at them. As pointed out by Melander (2009), they reflect the orientation and interest of the researcher at a specific moment, and she describes the relation between producing visual displays and analyzing data as a two-way influence, a “recursive interplay between analysis and methods of description” (Melander 2009:45). Visual displays “are essential to how scientific objects and orderly relationships are revealed and made analyzable” (Lynch 1990:153-154). In Grady’s presentation of Tufte,”Tufte suggests that visual displays are important not just because they confirm or disconfirm testable theories, but because they also generate knowledge that would be unavailable any other way” (Grady 2006:223). I will finish this introduction to the visual format of the analysis by subscribing to this vision. In this thesis, the visual displays – which includes all the illustrations in the thesis - have been instrumental for the analysis; it is made through them, and they preceded both the written text and its conclusions.

5. The setting

In this chapter, I will describe the backdrop for the video-recorded episodes that will be analyzed later: the institution, its architecture and daily routines, the role of games, and other activities at the LTC – in short, things that frame and constrain the interaction in the episodes that will be analyzed later.

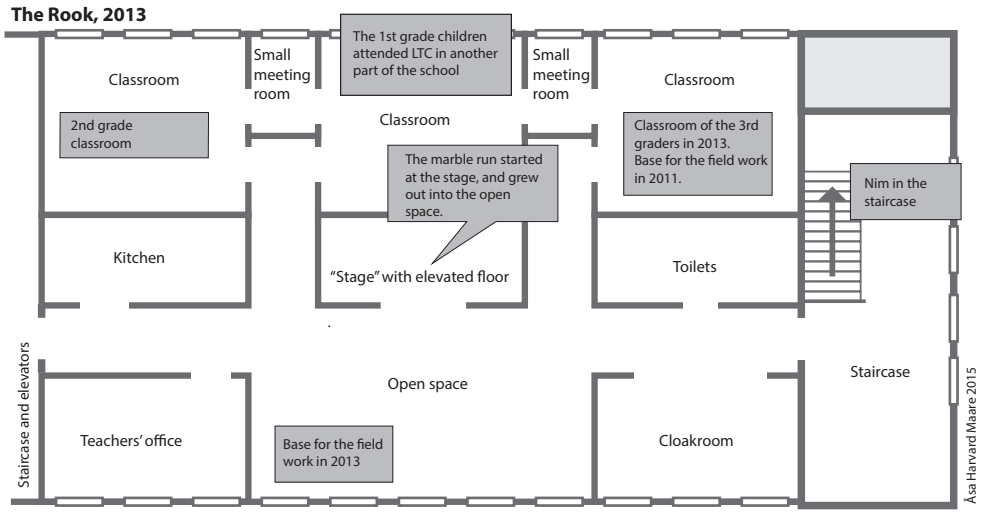

Figure 5-1. A plan over the classrooms and the leisure-time center.

The Rook

The Rook is an inner city primary school, from preschool class until year 9. The majority of the children in the school are second-generation immigrants, born in Sweden to parents born abroad. The building is modern, with three aisles rows surrounding a schoolyard opening towards a park, and the architecture reflects concerns about pedagogical and social aspects: there are no corridors, and teachers have their offices in close proximity of the spaces where children spend their recess.

In the department where I did my study, most children were second-language learners. There was no dominating minority language, and Swedish was the shared

language that children used for communicating and playing together. The children in the group I met spoke Polish, Bosnian, Arabic, Russian, Cantonese, English, Hungarian and Roumanian. There were also several bilingual children in the group, for example a girl with Arabic and Russian as her two family languages.

The part of the school where I did my study spanned the space between two staircases. The space contained three classrooms, small meeting rooms, an open space used by the leisure-time center, teachers' offices, a kitchenette, toilets, and cloakroom for the children (figure 5-1). All facilities were used both during the school day and for the LTC. The personal space for each child included a table in the classroom, and a space in the cloakroom for jackets, boots, and an extra set of clothes. At the Rook, children were not allowed to bring personal toys or mobile phones to school. Two of the classes attended this section of the leisure-time center, the second grade and third grade classes. Some of the LTC teachers also taught during school.

Figure 5-2. The open space The open space is the base for the leisure-time center. From the open space you can reach the classrooms, toilet, cloakrooms and exit. The open space is often used for smaller groups or project work during school lessons. Games are kept in the white bookshelf between the two windows to the right in this photo.

The open space (figure 5-2) is at the center of the leisure-time center activities. Children and teachers meet here to plan for the day, and many of the LTC activities unfold at the tables in the open space. It is often reconfigured; sofa corners, tables, and corners dedicated to different projects can be moved around. The teachers are able to create places and corners for various activities such as exhibitions of projects, Christmas or Easter decorations, Lego or Plusplus corners. With the exception of these special projects, the general rule is that things are to be put back in their places at the end of the day.

The activity at the LTC follows a fixed routine similar to that of school. Even if children are free to choose between activities, they are expected to follow the daily routine and keep an eye on the clock. This is also a part of the learning at the LTC (Lotta, in interview 2013-05-07). Children arrive to the LTC between noon and 2 pm. Around 2 pm, a snack is served in the dining hall, followed by outdoor play for about 30 minutes. At 2:30 children and teachers gather in the open space for a short meeting before breaking up into the various activity groups. In addition to the general LTC activities, there are scheduled weekly activities which children may sign up for: computer workshop, gymnastics, or dance. Most children leave around 4 pm, and the leisure-time center closes at 5 pm.

Activities on offer

Children in the LTC are free to choose what to do, but their choices are constrained by the availability of the activities.

- Games are a popular activity at the Rook: board games, card games, table tennis, Couronne, pedagogic games practicing letters and numbers.
- Outdoor play is part of the daily routine of the LTC for a minimum time but children are free to spend more time playing outdoors. Some groups of children spend a lot of their time playing football or other ball games in the schoolyard.
- Scheduled activities: sports, handicrafts, cooking, computer workshop. Children can sign up for these activities which are scheduled once a week.
- Creative materials. There is a wide array of colors, paper, pens, and creative materials available to the children. Many children engage in coloring pictures, often A4-sheets downloaded from the internet, representing popular characters from animated films or computer games.
- Seasonal projects and special projects. Easter decorations or Christmas gifts. Special projects in relation to themes in the education.

- Clothes and play furniture for fantasy/family role-playing. However I never saw children playing in the role-playing corner.

Outside of the computer workshop, there were no computers or Ipads available for the children at the leisure-time center. Still, computer games and digital media were one of the topics discussed by children. In the 2011 field studies, some of the participants expected our project to be about computer games and backed out as they realized that this was not the case.

When it came to prioritizing between the activities on offer, many considerations were at play. The scheduled activities, among them the computer workshop, were popular and a first choice for participants. Decisions were made based on which other children were present, and children usually chose activities in order to be with friends. Weather had an impact, too: the time set aside for my field studies fell in a period of cold and gray weather, throughout February and part of March. Finally, in the middle of March, the sun came back and the temperature rose; all children went outside to play. Jackets and coats were thrown off and lay in piles on the tables and benches of the schoolyard. As the warm weather came, no one wanted to spend time indoors with mathematics games.

Introducing new activities at the LTC

During the weeks before Easter, Lotta started the preparations for making Easter decorations. She took out materials, arranged them on a big table, sat down and started to craft Easter decorations. Very soon, a group of children joined her. As I arrived at the Rook with my mathematical artifacts, I followed the same procedure. Lotta and Pernilla helped me by talking to a few children who they knew were usually receptive to new activities.

> It is incredibly important who says that something is fun or not. If the right child says that this is incredibly boring, they can sabotage any game regardless of how much fun it might actually be. If I start playing with a child and we have fun, maybe other children will come and join us. Then even more children will come. If you want to introduce a new activity or game, you start it up with a few children. After that, they learn from each other. They [experienced children] explain the rules to the new children, as they understand them. This is often different from my own way of explaining, which goes many steps ahead (Lotta, in interview 2013-05-07).

Still, Lotta and Pernilla tell me that it is hard to know beforehand which activities will be adopted by the peer group, and which activities will not. The social processes determining the success of an activity are often unpredictable.

Figure 5-3. The Marble Run. Over the winter vacation, the the marble run was the most visible project in the LTC.

In the middle of February, school closed for one week for winter vacation, but the LTC remained open. About half of the children attended the leisure-time center during the vacation week. During this week, the atmosphere at the LTC changed. There were fewer people around, and more uninterrupted time for engaging in the various activities. Both teachers and children gave the impression of being more relaxed.

One event marked the winter vacation at the Rook: the marble run, a construction toy for building tracks for marbles. It was a recent purchase of the teachers, and it was introduced a few days before the winter vacation started. In the beginning, Lasse was part of building the marble run, but as a core group formed around the project he backed off. The marble run kept growing throughout the week, from the "stage" area (see figure 5-3) out into the open space. As it was a vacation, the marble run was allowed to grow and remain over the entire period. Furniture and other toys were used to support the structure. Most of the children spending their vacation at the

LTC engaged in it in some way. The core group, about four boys, spent all their time in building and perfecting the marble run, trying it out with marbles of different weights and sizes. The LTC during the vacation changed, and children were allowed to control and occupy the space in other ways than were possible during the school semester. My project moved out into the staircase (see chapter 7).

One reason for describing the the marble run is that it changed from a teacher-initiated project to a peer-driven project – in contrast to the game prototypes that I introduced. At the start, children and teacher worked side by side until there was a group that could take charge of the project. Another factor that may have contributed to the children's interest and engagement was that the activity in itself was interesting (sometimes constructing, sometimes testing marbles), that it allowed for peripheral participation (testing marbles without interfering with the construction, or adding new parts at the periphery of the the marble run) and, not least, its visibility: there was no way to get past it without noticing.

Mathematics lessons

Eva and her colleague Krister shared the mathematics teaching between them. Krister had the responsibility for planning the mathematics lessons. My field studies fell right before the year 3 national tests in mathematics. All mathematics lessons during February and March had to be reserved for preparing the children for the tests. Eva told me that many of the children in her class found it difficult to read and apply written instructions, and hence to solve mathematical "word problems".

Figure 5-4. *Left:* Numbers in many shapes on the whiteboard in the classroom of 3A. *Right:* Wooden Dienes' blocks in the classroom of 3A. In the background, a container with another mathematical manipulable: dried beans.

I sat in on two math lessons, one with Eva and the other one with Krister. In Eva's lesson, the topic was word problems. Eva explained the different steps in solving a word problem: *"Read the task. Extract the problem. Make a simple drawing of the problem. Think about what method to use. Addition? Multiplication? Subtraction? Then calculate. Formulate an answer. Write down the answer."*

The problem in the mathematics book was the following: *"Julia will be 8 years old in 2017. In which year was she born?"* In the discussion many of the children proposed different methods for solving the problem. None of the children managed to identify that the problem involved subtraction, and in the end Eva had to tell the children how to solve the problem step by step.

Krister's classroom, downstairs, had math- and science-related posters and formulas hanging on all the walls, all the way to the ceiling. One of the children told me, on a positive note, that the same posters and illustrations had been hanging there since he started his first year in school. As I entered the classroom, Krister was engaged in a discussion with some of the children about the advantages of different mobile phones.

All children had a handful of centicubes at their desk. There were also centicubes at the overhead projector. The topic of the lesson was division, and the problem proposed by the teacher was dividing 24 by 6. The children were asked to show how it is done using the centicubes, and Franz is invited to show it to the class at the overhead projector. Krister asked how they would explain 24 ÷ 6 to somebody that does not know. Greger proposed the example of 6 children having to share 24 candies. At the end of the lesson Krister repeats the names of mathematical concepts: sum, product, difference, quota, addition, subtraction, multiplication, division.

From the back of the classroom I could follow how two of the girls disengaged with the mathematics lesson. They were making drawings and whispering to each other. The same girls had earlier explained to me that they hated mathematics, and they did not volunteer to play Set or Nim during my field studies.

As teachers feel compelled to prepare their pupils for the national tests, these tests will set the standard for how to teach mathematics - something that became apparent during the mathematics lessons I visited. The national tests for Swedish have two versions, one for native Swedish speakers and one for second-language learners, whereas the mathematics test only has one version. Petersson (2012) has shown that in the year 9 national test, second-language learners have difficulties with those parts that involve reading. This is likely to be the case also in the year 3 national tests.

Playing games at the leisure-time center

Figure 5-5. Board games at the Rook (photo: Niclas Bränström). The teachers told me that children enjoy playing games, but teachers seldom have the time to join children playing.

Games are popular and part of the standard activites offered at leisure-time centers (Sparrman, 2002), and the Rook is no exception. Games are kept on a shelf in the open space where all children can find and use them. Booklets with rules for the games are kept in a special binder in a locked cupboard.

The game played most frequently, according to the teachers and my own observations, was Uno. It could be played without support from teachers or adults. Uno cards - from several decks, as cards get lost from time to time - were kept in a plastic container. When a group of children wanted to play Uno, they took an appropriate number of cards from this container. Another popular game was the Lost Diamond (Jakten på den försvunna diamanten). In 2011, it was one of the games that children wanted to play with us. The rules are complex, and only a few were able to play the game without the support of adults or teachers. I will return later to how children solved the problem of not being able to read the rules of the game.

I had a conversation with LTC teachers Lotta and Pernilla about games at the LTC. They told me that children often want to play games, but that teachers seldom have time to play. New games have a tendency to remain unopened in their boxes since

nobody has the time to open them and read through the rules. Many of the games at the Rook are too complex for children to play without an adult participant.

In 2011, when the children were in first grade, I talked to Eva about games and learning. Eva mentioned a number of things that her class could learn from playing games: turn-taking, following rules, communication, and finally learning to be a good loser. We also discussed what children were engaged with during the mathematics lessons, and which aspects a math game could capitalize on, or provide training in: simple additions, 10-friends[15], doubles, counting from 1 to 20.

Figure 5-6. Rules and games. Booklets of game rules are kept in a binder behind locked glass doors, as shown in the picture to the left. Uno, the most popular game at the Rook: several incomplete decks of Uno are gathered in a single plastic container.

Hundreds or thousands

In many of the video recordings from 2011, children don't distinguish between hundreds and thousands in referring to play money. It is hard to tell whether they are aware of the difference, as in the example of Tony and Jenny playing the Lost Diamond. In the game there are bills of 1000 and 10 000. Jenny refers to the 1000 bills as "hundreds" or "thousands" interchangeably. Tony does not protest, and he even follows Jenny's lead by calling the 1000 bill "hundred". When Jenny reaches out for a 1000, but actually grabs a 10 000 bill, Tony protests, and changes the 10 000 bill for a 1000 bill (20110315_LD).

Jenny was not alone in mixing up hundreds and thousands. In order to find out more, we prepared a paper-based assignment to probe their understanding of 100's

[15] 10-friends: Two numbers whose sum is 10. Doubles: multiplying by two.

and 1000's (see figure 5-8). The text is the following: *"This is what four potential buyers are offering for the diamond you have found. To whom would you sell it?"*

Sofi, Niclas and I sat with the group of children as they worked with the assignment, and took part in the discussion. One boy said that he *knew* that a bill of 10 000 was more, but that 10 bills of 200 *felt* like more. He resolved this by making two crosses at his paper. Several of the other children shared his point of view, and adopted the same solution: putting two crosses at their papers.

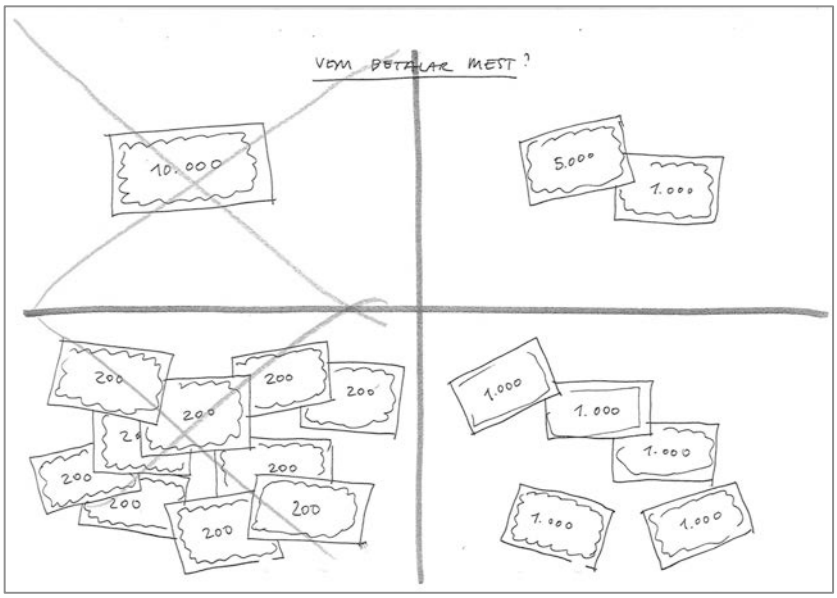

Figure 5-8. Who pays the most? *"This is what four potential buyers are offering for the diamond you have found. To whom would you sell it?"* Several of the respondents chose to give two answers, one for the largest amount of money and another for the largest number of bills.

There are two conclusions to draw from this experiment. The first is that the children are in between understanding quantity as the total number of bills and quantity as the value of the bills. The second is that viable solutions to shared problems spread through observation in the peer group.

Local rules

When playing, children often need help to read and apply rules. When no help is available, the solution may be to invent new rules. A teacher for the first grade children mentioned another reason for inventing rules: modifying the level of difficulty of a game. He told about a group of children that were engaged in playing Couronne over a longer period. Couronne is a downscaled version of pool, with

wooden rings instead of balls. As the children started playing the game, it was too difficult for them to play by the original rules. They invented an easier version of the game. Little by little, the players got better at it and the rules had to be modified again in order to match the improving skill level of the players. Tony and Freja demonstrate the local rules in a videoclip (2011-03-15_CO, see chapter 7).

> Åsa: If players make up their own rules, isn't there a risk of disagreement? What if they think differently?
>
> Freja: Yes, but not if you have the same…the same…what is it called…the same thoughts in your mind, then you don't disagree. (2011-03-09)

The Lost Diamond game offered many examples of local rules as well, invented in the absence of the written rules and often based on reinterpretations of the visual symbols on the game pieces and the board.

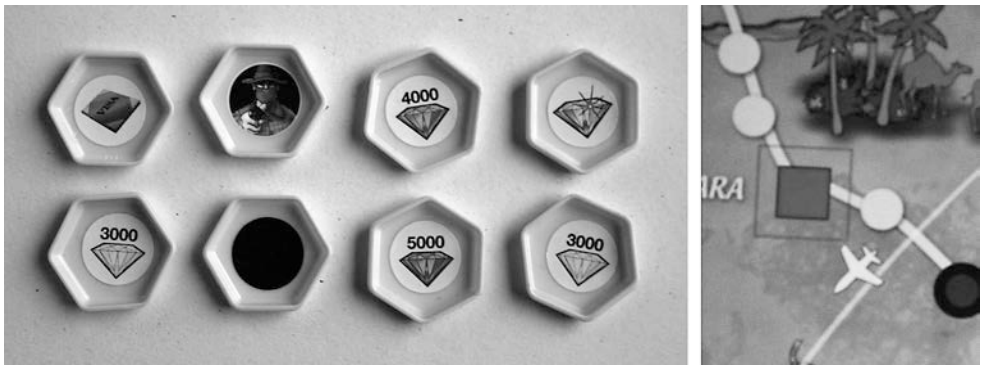

Figure 5-9. Examples of local rules based on reinterpretations of the visual symbols in the Lost Diamond: Visa (upper left) airplane ticket, allows its owner to fly for free. The black circle: "fall into the well and loose all one's money": the reinterpretation mirrors that of the thief. To the right: Air traffic routes: the reinterpretation states that they are one-way, in the direction of the symbol of the airplane.

The children that I talked to and played with had no difficulty in relating to multiple sets of rules. Inventing local rules was not a matter of not understanding or not knowing that there exist "printed rules". The printed rules demanded the extra resource of a participating adult (see figure 5-10), and in absence of this, local rules were invented.

> Freja: When a person has found the diamond, she can take the airplane home! But in the *real* rules it is the person who arrives home first that wins (Freja in conversation, 2011-03-09).

There has to be agreement about rules among the players. A strategy used when inventing local rules was to create them based on the visual symbols in the game. In this way, the rules acquired a visual presence for all players. Figure 5-9 presents some examples of local rules built from reinterpretations of the available visual symbols in the Lost Diamond game.

Figure 5-10. Tony points at Cape Town and says: You get 500 when you arrive here. I reach out for the booklet with rules to check what the rules say: "The player that arrives first to Cape Town receives 5000 from the bank". I ask who arrived first at Cape Town. Virginia answers: "I did!" Tony (playfully): "Why did I tell them! I'm an idiot!"

The uses of games

> [T]wo prizefighters […] are engaged in cooperative collective behavior at a higher level, within which the antagonistic hostile behavior can take place (Searle 1996:24).

Playing a game is a collaborative accomplishment. The group has a joint goal, which is to play the game until the end. In order to play the game successfully, it must be at the right level: not too difficult – that would cause a break-down – and not too easy, in which case there is no winner.

Board games offer many interactional qualities besides winning; they frame interaction. Within the span of the game, many actions are made meaningful. They afford mastery and skilled participation. Games offer opportunities for emotional displays including the exaggerated display of emotions which are not commonly seen outside of games, such as the display of joy and satisfaction at anther player's misfortune. Games are often used as toys for playing *with* (Sparrman, 2002; see also 2011). Sparrman points out that "playing with games," i.e. using games as a collection of toys, invites children to interpret and negotiate the visual symbols of the game.

There are many ways of playing a game: competitive, explorative, for practice, as a form of play – and the use of rules depends on what the players use the game for. However, the experience from the Rook points to a problem with many game rules, as the way they are written often made them inaccessible to children at the LTC, or made the playing of the game dependent on support from adults or teachers.

Figure 5-11. Exploring children's preferences of visual style. A collection of pictures from children's media were displayed on a table. Children arrived after a break, in small groups, and we gave them stickers with smileys/dislikes to attach to images that they liked or disliked (2011).

Peer influence and visual style

A topic often discussed in peer groups of children is identity and style (Sparrman 2002; Änggård 2005). Visual artifacts are used for expressing children's identities and subgroup affiliations. In 2011, Niclas, Sofi, and I undertook some activities in order to probe visual style from a children's perspective. We assembled a collection of pictures from children's mass media: computer game graphics, patterns, comic book characters, child-related brands. The images were printed on A3 paper and displayed on a table in the classroom. Each participant entering the room was given six stickers, three with a smiley and three with a sad face. We asked them to put the stickers on the images that they liked, or disliked.

The first group of children placed their stickers, and then proceeded to play a game. As new children came in and placed their stickers, the first participants returned to check which images had been chosen by the other children. If the newcomers had chosen other images, many of the first participants decided to move their stickers in order to align with the opinion of the others. In some occasions, moving stickers to new positions was based in misperceptions: some of the girls started by putting their smiley stickers on Hello Kitty. Later, some boys put their dislike stickers on Hello Kitty. As the girls returned, they saw the dislikes, but could not see who had put them there – and decided move *their* smileys to other pictures too. After all the children had placed their stickers, it was the Manga-style illustrations of boy heroes which had

collected almost all the smiley stickers, whereas the popular children's books characters of Pettson and Findus had only dislikes.

The outcome of this activity was certainly due to the format in which children were allowed to come and go, to see the answers of other children and then modify their own answers. Modifying answers was not something we specifically allowed; we had simply not foreseen that this would happen. Still, the outcome points to the same processes as the hundreds/thousands task: children were attentive to the opinions of peers, and ready to change their own answers in order to align with the group. Furthermore, there is something to be learned by the many dislikes assigned to Pettson and Findus: preferences in visual style are part of identity work (Sparrman, 2002) and, in a peer group context, children avoid expressions that may be perceived as "childish." As a consequence, child-related visual styles are rejected in favor of more teenage-oriented visual styles.

6. Design

In this part of the analysis, the designed prototypes will be presented. They are organized into two genres: mathematical manipulatives and combinatorial games.

Mathematical manipulatives

The prototypes for the first version of Ramsamsam, in 2011, were within the genre of mathematical manipulatives: material objects with shape and weight, embodying mathematical relationships. The choice of genre reflects how I, at that point, envisioned mathematics learning at the leisure-time center: hands-on, practical and social. I wanted to explore how the manipulation of three-dimensional objects could contribute to making the thinking of one learner visible to others.

The pedagogical foundation for using mathematical manipulatives was formulated by Piaget, Montessori and Bruner among others (Uttal et al. 1997), and it builds upon the assumption of children's preference for the concrete and sensory. Through mathematical manipulatives, learners should be helped in finding connections between the concrete object, the abstract concept, and the written mathematical expression. It is not clear whether this aim has truly been met, partly because the manipulative in itself adds an extra layer of representation (ibid.).

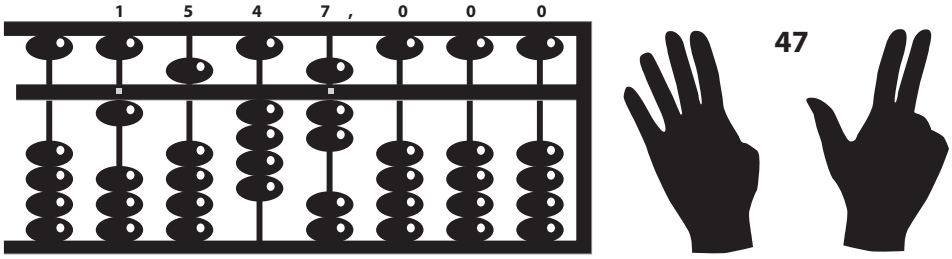

Figure 6-1. A Japanese "Soroban" abacus, and the Chisen-bop finger counting technique: both part of the inspiration for the "missing 10" structure of the Marbles Calculator and the 100-cards. A Soroban has four beads with the value 1, and one bead with the value 5. Beads count when pushed towards the middle bar. Chisen-bop uses a similar way of mapping numbers: on each hand, the thumb counts as five and the other fingers count as one.

For the prototypes in 2011, I designed shapes using Adobe Illustrator and had them cut in MDF board using a laser cutter. The game boards had holes for placing marbles. I also designed playing cards using a design similar to that of the game boards.

The Marbles Calculator and the 100-cards

The Marbles Calculator allows the user to add numbers up to 1000 by placing marbles on a multilevel game board with nine holes in each of the three levels. As one level fills up, the 10th marble is added to the level above and the nine marbles below are cleared. The Marbles Calculator was accompanied by playing cards using the same metaphor for the base-10 system.

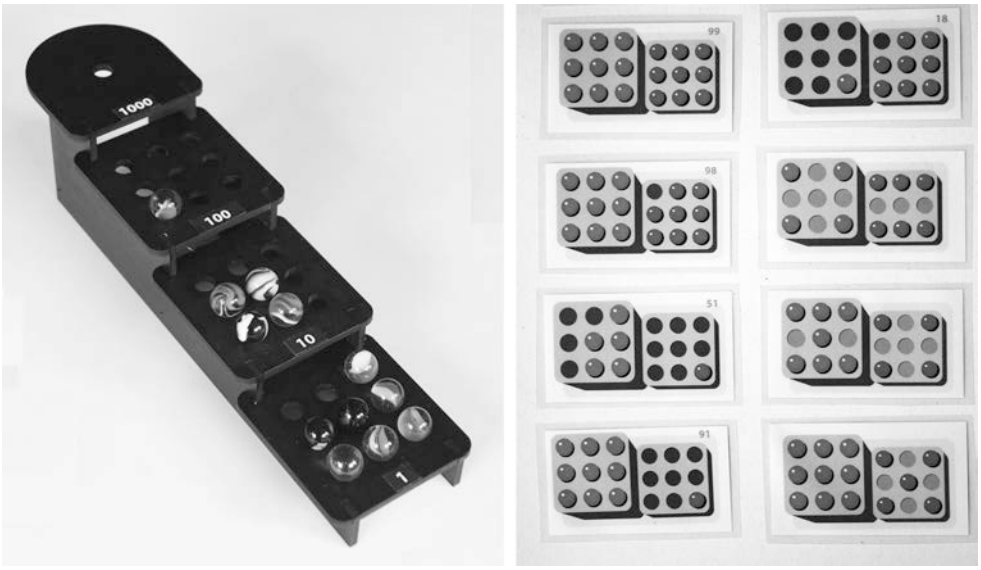

Figure 6-2. The Marbles Calculator and 100-cards. In the card version the marbles were color coded: red for ones, green for tens.

We used the Marbles Calculator for playing a math game of addition inspired by the Squares Family game (Pareto 2004). The first attempts at playing the game illuminated many flaws both in the prototype and in the game. The marbles were made of plastic, and were originally part of a Chinese Checkers game. They were very light, and with even a gentle push on the gameboard they would pop out of the holes and start rolling off the table and down on the floor.

Players earned points as they shifted from the level of ones to the level of tens, or from tens to hundreds. This involved emptying the lower level of its marbles. As players were gaining points and at the same time removing marbles from the game

board, they kept the removed marbles as something they had won rather than eventually returning them to the board. This way of playing quickly drained the game of all its marbles. In addition, the children who managed to calculate using the Marbles Calculator actually added the numbers mentally first, before updating the counter. The Marbles Calculator did not facilitate addition, but obstructed it. A few weeks after the first try, I brought it once again, as a revised version – but the participating children did not agree to play it a second time.

he 100-cards, however, were better received by our participants. Some of the children used them for playing other games, instead of dice. The cards were also used for finding pairs of numbers whose sum is 100 (43 and 57, 20 and 80 etc.). Over a few weeks, I experimented with different versions of the 100-cards: with numbers, with illustrations, with supplementary information about multiplication, triangle/square numbers etc.

Figure 6-3. First version of the Marbles Calculator and the 100-cards. Using the marbles counter put high demands on dexterity: just a small push and marbles started rolling around (2011).

In the following episode, Urban is looking at the cards while thinking about what the different symbols mean. Niclas is holding the camera and listening to Urban, who is, as far as I can judge, both thinking aloud and putting forward his theories for Niclas (figure 6-4). Urban forms a hypothesis about the color green indicating odd numbers and the color red indicating even numbers. He abandons this idea a little later (in the card design, green is used for tens and red for ones) but the process of exploring the symbols and colors in order to make sense of the game is an example of a ”literal” way of interpreting and assigning meaning to visual symbols.

Figure 6-4. Urban quietly reads the text on the card: 91 is an odd number. He says: “This is an odd number”. Then, looking at another card, “Strange!”. He looks at two more cards, pointing at them with his hands. “These are all even numbers. Even numbers. Niclas, who holds the camera, asks him what numbers were even. Urban responds that the red numbers were even. He fills in: ”I can see that. Two is an even number. Six is an even number. But the green cards are uneven”.

I have included this episode as an example of children’s consequent and constructive effort to read and make sense of visual symbols as part of visual artifacts.

Figure 6-5. Concept sketch for illustrated 100-cards, including some of the cards that Urban interprets in the previous example.

The 100-board

The 100-board is a variation on the Marbles Calculator. The 100 board starts with 0 in the bottom left and advances towards 99 in the upper right corner. It was was used for playing the same addition game as the Marbles Calculator. It has many practical advantages compared to the Marbles Calculator: it can be used with a single marble, which is moved upwards for adding tens and from left to right for adding ones. This prototype can facilitate addition and subtraction by projecting these as horizontal or vertical movements in the two-dimensional number space. The design was inspired by Furness (2001), and, besides addition, it has also been used for building patterns using multiplication tables: vertical lines of the 2 times table, oblique lines of the 3 times table, an X of the combined times tables of 9 and 11.

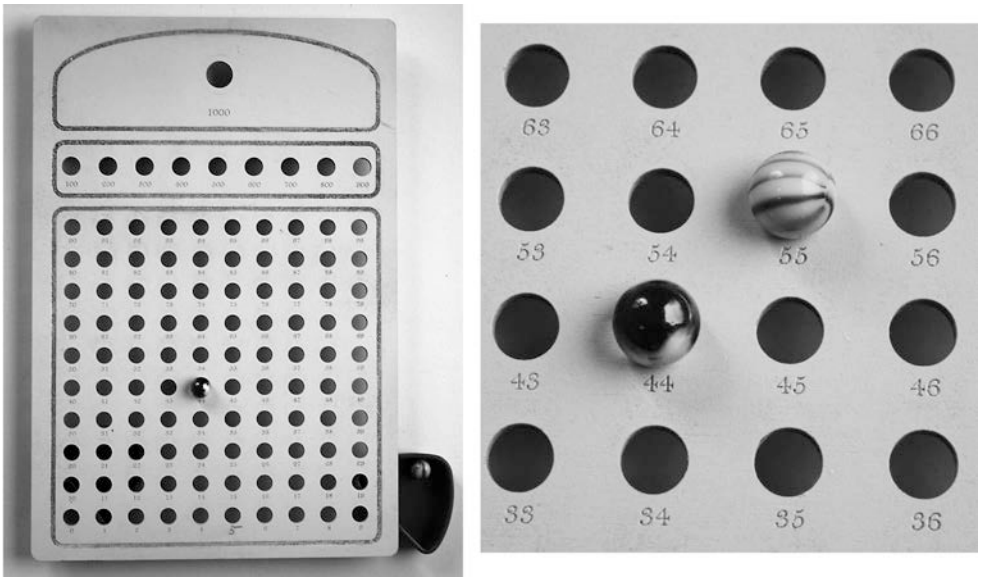

Figure 6-6. The 100-board, overview and detail. The size is about an A3: 30 x 42 centimeters. Numbers start with 0 in the bottom left corner and end with 99 in the upper right corner. The upper space contain a place for each 100 and the uppermost is 1000.

Reflections on the 2011 prototypes

During the visits by me and my students to the Rook, we discovered that the classroom of 1A contained an impressive collection of mathematical manipulables: Dienes blocks, role-playing dice, balances, centicubes, flash cards and card games, abacuses, etc (see figure 5-4). If we had previously imagined that there was a void in the math learning - and in the classroom - that could be filled with new mathematical manipulatives, we were mistaken. Furthermore, the marbles calculator and the 100-

board tapped into a kind of assignment which the participants associated with mathematics class, and for this reason was met with resistance. We were told that the games were boring, and some children declared that they hated mathematics.

As I mentioned at the start of this chapter, I was interested in mathematical manipulatives because of their potential for making thinking visible to observers. In fact, the playing cards proved to be just as good as the physical manipulables in this respect. Certainly, the playing cards are not affording sensory feedback in the same way as marbles or Dienes' blocks, but they are still manipulable and combinable – and the marbles (as printed shapes) stay in place regardless of how the cards are tilted.

Another important finding from the 2011 field studies was how children engage in interpreting and making sense of visual symbols, modifying rules, and using the visual symbols for anchoring rules and sense-making. Related to this, a second important finding was the shortcoming of conventional games' rules in assisting children to figure out how to play a game and agree on its rules.

The point made by Uttal et al. (1997) on the concretion and detail of a physical object as an obstacle when attending to its representational content is applicable to the marbles counter, which provided an additional source of distraction: trying to stop the marbles from rolling around.

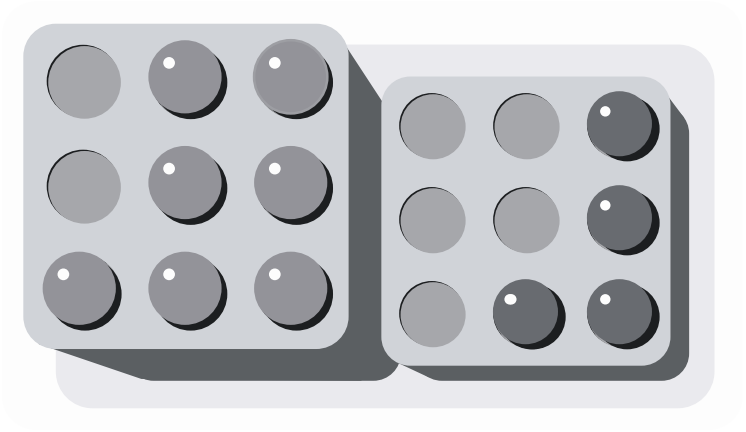

Figure 6-7: A 100-card: seven tens on the upper level, four ones on the lower level.

Combinatorial mathematical games

Combinatorial mathematical games are games with "no chance and no hidden information."[16] Since there is no chance involved, players are nudged into thinking logically instead of hoping for luck. Since no information is hidden, all participants - players and observers - have access to the same information. Examples of the genre are The Towers of Hanoi, Chess, Kalaha or Tic-tac-toe. The history of combinatorial games is connected to that of recreational mathematics (Gardner 2001), and many games have a history as mathematical demonstrators. The game Towers of Hanoi is neither traditional nor Asian, but a mathematical puzzle created by the 19th century French mathematician, Édouard Lucas (Wells 2012). The same applies to Nim, which is more of a pedagogical mathematics game than a playable game. Combinatorial games have, as I described in chapter 3, a special place in the history of cognitive science.

In preparing for the 2013 round of field studies, I shifted design genre from mathematical manipulatives to combinatorial games. Some of the reasons for this shoft were described in the previous section. A strong argument for exploring combinatorial games was the positive experiences of playing Set in 2011 (see chapter 7). The games I have found the most useful for my study have a common characteristic in that they consist of a set of mathematical relationships which are gamified through a combination of material gestalt and playing procedure. In other words, the competitive element is not intrinsic to the content but part of the presentation. Besides Set, I also used the game Nim, and I engaged in the design of a new combinatorial game, Symmetry.

I will present and discuss the design of Set in a localized version of secondary artifacts for Set, and the design of Symmetry in this chapter. The very basic designs of Nim are presented together with the video material in chapter 7.

The localized Set game

Set is a combinatorial card game, published in 1991. The game developed from a coding schema for tracing heredity in dogs, developed by the designer Martha Jean Falco, who is a geneticist by profession. The game Set is widely used in mathematics

[16] The title of a series of books on combinatorial games. A more detailed definition is proposed by mathematician Richard Nowakowski: This is a game in which there are two players moving alternately; there are no chance devices and both players have perfect information; the rules are such that the game must eventually end; there are no draws, and the winner is determined by who moves last (Nowakowski 1998).

teaching, and it has won many awards both for its entertaining and pedagogical qualities.[17]

The game consists of 81 cards with different combinations of shape, color, number and fill. The task is to find sets, combinations of three cards that fulfill the requirement of being ”all similar or all different” for each of the four features. For any combination of two cards, there is one single card in the deck that makes a set.

> **SET:** A deck of 81 different cards, each with a combination of one of three values for four different features (shape, fill, number, color).
>
> In the localized version used in this study the values are:
>
> Shape: square, circle, triangle
>
> Color: red, green, blue
>
> Fill: Solid, striped, outline
>
> Number: 1, 2, 3
>
> There are 1080 possible sets to be constructed from the entire deck of cards. Sets can be categorized after the number of different features:
>
> 108 sets have one feature that is different and three similar (SSSD)
>
> 324 sets have two features that are different and two similar (SSDD)
>
> 432 sets have three features that are different and one similar (SDDD)
>
> 216 sets have four features that are different[18] (DDDD)

Based on the experiences in 2011 (see chapter 7), I wanted to use the game again since it matched my design criteria of making learners look for mathematical relationships and talk about them with peers. The original Set game that was used in 2011 lacked Swedish names for some of the shapes and colors, so I started to sketch different variations in which the shapes and names were known to the participants. At the start, I looked for systems of objects that could match the Set space: mythical animals or cutlery (see figure 6-8 for some of the sketches). I made a full deck of 81 cards on the theme of cutlery: knife, fork spoon. One, two, three. Gold, silver, bronze. “Old French”, striped 1950s design, “contemporary.”

Making the prototype was enough for me to realize that it was not going to work; the different relations between knives, spoons, and forks are already formalized, and they carry strong associations for most people. Three forks in a row do not make sense. The study of Uttal et al. (1997) that I referred to in relation to the mathematical manipulatives once more offered a potential explanation to the problem with the new

[17] From the homepage http://www.setgame.com (accessed 2015-09-25).

[18] http://home.comcast.net/~tamivox/dave/setgame/Tables3Values.html (accessed 2015-10-18)

playing cards: the illustrative and representational style obstructed players (or participants) from perceiving the mathematical relationships by being too present, and maybe also by being too "hand-drawn": the slightly shaky lines and the concern for reflections and shading also demand the attention of the user.

A crafts-related problem with the cutlery version was to find a suitable color for cutlery in "bronze" that would not be mistaken for "gold". As I visited the Rook to prepare the second round of field studies, Eva mentioned the national tests and the importance of knowing words for geometrical shapes. I finally based the local version on geometrical, computer-generated primitives: circles, triangles, and squares.

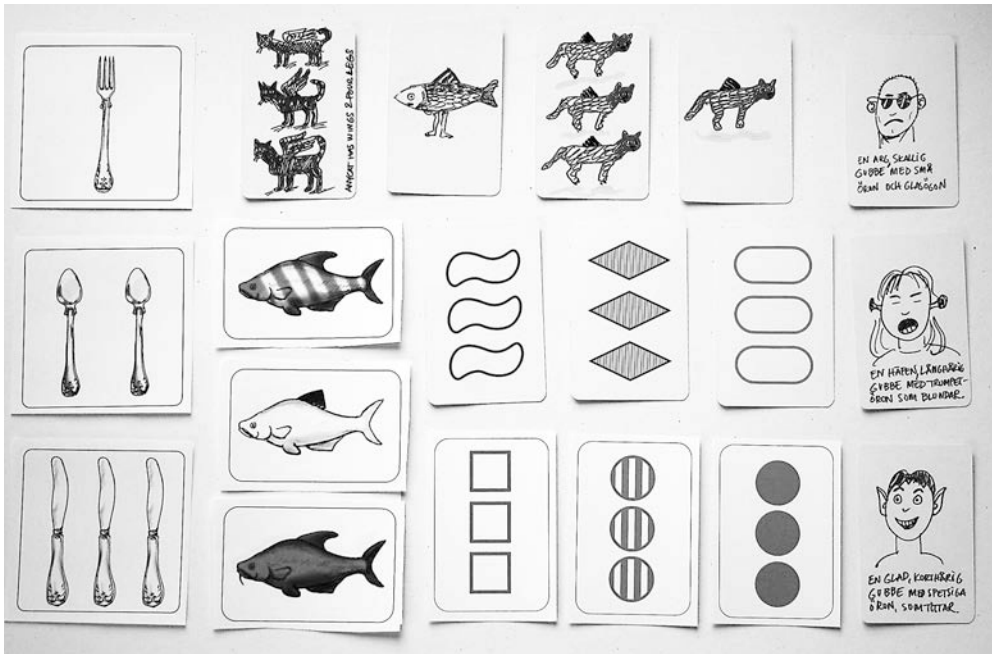

Figure 6-8. Fanciful versions of the Set combinatorial space: cutlery, mythological animals, combinatorial fish, human heads with different eyes, mouths, ears and hair. In the middle, the original game. Below, three cards from the "undesigned" localized version.

These were the changes I made to the Set deck:

- I shifted the shapes from diamond/squiggle/oval to square/triangle/circle.
- The symbols of the original cards are wide, and the proportions are such that three symbols fill the whole card. The new symbols can be inscribed in a square, with the consequence that the edges of the card are empty. I added a thin black line in order to define the shape of the card.
- I exchanged the color "purple" with "red", in order to use a common color with an unambiguous Swedish name.

- The outlines were made thicker, and the color of the fill in the solid cards was lightened somewhat in order for all cards to have a visible outline and three different fills: full, striped or empty.
- In the original striped cards, the stripes are thin, and the name for striped cards is "shaded". As the children I have listened to normally call these cards striped, I adapted the fill to the word, making the stripes wider.

The result is a deck of cards with better – but not perfect – visual balance, and with shapes and colors with unambiguous names that also connect to concepts used in mathematical discourse (see Figure 6-11).

Secondary artifacts

One of the findings in 2011 was that, in most cases, game rules and instructions were, inaccessible to children for various reasons. This finding was re-actualized during the 2013 field studies. In many cases, children came to look or to join in as the game became most intense. I could not explain the game and act as a game master at the same time, so I needed something to hand over to the observers, to guide them in understanding what the game was about without having to explain it myself.

The Set guide (figure 6-10) presents the basic features of the game. It presents the verbal formula for assessing sets (All Similar or All Different), and illustrates this through some specific examples of sets and non-sets.. It fits on one A4 page, affords pointing while explaining, and can be used for comparison to an ongoing game. For the non-sets I included an empty space where the correct card could be drawn, but this feature was not used.

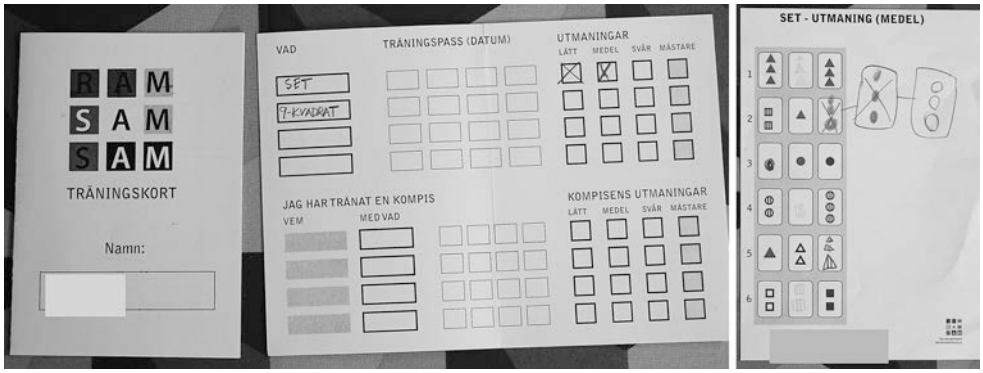

Figure 6-9. Training card (cover and inside). Challenge: Draw the missing card that makes a set of the other two. The participant had to try several times before he managed to produce a drawing with a blue outline. For the first try, the learner made a black outline with blue fill inside. In the second try, both outline and fill were blue. Only in the third try did he get it right.

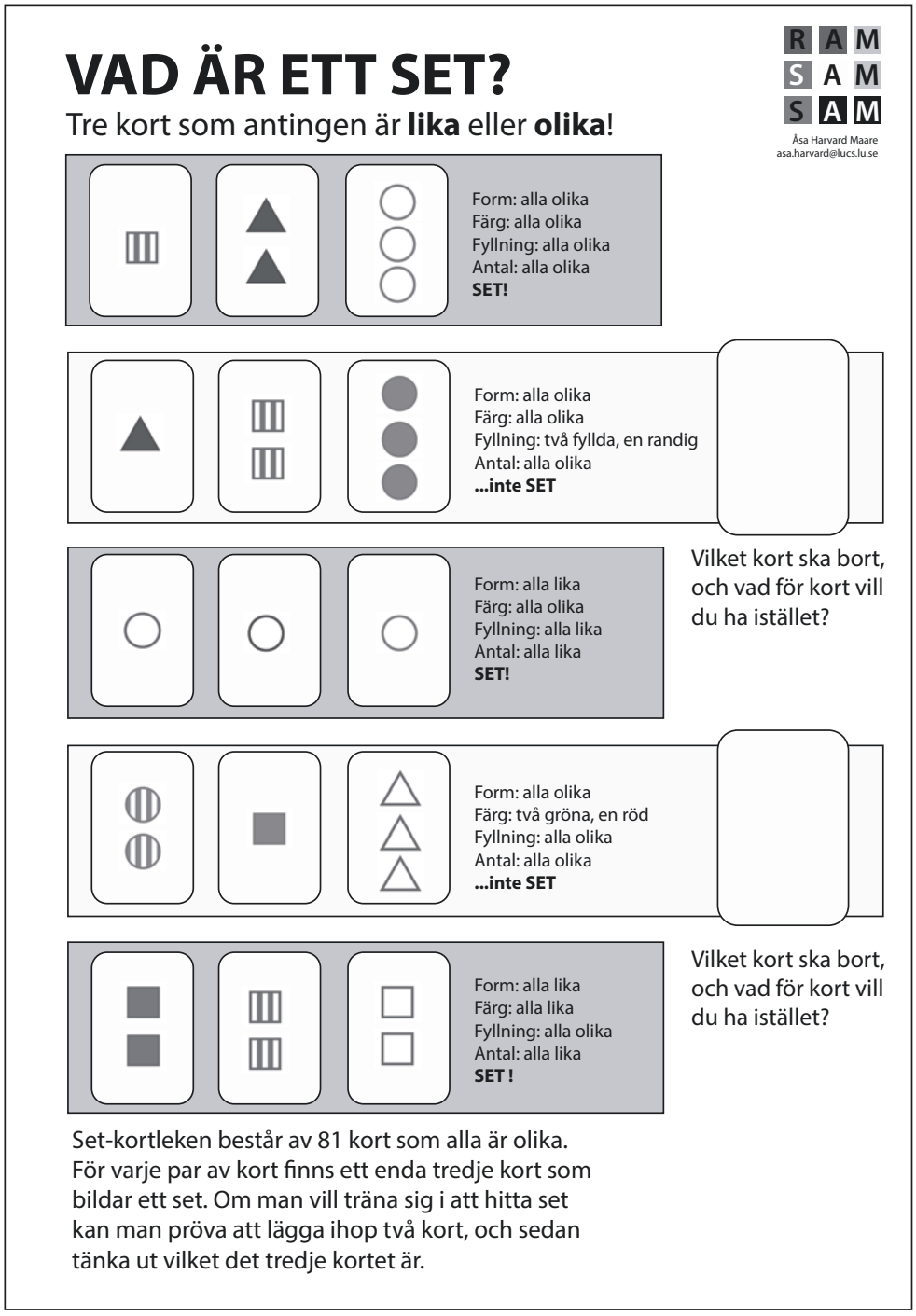

Figure 6-10. The Set Guide. The Set Guide is intended as a support for verbal explanation of the game, and a reference for observers, pointing to the relevant details of the game.

Training cards and challenges

The challenges (figure 6-9) are paper-based tasks where learners have to work out whether three cards form a set, or which third card would create a set with two given cards. The rationale for the challenges was (1) to have some activities ready for observers, and (2) to offer a non-competitive, non-stressful environment for figuring out the logic of the game and help the learner focus on one specific problem instead of shifting between many potential sets.

The training cards (also figure 6-9) were inspired by workout cards used in gyms, visual aids for learners to become aware of their own progression. The outcome from my field studies is not conclusive. A group of children spent one day solving challenges and getting marks in the training cards, but the cards were left at the table as they went home or shifted to another activity.

The Set Map

The Set Map, a graphic overview of all 81 cards (figure 6-11), was also inspired by one of my many conversations with Eva. She talked about the difference between those children who have internalized the number line or number space, and those who have not. Children who have a mental model of how different numbers relate can use it when calculating, and use shortcuts because they see patterns in numbers. The intention with the Set Map was to create a visual support for children to internalize the Set combinatorial space (see the learning chapter). The Set Map (figure 6-10) visualizes the regularity and pattern of sets. Similarity sets are mapped on horizontal or vertical lines whereas sets with many different features create oblique lines.

Besides the primary function of visualizing a combinatorial space, the Set map also had some practical functions: the map made it possible to point at any combination of cards, even for a child with small hands. Since the cards were ordered, it was easy to locate a card for reference.

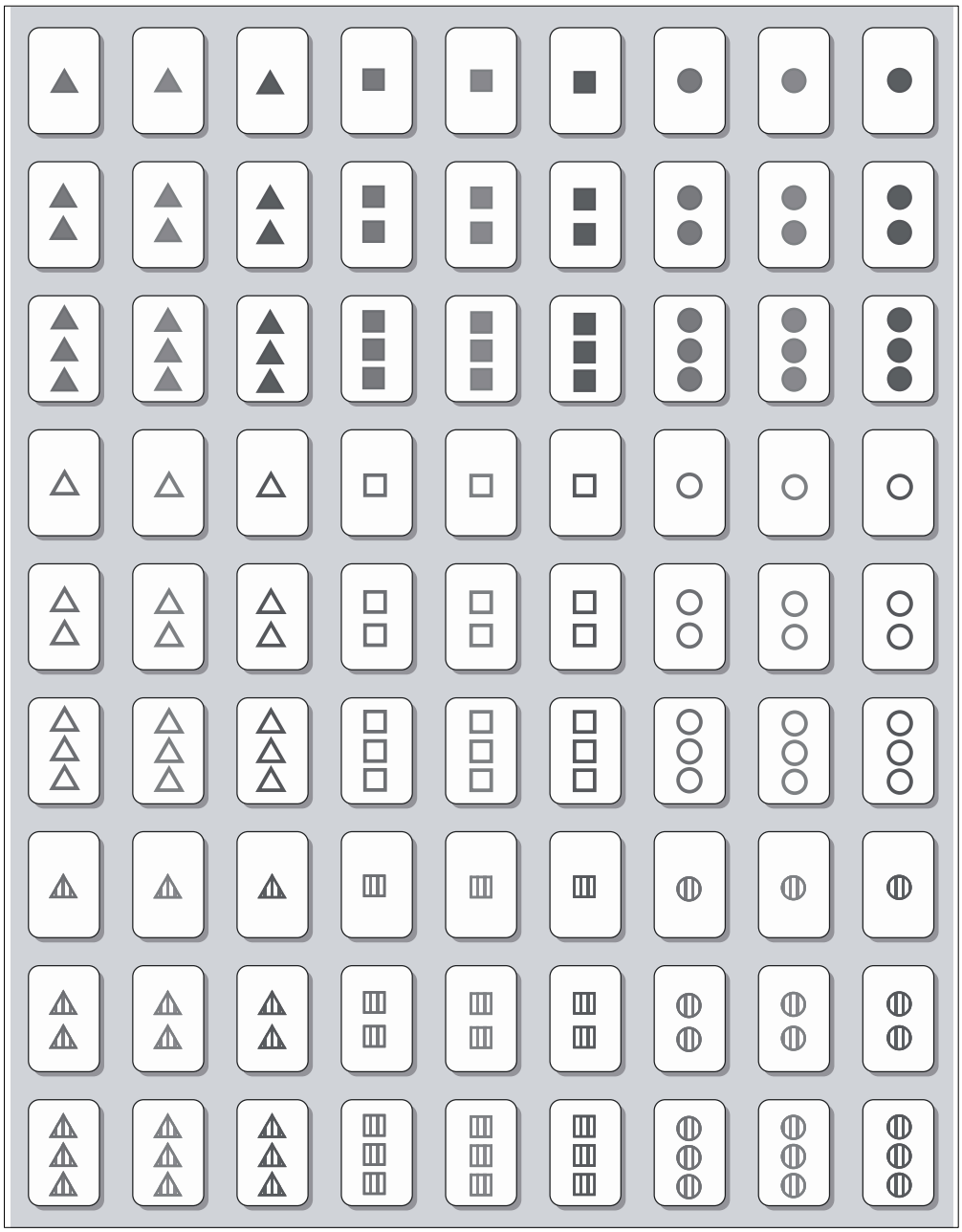

Figure 6-11. The Set Map. In this layout, shape (columns) and fill (rows) are prioritized over color (columns) and number (rows). Sets can be found along horizontal, vertical or diagonal lines. As this picture is in grayscale: columns 1, 4, and 7 have red shapes, columns 2, 5, and 8 green, and 3, 6, and 9 blue.

SOS/Symmetry

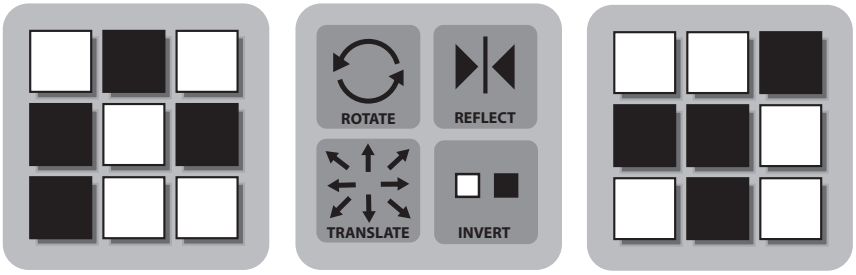

Figure 6-12. Symmetry cards and operations.

As a design researcher, I envisioned the second round of field studies as an opportunity for developing a new game. I brought early versions of the game Symmetry a few times to the Rook, but the game was not at a state where it could be played, which led me to focus on Set for the analysis and put Symmetry aside.

SYMMETRY: 68 square cards with a black and white pattern on a 3x3 grid. 34 cards with 5 black/4 white squares, and 34 cards with 5 white/4 black squares in all possible permutations

Four operations: rotation, mirroring, inversion and translation

The task: identify different kind of pairs. Simple pairs: rotated, mirrored, inverted or translated. Complex pairs: rotated and inverted; translated, mirrored and inverted etc. Impairs: cards that will remain different regardless of the number of operations applied to them.

The 256 possible permutations can be organized in **14 basic pattern groups** consisting of nine permutations each. No permutation is part of more than one pattern group.

Note: A deck of 256 cards includes all variants of rotation. Without rotation the minimum number of cards is 68, as some of the cards can be used for producing two or four permutations depending on its orientation. (The decks of cards that I have used with children have had about 90 cards, with some overlap in order to provide pairs for all cards).

The version used in 2013 (SOS) had more cards, and the cards had varying numbers of black/white squares (figure 7-15). In Symmetry, all cards have 4 squares of one color and 5 of the other, and the operation "translation" is added (figure 6-12) The pedagogical aim is that of Ramsamsam: to make players look for mathematical relationships and talk about them with peers, and through this, acquire an understanding of different kinds of patterns and symmetries that can be further elaborated in mathematics class.

The SOS/Symmetry game is not in itself an outcome of the project, but I have used it as a concrete setting for approaching research issues and design implications in a hands-on way. I will come back to Symmetry in relation to some of the design implications, in chapter 10.

Aspects of card design and prototyping

Following up on the discussion about mathematical manipulatives (Uttal et al. 1997) I would like to mention something about the *representational* content of playing cards (their organizational properties will be discussed in chapter 8). The squares and triangles of the ”localized” Set game are not simply representations of squares and triangles: they *are* squares and triangles. But representation is present in another sense: as a component of the entire deck of cards, each single card represents one point in a mathematical space of permutations. The forks and knives of the Cutlery Set are both representations of forks and knives and representations of different points in the same mathematical space. Forks, spoons, and knives also represent another space of possible combinations, that of table-dressing. The presence of these two combinatorial spaces generates conflict in how the cards are to be combined. In this sense, symbols with a weak associative network are easier to use than symbols carrying strong associations to cultural representation systems.

Childhood genre markers

When a product is targeted to children, this often goes together with a number of ”genre indicators”: bright colors, smiling faces, gold coins, animals, and references to children’s mass media. In the Ramsamsam project I have tried to avoid including genre markers indicating child-related products. The style is dry, motivated by the concern to keep representation at a minimal level. The children who have participated in the project have not commented on the visual style of the playing cards. My interpretation is that the real world sociality of the peer culture at the LTC outweighs the illusory sociality of fictional characters and smiling faces. Childhood genre markers may be functional in helping children and their families identify products intended for children, but this does not imply that they reflect children’s needs or stylistic preferences in terms of visual media.

Prototyping and weight

Throughout the project, I have experimented with various types of playing card prototypes: hand-drawn on special blank playing cards, printed on standard 80 g

printing paper, laminated, cards printed on heavy 240-250 g paper. Figure 6-14 shows four different playing cards (prototypes) and the weight of 10 cards, from left to right: standard playing cards 16 grams, 80 g printing paper 8 grams, heavy 250 g paper, 14 grams, plastic laminated paper, 22 grams. The 80 g paper prototypes were impossible to use. They were difficult to get hold of, and easily disturbed by sudden movement or breeze from an open door. The best prototypes were those printed on thick 250 g paper. I printed 12 to 16 cards per A4 sheet, and cut them down with a photo cutter. The process was easy, and yielded an acceptable result even though the cards were hard to shuffle.

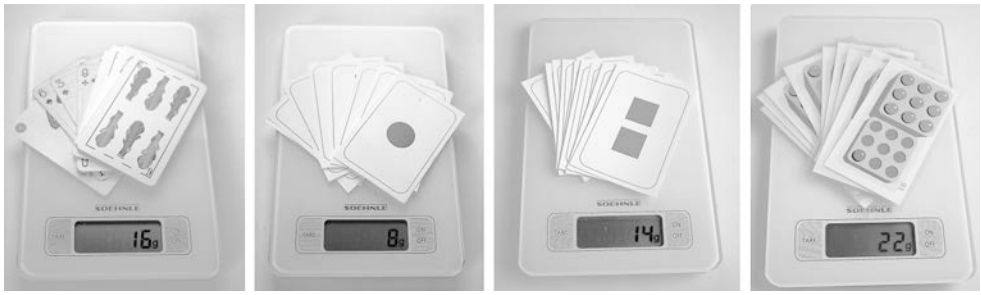

Figure 6-14. Weght as an aspect of prototyping.

Weight was also an issue with the marbles. The lightweight plastic marbles of the Marbles Calculator moved too easily, which meant that players had to restrain from expansive or sudden movements. This makes it difficult to engage in the joyful, exaggerated emotional displays which players often take pleasure in making (see figure 7-3 for an example).

	File	Dur.	Participants	Setting	Description
2011	20110201_A	11:54	Tony, Adam, Åsa	LTC	Set: Introducting the game, 27 cards
	20110208_A	03:55	Niclas, Molly, Richard, Freja,	LTC	Set: Introducting the game, 27 cards
	20110208_B	09:46	Niclas, Molly, Richard, Freja, Stella, Jenny, Virginia	LTC	Set: First try with 81 cards
	20110315_CO	6:58	Freja, Tony	LTC	Couronne: local rules
	20110322_LD	16:48	Tony, Jenny	LTC	Playing at playing the Lost Diamond
	20110329_100	7:00	Urban, Niclas	LTC	Interpreting the 100-cards
SET 2013	20130204_A	17:09	Nick, Adam, Greger, Richard, John, Gnar	ML	Introducing the game, 27 cards
	20130204_B	57:24	Leo, Ivan, Bruno	LTC	Introducing 27 cards, playing with 81
	20130205_A	45:26	Gnar, Ella, Leo	LTC	Collaborating and competing
	20130206_A	54:12	Freja, Emma, Ella, Nemo	LTC	"Leaking" and collaborating
	20130208_A	25:57	Nick, Adam, Greger, Gnar, Franz, Joseph, Adina	ML	Greger explains, then engaged in play
	20130212_A	56:50	Leo, Ivan, Emma, Lovisa	LTC	Playing the game with 81 cards
	20130218_B	9:42	Jacob, Leo, Jessica	LTC	Jessica shifts from observer to player
	20130308_B	22:54	Joseph, Ella, Richard, Franz	ML	"Embodied set" using hands and feet
SOS	20130204_B	11:00/57:24	Leo	LTC	Last minutes: looking at SOS cards
	20130211_A	22:00	Ella, John, Adina	LTC	Sorting and pairing many SOS cards
	20130215_A	10:40	Ella, Richard, Nicholas	LTC	Playing SOS with a 4x4 gameboard
NIM	20130218_A	24:34	Jacob, Leo	LTC	Stairs. Leo and Jacob's first try
	20130219_B	11:08	Jacob, Leo	LTC	Stairs. Discussion on numbers.
	20130219_C	4:33	Emma, Jacob, Leo	LTC	Stairs. Marking numbers in the stairs
	20130219_D	5:49	Emma, Jacob, Leo	LTC	Continuation marking numbers.
	20130308_D	4:57	Jacob, Leo	LTC	Color pens. Magical numbers

Figure 7-1. Overview of the video material. Åsa is present in all recordings from 2013. The duration is that of the whole clip, except in the two SOS episodes at the end of SET episodes. If two games are played in the same clip, the clip appears twice in the list.

7. Presentation of the video episodes

In this chapter I will present the video-recorded episodes that will feed into the analysis of the following two chapters. The analysis of the use of visual artifacts builds on the episodes of playing Set recorded in 2013, whereas the analysis of motivation and learning also involves some of the other recordings. I will also present some of the episodes from 2011 and 2013, as I refer to them elsewhere in this thesis.

The aim of this chapter is twofold: it serves as a catalogue in which references from other chapters can be traced back to the relevant video clip, and it is also a documentation of enactment: what the different participants and the environment brought to the interaction. The list in figure 7-1 represents a subset of the total amount of video recorded in the project. I have chosen these clips in order to confine the material to the games and activities that are most important for my analysis.

The video episodes, 2011

20110208_ A (3:55), 20110208_ B (9:46)

Context: Leisure-time center, in the classroom.

Participants: Freja, Stella, Molly, Richard, Jenny, Virginia and Niclas.

Content: Niclas explains the game to Freja, Molly and Richard. Molly finds a set. Later Jenny, Virginia and Stella join the game.

Artifacts: The original Set deck of cards.

In these two clips, Niclas acts as the game master. In the first clip, he explains the game to Freja, Molly, and Richard using the 27 solid cards of the Set deck. This is the approach that is recommended in the original rules when playing with children. After a short while, the players want to play using the entire deck of cards. Molly and Freja are very active proposing new sets. For each proposed set, Niclas explains feature by feature, whether the proposed set meets the requirement of ”all different or all similar”. After several attempts, Molly finds her first set. Soon after, three more children want to join the game. Niclas interrupts the game and starts explaining to the new players. Molly takes out her set and uses it for demonstrating to the newcomers. When the game is resumed, now with six players, all call out for sets.

Niclas urges the players not to say Set until they are sure they have found one, but this does not have any effect.

I have a few comments on these first Set recordings, one on the procedure of playing and two on the card design. After calling out for a set, the player is expected to show it to the other players. This gives the player the opportunity to move the cards and pick out those she wants to use for building a set. Since many new players are dependent on touching and moving cards for searching, they call for sets without having found one (or when having found two cards of three, which is about the same thing). A second reason to call for a set is that the player gets both feedback and attention from the game master. As Niclas explains why the proposed cards are or are not a set, he gets the attention of all players.

Figure 7-2. Niclas points at the cards and explains their relations. Molly raises her hand to get the word. Molly brings out her found Set when Niclas explains the game to new participants. Jenny and Stella look at the cards, at Molly and at Niclas in order to grasp the game. (20110208_B).

The symbols used in the original deck of Set are diamond, oval, and squiggle. As Niclas and the other players talk about the cards, they need names for the symbols and colors. Some of the symbols have no self-evident Swedish translations. Diamonds becomes ”rutor”, ovals are ovals, and there is no good name for a squiggle. The lack of corresponding words for the shapes forced players to invent creative substitutions: *”en sån där korv”* (that kind of sausage thing, referring to squiggles).

It is often hard to see the difference between colors in the outlined version of the cards, in real life and even more so in the video recordings. The outlines are very thin

and, contrasted with the white background, the outline appears almost black. Many players therefore make mistakes about the color of outlined cards. The solid cards, on the other hand, ”pop out”: an evenly colored surface, saturated color, and a well-defined edge of the shape; some of them are also more visually salient than others.

Playing at playing a game: the Lost Diamond

20110315_LD (16:48)

Context: Leisure-time center, in the classroom.

Participants: Jenny and Tony, Åsa behind the camera.

Content: Tony and Jenny play the Lost Diamond. Both cheat, both are aware of me filming them.

Artifacts: The board game The Lost Diamond.

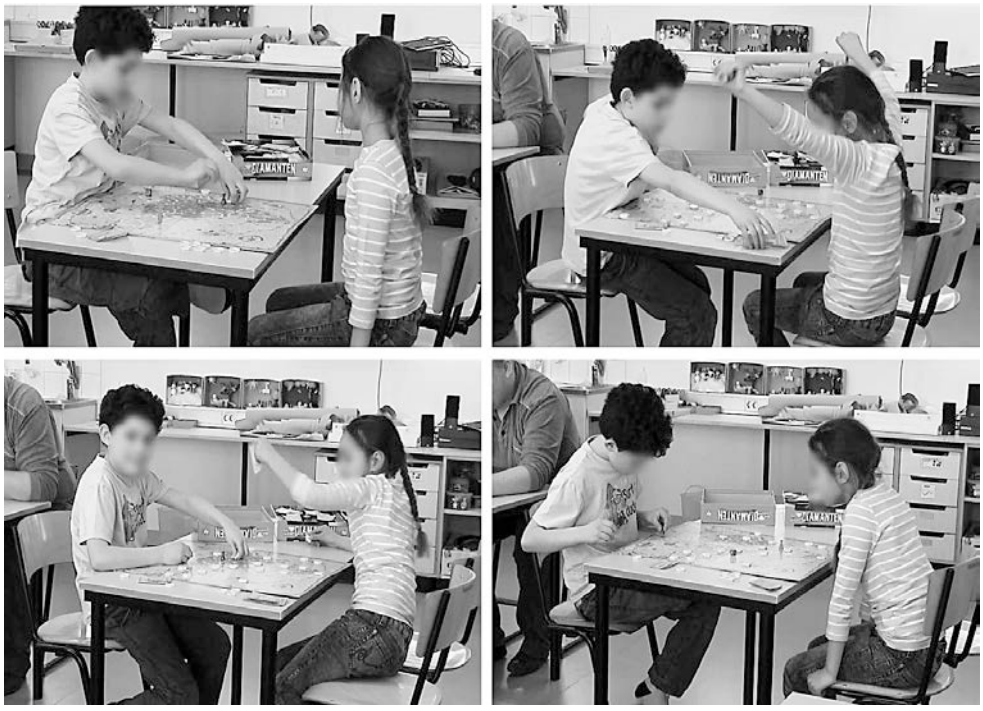

Figure 7-3. Tony and Jenny play at playing the game. Left: emotional display of Jenny (20110315_LD).

Tony and Jenny start playing the Lost Diamond. I stand a few meters away (the video recorder is charging, so I have to stand next to the power outlet) but I zoom in on their game. Both children are aware of being observed and video recorded, and to some extent their game is a performance in front of the camera. In the first round of the game, Tony finds the diamond after just a few turns, and wins. They agree to continue playing in spite of this, but the game becomes more playful. Neither of the players wait for the other to finish before starting a new turn, and both cheat. Since they don't play to win, victory does not matter: they play at playing the game. The game, in turn, makes it acceptable to express emotions, even exaggerated ones, and to display normally forbidden feelings of vengeance and gloating (see figure 1-1).

Couronne: local rules and written rules

20110315_CO (7:00)

Context: Leisure-time center, in the classroom.

Participants: Freja, Tony, Åsa behind the camera.

Content: Freja and Tony demonstrate how to play Couronne using local rules.

Artifacts: Couronne game.

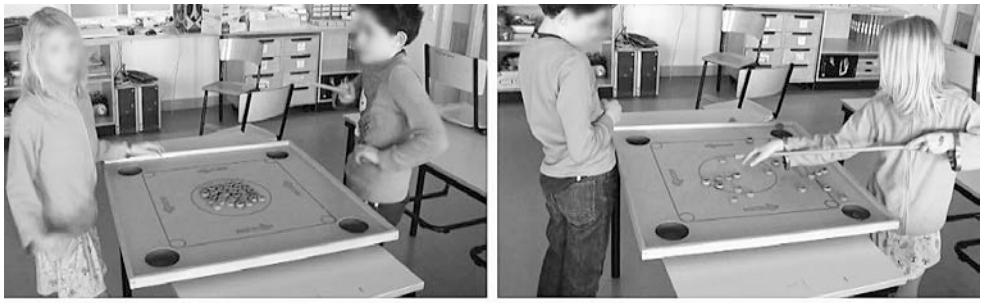

Figure 7-4. Tony and Freja demonstrate how to play Couronne with local rules.(20110315_CO)

Tony and Freja play Couronne in order to demonstrate the local rules in use at the LTC. As in the previous episode, they do not play to win, and I am a participant in the episode from my position behind the camera.

Set episodes, 2013

In 2013, there are seven recorded episodes of children playing Set. In the first six, we use the redesigned version with geometrical shapes. The last session is an experiment with an ”embodied” version of the game, using hands, feet, and furniture for expressing the relations between number, shape, color and fill. Class 3A had short mathematics lessons, 20 minutes, before the lunch break on Mondays and Fridays. On this day, the children were given the choice to play mathematics games with me instead of attending the regular mathematics class. Six children wanted to play games. I had the impression that they knew each other well, and that most of the group was used to playing games together, and ready to take some responsibility for ensuring that the game could be played.

Monday February 4th

20130204_A. (17:10)

Context: Mathematics lesson.

Participants: Gnar, Richard, John, Greger, Adam, and Nick (3rd graders).

Content: Most of the time was spent explaining the game. At the end, two teams of three players each take turns playing.

Artifacts: The re-designed Set deck of cards.

Location: The open space. No observers.

Figure 7-5. The six participants play three by three. As I divide them into two teams, they display ”team spirit”, holding each other by the shoulder. (20130204_A)

I start by explaining the game using the 27 solid cards. After 12 minutes, I divide the group into two teams of 3 players, taking turns playing. The teams put their arms

around the shoulders of their team-members, indicating engagement and we-ness in the team. We had enough time for a few turns, despite being interrupted by explanations.

As players become impatient, cards start drifting over the table. I have to interrupt the game and ask children to keep their hands off the cards except when it is their turn. Three of the children are attentive to the game while the other three attend more to their friends and to making funny faces at the camera. Suddenly, all stand up: the lesson is over; I am the only one not noticing it. Gnar stays a while. He asks about the system for counting points in Set: are you supposed to count the symbols, the cards, or the found sets?

Figure 7-6. Leo has found a set. He indicates the three cards with his hands, and looks at the game master for confirmation. Ivan follows attentively, and tries to get a glimpse of the three cards under Leo's hands (20130204_B).

20130204_B Duration: 57:20

Participants: Leo, Ivan, Bruno (2nd graders), and Åsa.

Content: 8 minutes introducing the game. Bruno leaves after a short while, Ivan leaves after 30 minutes after which Leo practices finding Sets. In the end, Åsa and Leo look at SOS cards.

Artifacts: Two copies of the re-designed Set deck of cards.

Location: The open space. Numerous observers.

I come back in the afternoon, this time to the leisure-time center. The LTC teachers have been talking to some children they think could be interested in math games. Three children in the second grade come over and want to play. I invite them to play and I give a quick introduction to the game (8 minutes). We use the full deck of 81 cards from the start. We start playing, with many interruptions for explaining the game. Many children stop by to watch what we are doing. I have two decks of cards but nothing else to hand over to interested children.

Leo and Ivan are very attentive to the game. Bruno finds the game difficult, and chooses to quit after a few rounds. After a while, Leo starts to get a feeling about how to play, and Ivan follows attentively and smiles as Leo finds sets. 30 minutes into the episode, Ivan leaves. Leo and I continue, and Leo is by now picking out sets with some assurance. Finally we run out of cards. We spend ten minute exploring the SOS cards (see later in this chapter). As I prepare to leave, Ella comes over and asks if we can play next time.

Tuesday February 5th

For the next day, I prepare a Set Guide with examples of sets and non-sets, and I print out some copies of it (see figure 6-9). As I arrive, Ella and Gnar want to play. Explaining the game using the Set Guide takes 4 minutes. The Set Guide is lying on the table as we played. Ella looks at it from time to time, comparing the examples with the displayed cards on the table.

20130205_A (45:26)

Context: Leisure-time center.

Participants: Ella, Gnar, Leo, and Åsa.

Content: 4 minutes introducing the game using the Set Guide. Ella and Gnar collaborate in the beginning, but the game turns into a competition over time. In the end, Gnar leaves and Leo takes his place.

Artifacts: The re-designed Set deck of cards, the Set Guide.

Location: The open space. Numerous observers.

In the beginning, Gnar and Ella collaborate in finding sets. Both move cards to a shared matching area (se figure 7-7) located inbetween the two of them. Gnar has a strategy for searching, and Ella supports him with the cards he needs. After a while the matching area has moved over to Gnar's side. Ella establishes a new matching area in front of herself. The collaboration is over.

Gnar is very focused on the cards, and he uses the same search procedure over and over. He starts with a 3, then a 2, then a 1. If they are not a set, he shifts the 3 for

another 3, etc. In the two recorded episodes with the large group (20130204_A and 20130208_A), Gnar is intensely engaged in the playing of the other partipants through sounds, sighs and gestures. This is not the case in this recording: he hardly looks up from the cards.

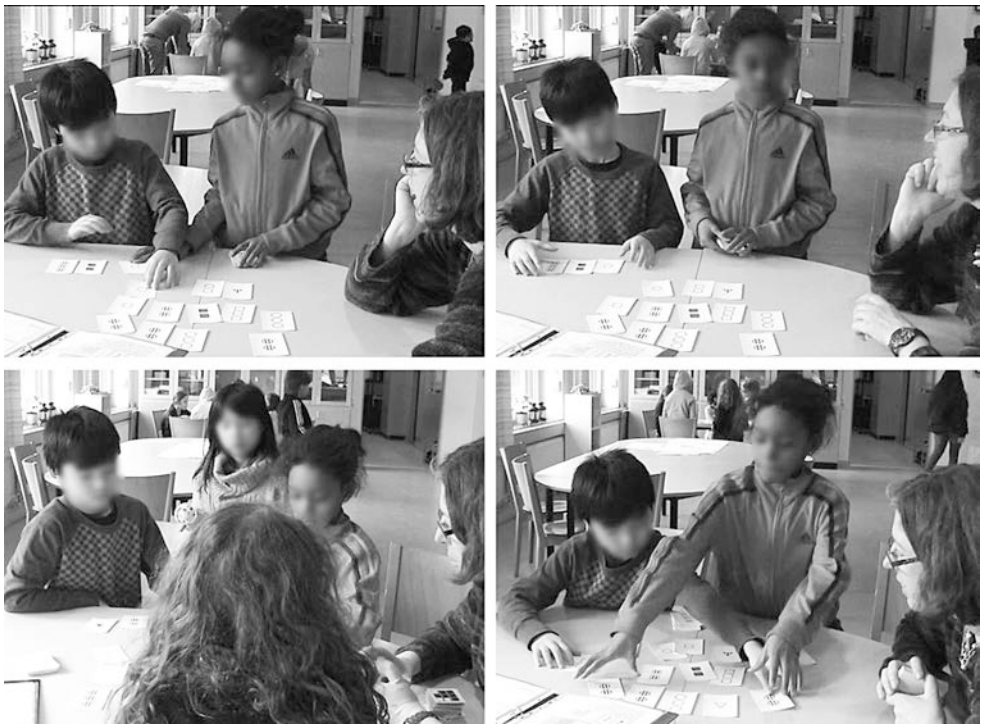

Figure 7-7. *Top left:* At the start, Ella and Gnar collaborate. Ella pushes a card in under Gnar's arm to finish the set they are looking for. The construction area gradually moves to Gnar's side until it isn't shared anymore. *Top right:* I tell them that I see a set. *Bottom right:* Ella follows my gaze and takes the set. Gnar protests: "Are you going to take that one, Ella!?" (20130205_A).

Wednesday February 6th

20130206_A (54:12)
Context: Leisure-time center.
Participants: Freja, Emma, Ella, Nemo, and Åsa.
Artifacts: The re-designed Set deck of cards, the Set Guide and hourglasses.
Location: The open space. Numerous observers.

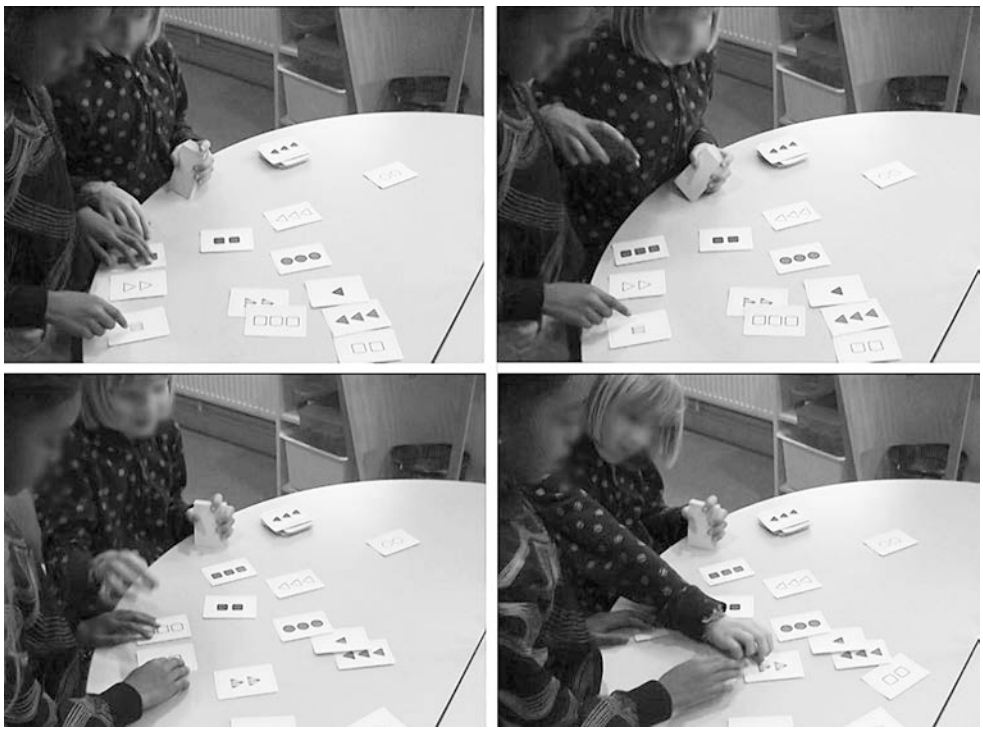

Figure 7-8. Leaking information. Ella stands next to Freja and looks at the cards. After a while the two collaborate in looking for a set. Both use talk to structure their search: they think aloud, and by moving cards to the matching area it is made clear to both which cards are involved (20130206_A).

Most children want to move cards around while searching, and not play by the rules, that is, finding sets only by looking at the displayed cards. In order to let one child at a time search for sets, and using hands in doing so, I need to limit the time for each player. On the Wednesday, I bring two hourglasses, measuring 30 and 180 seconds.

Emma, in 2nd grade, and Freja, in 3rd grade, want to play. Freja was part of the group playing Set already in 2011. For Emma, it is the first time and she finds the game difficult. Freja gradually takes over the helper functions: displaying new cards, aligning cards, managing the hourglass. Freja supports Emma by asking her questions or arranging the displayed cards to make it easier for her to find a set. When Emma attempts to arrange the displayed cards in the same way as Freja just did, Freja tells Emma that she does not have the right to do this. She should stick to playing by herself. A little later, Emma's mother comes to get her. After Emma has left, Ella approaches, and starts observing what Freja is doing. After a short while, the two search for sets together. Their search is highly synchronized, they think aloud using the same words and in the same tempo. At the end of the episode, Nemo wants to join them.

Friday February 8th

20130208_A (25:57)

Context: Mathematics lesson.

Participants: Franz, Adam, Gnar, Adina, Joseph, Greger, Nick, and Åsa.

Content: 4 minutes introducing the game using the Set Guide. Ella and Gnar collaborate at the start, but the game turns into a competition over time. In the end Gnar leaves and Leo takes his place.

Artifacts: The re-designed Set deck of cards, the Set Guide and hourglasses.

Location: The open space. No observers.

The setup on Friday is similar to that of Monday. Six children want to join the "math game group." Four of them were playing on Monday. A seventh player joins the group after a while. I ask Greger to explain the game to the newcomers. Greger struggles to find the right words for the cards he talks about. Nick and Joseph assist him by finding the card that they understand he needs. After that we play, using turn-taking and limiting the time for each player with the hourglass.

Figure 7-9 aims to capture the gist of the video episode, and also serves as input on the theme of "helping out." Franz, who plays for the first time, asks for help. Adam accepts, and they start searching for sets together. As they present their three cards, Nick sees a mistake and proceeds to fix it directly, without asking for permission. Franz protests, but Nick takes his hand and moves it away from the cards. This annoys Franz, who is the active player, and Adam defends his right to play: "Let Franz do it!" Gnar is also starting to play during Franz's turn.

I introduce a new rule: no help unless the player explicitly asks for it. When it is Greger's turn, Joseph asks him whether he needs help. Greger does not answer, since he is busy searching. In the end several of the participants, including me, are engaged in helping Greger (who has not asked anybody for help) through talking, pointing, and naming cards. In the end, Joseph finds the card that will make a set of the two cards Greger has lined up, and he pushes it gently towards Greger. Greger sees it and takes it. As the third card is put into place, there is a sense of relief. Adam exhales. Joseph smiles: "It's a set!"

In the following turn, Gnar, for the second time in this episode, collects a set without hesitating, using his 3-2-1 strategy. Everyone's spirits are uplifted, and Franz starts singing: "We are the champions!"

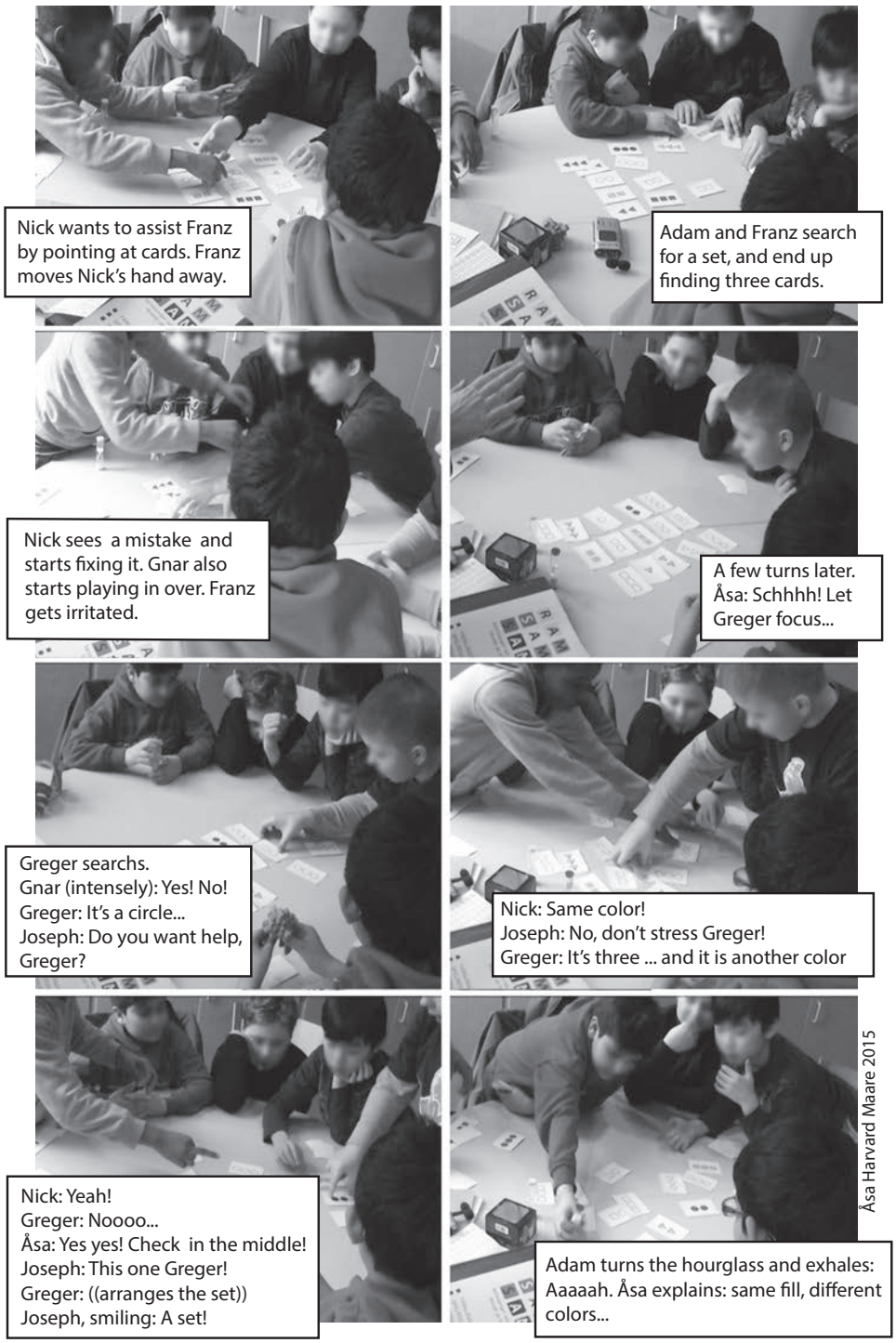

Figure 7-9. Frame grabs from Franz' turn and Greger's turn (20130208_A).

Tuesday February 12th

20130213_A, (45:26)

Participants: Emma, Lovisa, Ivan and Åsa

Content: Leo works with challenges. Emma, later Lovisa and Ivan join. Emma searches for sets, Lovisa looks at the various secondary artifacts and the cards.

Artifacts: The re-designed Set deck of cards, the Set Guide, hourglasses, training cards and Set Challenges.

Location: The open space. The only observer is Emma's mother coming for her daughter.

For the next Tuesday I had prepared membership cards and "challenges," paper-based problems that interested children are invited to solve. Many of the children who had played Set came around and wanted to try the challenges. In the start of the video episode, Leo fills out a challenge.

Later I am approached by Emma, who this time brings her friend Lovisa. Emma introduces her by telling me that she is new in the class, and that she does not know much (Swedish, as I understand Emma's intended meaning). In comparison with Lovisa, Emma is an expert. Lovisa takes up the cards and looks at them, but she does not engage in playing. Emma looks for sets, and the two bump into each other at several occasions while stretching out to reach a card.

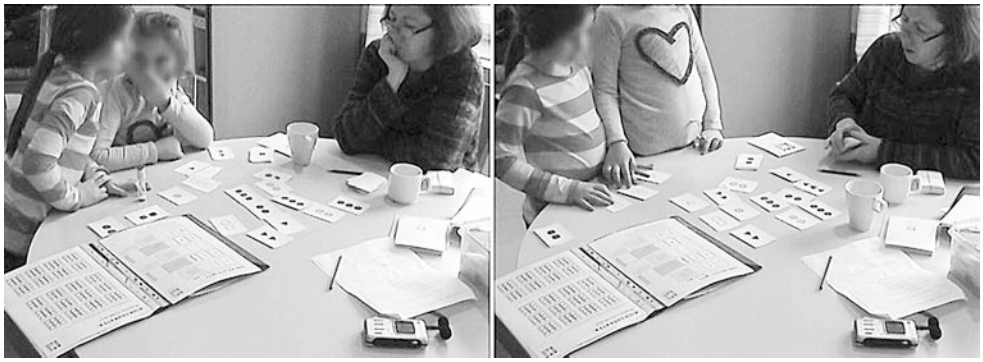

Figure 7-10. Emma and Lovisa playing set. (20130213_A)

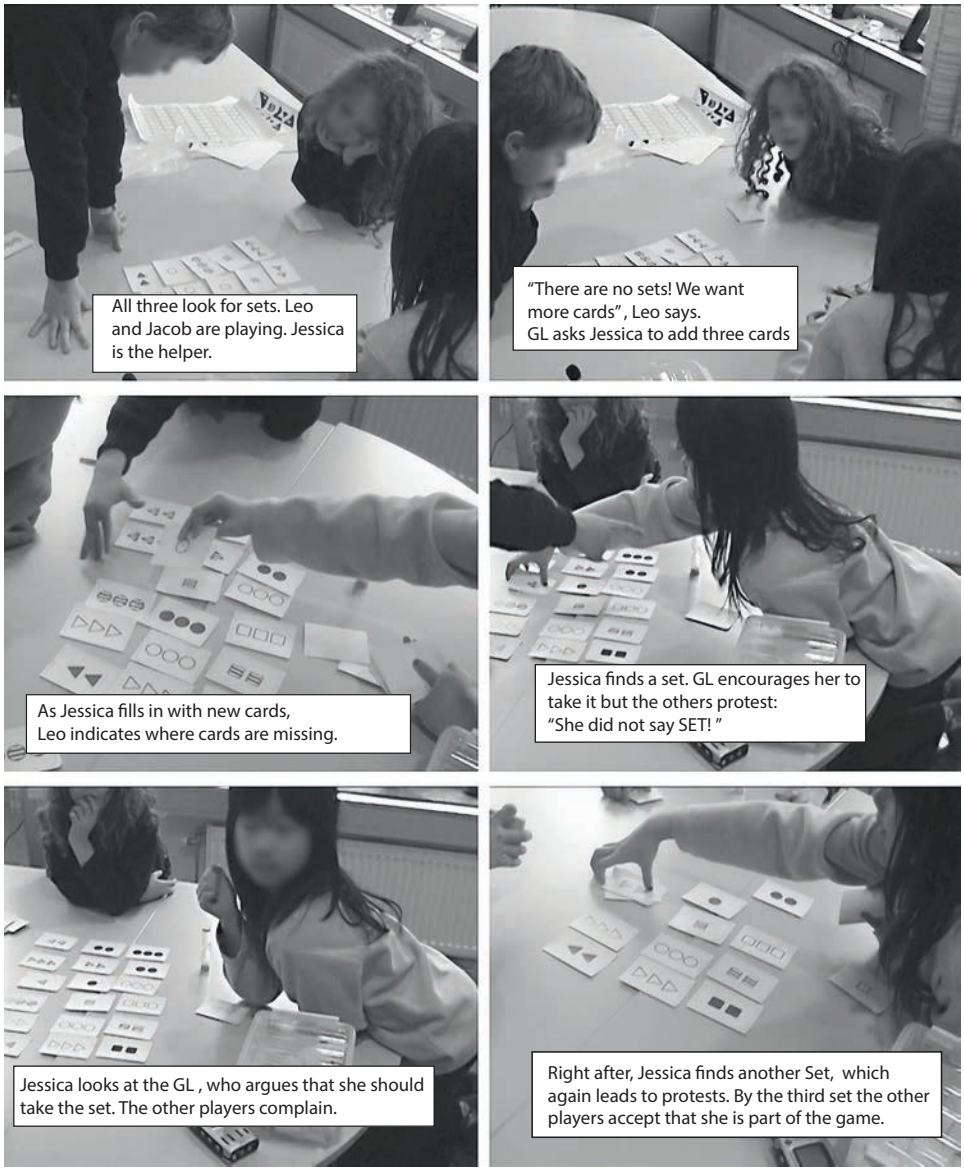

Figure 7-11. Jessica starts as a helper and observer, but as she find two sets I encourage her to claim her sets and enter the game as a player. This leads to protests from the two other players. (20130218_B)

Monday February 18th

20130218_B (9:42)

Context: Leisure-time center (winter vacation: no school, few children in the LTC).

Participants: Leo, Jacob, Jessica, and Åsa

Content: Leo has explained the game to Jacob using the Set map. Jessica acts as a helper, but starts playing as well.

Artifacts: The re-designed Set deck of cards, the Set Guide, the Set Map.

Location: The open space. No observers.

There is no school during the winter vacation, but the leisure-time center is open for those children whose parents are working. The group is half the normal size. Since I did not have to adapt my schedule to lessons, I arrive at the LTC in the morning.

Leo wanted to play Set with Jacob, and he gave his friend a brief introduction to the game. He used the Set poster for explaining the game to Jacob. Since the thumbnail images of each card are small, he could easily point at any combination of three cards.

Jessica came by to look, and I suggested she take the role of helper. After a while Jessica looks at me, and makes a hesitating sound indicating that she has found a set. I confirm that it is a set, and I encourage her to take it. At this point, Jacob and Leo protest: Jessica had not played by the rules since she did not say Set first. This sequence of events is repeated once more: Jessica finds a set, I encourage her to take it, the boys protest. After that, Jessica is accepted as a player. They children stop playing when I leave.

Friday March 8th

20130308_B (22:54)

Context: Mathematics lesson

Participants: Joseph, Ella, Richard, Franz, and Åsa

Content: Åsa initiates an "embodied set" game using the body to express Set relations. As children elaborate on the idea it gradually develops towards dance and movement.

Artifacts: Chairs, foam tiles, own bodies.

Location: Inside one of the classrooms. No observers.

On Friday the 8th I came for the mathematics lesson, and Eva asked who wanted to do math games. We attempted to translate the game of Set into a full-body version in which the Set parameters are expressed using arms, legs, and body position. All four participants had played Set earlier. We began in the open space by putting chairs into a row. After a few minutes, we were asked to move into one of the classrooms. We did so, then arranged the chairs and found some soft foam tiles to put on the floor. The session ended up being very funny and very messy. It was really hard for everybody – including me – to ”read” the participants as Set signs, as they were so information-rich through mimicry, gesture, giggling, clothing….

Figure 7-12. To the left: three persons lying on the floor lifting one arm but keeping both legs down. To the right: participants proposed that the three embodied ”cards” had small platforms to stand on, and the next step was dancing instead of standing still (20130308_B).

This was the setup:

- Hand position (same as in the game rock-paper-scissors)
- Feet: both on the floor, both in the air, one up and one down.
- Body position: lying on the floor, sitting, standing

The Embodied Set was too different from the card game to be conclusive. The children participating recognized the structure from Set – I was explicit about it – and engaged in translating it into movements. I imagined the embodied set as a static game of taking positions and keeping them for some time, but the children participants changed the context towards dance, but maintained the structure of features and possibilities: how would the dance look if you were a hiphop dancer teaching mathematics?

It turned out to be very difficult to read a person as an embodied Set card. Using the hand symbols from the rock-paper-scissors game was problematic, since the children started applying the logic of rock-paper-scissors. Instead of the Set logic (all different or all similar) they wanted to produce the “winning” sign, paper over rock, etc.

One of the combinations of the embodied system was "stand up with both feet lifted from the ground." The effect of this impossible instruction was that the whole activity took a turn towards playfulness, allowing participants to add new ideas like the dancing Set combinations.

Nim and SOS, 2013

Nim, in the version used here, is played as follows: two players take turns in removing objects from a shared stack of 20 objects. For each turn, a player may choose to remove one or two objects. The player who gets the last object wins. In a pedagogical context, the total number of objects and the number of objects that Nim, in the version used here, is played as follows: two players take turns in removing objects from a shared stack of 20 objects. For each turn, a player may choose to remove one or two objects. The player who gets the last object wins. In a pedagogical context, the total number of objects and the number of objects that players may take can be adjusted in order to encourage children to gain an understanding of the relationship between the total number of objects and the number that can be removed each time, and also, as a consequence, which numbers to attend to in order to win. We only played the game in the configuration described above, in which the "trick" for winning the game is to go to the positions that are 20 minus a multiple of three (making 17, 14, 11, 8, 5, 2). Once this is understood, the game is over: the first player to get it wins.

The Staircase Nim was played using twenty numbered stairs, where players had to move upstairs one or two steps for each turn. The Colored Pen Nim was played using 20 colored pens, from which players take turn removing pens. Nim did fit with the design aim of teaching children to look for mathematical relationships and talk about them with their peers.

20130218_A, (22:54) 20130219_B, (11:08)

Context: LTC, winter vacation.

Participants: Leo, Jacob, and Åsa.

Content: Trying out Nim.

20130219_C, (4:33) 20130219_D, (5:49)

Participants: Leo, Jacob, Emma, and Åsa.

Content: marking "special" numbers for playing Nim.

Artifacts: Stairs, sheets of paper with numbers on the front of each step.

Location: In the staircase.

Figure 7-13. Staircase version: 20 stairs are numbered. Two players alternate walking up the stairs, one step or two steps. The person who first sets the foot at step 20 wins. (20130218_A, 20120219_C).

The staircase game takes place over two days during the winter vacation. Jacob, Leo, and later Emma participate. We start by marking the stairs: we write numbers on paper and tape them to the vertical side of each step. When this is done we take turns playing Nim. In the first round, Jacob and Leo advance at a steady pace until just before step 17. Then Jacob slows down. Leo asks him to continue, several times, but Jacob remains where he is, thinking. It seems that Leo does not understand why Jacob has frozen, and he becomes impatient.

After a few rounds, I ask Jacob and Leo if they have any thoughts about "magical numbers": if there are numbers that a player should choose in order to win. I encourage them to draw color dots on the numbers they find special.

Two weeks later (20130308_A), I propose that Jacob and Leo play a game with colored pens. I do not mention any connection between the colored pens and the game they have played in the staircase a few weeks earlier. We play two rounds. I ask them if they had played the game before, and Leo answers no. It is only after I mention the game in the staircase that they see the connection.

20130308_A (4:47)

Leo and Jacob play Nim with colored pens.

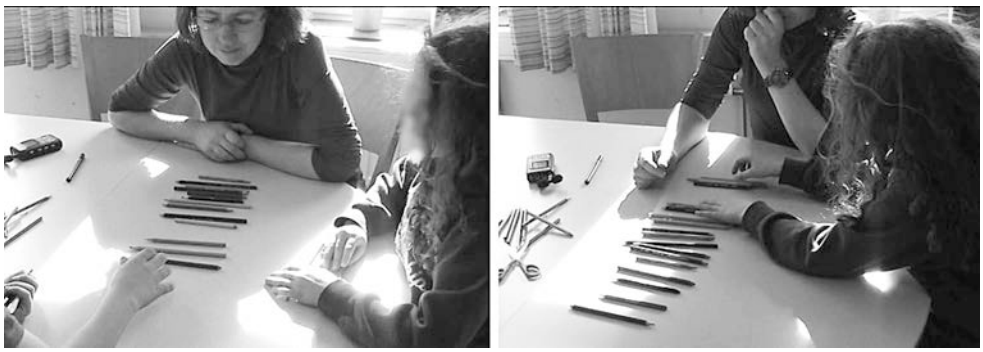

Figure 7-14. Nim with colored pens: pens form heaps. Pens easily start rolling. In contrast to the stairs, the pens were not numbered. From my adult perspective, Nim with pens was much more difficult to play since there were few visual cues for the orderly system of the number line (20130308_A).

Testing the SOS cards

20130204_A, (11:00). Leo and Åsa looking at and playing with SOS cards (all numbers of white/black squares).

20130211_A, **(22:00).** Ella and Adina sorting and pairing many SOS cards

20130215_A, (10:40). Ella, Richard, and Nick playing SOS with a 4x4 game board

20130204_A: After having played through Set together with Leo, I take out the SOS cards and we look at them. Leo taps with his finger on the squares, as if they could be switched on and off, and looks for the numbers of black/white squares. We play with a setup similar to Uno: placing cards with same number of white or black squares in the stack.

In 20130211_A each player gets 9 cards and they look for pairs: mirrored cards, pairs, inverted pairs. Ella and Adina collaborate. John taps the cards while comparing them, counting the number of squares. Two cards may appear similar, but when they are placed side by side it may turn out that they are not symmetrical.

As Ella shows her pairs to me, she explains: ”These are mirrored, and these are mirrored too. These are inverted.” Ella and Adina collect pairs and line them up on the table, a growing visual display of different types of pairs. I provide them with new cards, and the matched pairs are left on the table. In the end, a large number of cards are lying all over the table, some matched in pairs, others not.

20130215_A: In trying out SOS I introduced game boards in order to provide a visual structure for the different kinds of pairs that could be found. The intention was to increase the visibility of the different card pairs by assigning dedicated spaces for them on the game board. This did not produce the result I had hoped for, as players collected their found pairs and put them in their own stack; the game board remained empty. Players rotated cards in order to match them. Nick plays strategically, and starts creating pairs horizontally on the game board – a possibility that I had not foreseen. The game board forced players to consider the card relationships as reflected/inverted patterns.

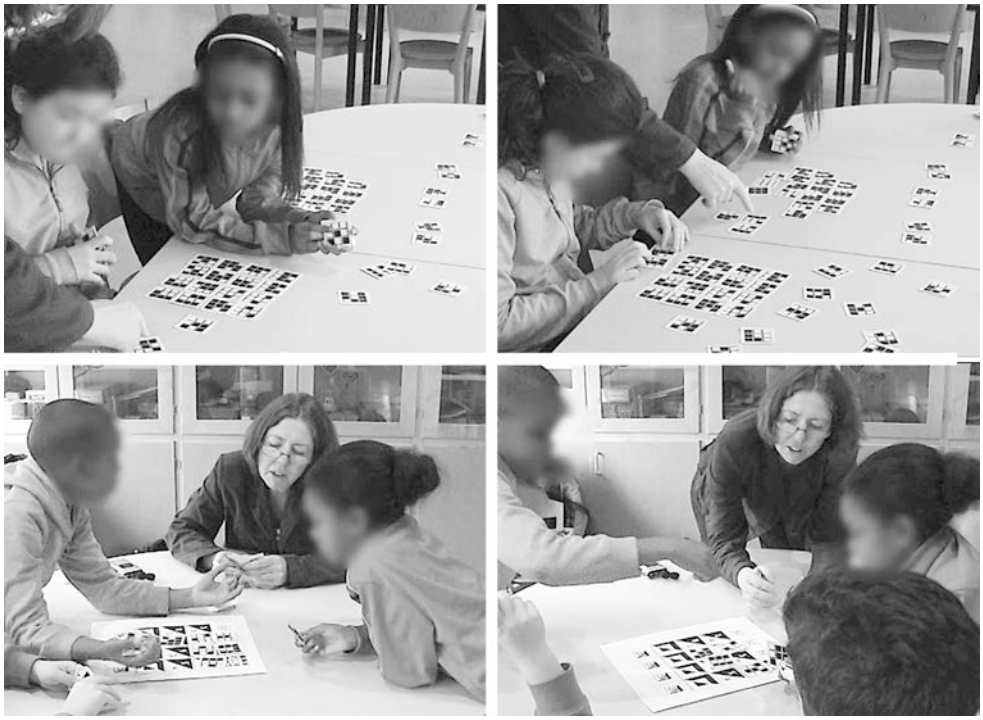

Figure 7-15. Above: Ella and Adina find pairs of cards that are mirrored or inverted. Adina arranges her found pairs in a square shape. Below: cards are supposed to be placed on the game board in the spaces for mirrored, inverted, and mirrored and inverted pictures. However, players collected their found pairs in personal stacks; no growing visual resource (20130211_A, 20130215_A).

Figure 7-16. Starting point for the design in 2011: an assortment of mathematical manipulatives for on-the-fly game bricolages.

8. Using visual artifacts

After presenting the setting, the design, and the video-recorded episodes of play, I will now turn to the research question of how participants communicate during gameplay, and what is the role of visual artifacts for communication. With the second part of the question I intend to explore how co-present participants use visual artifacts – in this setting, mainly playing cards – for communication and coordination purposes. This means that I will look at communication on a horizontal axis, between participants, and not along a vertical axis, from designer to user.

The premise of the analysis is that of embodied interaction: players communicate multimodally, and visual artifacts are an integrated part of this communication. Hence, the analysis focuses on organizational properties of visual artifacts, not on representational content. Only visual and auditory channels for communicating are included. The analysis is built upon the episodes of playing Set, since these offer the richest sequences with many participants interacting and learning over time. However, I have also included the playing card prototypes for SOS and 100-cards, in order to look at the role of specific graphic elements: shadows and embossing.

The communicative scene

In the video episode 20130208_A, seven children are engaged in playing Set. One of the children is out of the frame, and so am I since I stand next to the camera. I am also a participant, in the role of game master. Four players have played the game before. Players take turns searching for sets, and the time for each player is limited to 3 minutes. Turning the hourglass marks the start of the turn.

The "communicative scene" is defined by the participants and their bodies, and by the table that provides a surface for interaction while also obscuring the space under the tabletop. The attention of participants is directed towards the playing cards on the table. The video camera is also a part of the scene, shaping the interaction as participants pay attention to it and orient themselves in relation to the position of the camera. The *communication channels* that are in play are body position and gesture, sound, arrangements of visual artifacts (figure 8:1), or combinations of these. For example, players draw attention to their own actions, and sometimes also the actions of others, by sighing, tapping the table, exclaiming "Oh no!" or "Yes!" Some of the

players think aloud as they are searching. Gaze may have communicative intentions: if a player expects another participant to do something, he will look in the direction of that player.

In figure 8-1, Greger (to the right) prepares for his turn, which will start as soon as I turn the hourglass over. My hand is visible to the left. The other players look at Greger, or at the displayed cards. Two participants produce sounds, tapping the table and rattling a wooden puzzle.

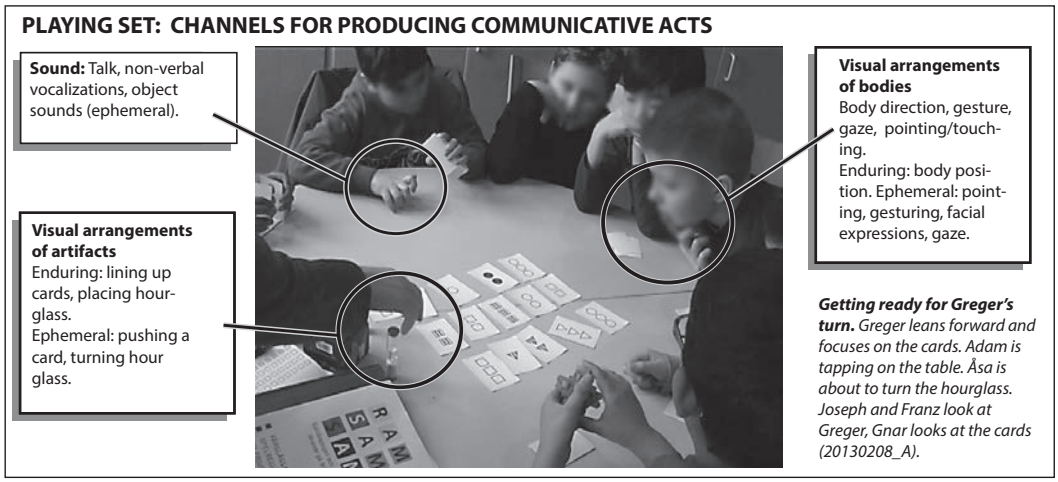

Figure 8-1. Playing Set: Channels for producing communicative acts (20130208_A).

Temporal patterns

In the recorded episodes of Set there are two different turn-taking models. The original rules propose an "auctioneering model": any player can, at any moment, declare that they see a Set, after which they have to show it to the other players who check if they can accept it (see 20110208 or 20130218_B). In 20130208_A (figures 8-1 and 8-2) the game is played using a conventional turn-taking procedure: each player gets to search for sets for a limited time, measured with the hourglass.

Each turn follows roughly the same procedure: preparing the displayed cards, turning the hourglass, the active player/s starts searching for a set, the active player/s present three cards as a set, the game master assesses the set. The repetitive temporal structure and the present visible structures of the game provide common ground and reduce the need for explicit communication. As a player proposes a Set to the game master for assessment, the "proposal" consists in aligning three cards, leaning back, and looking in the direction of the game master.

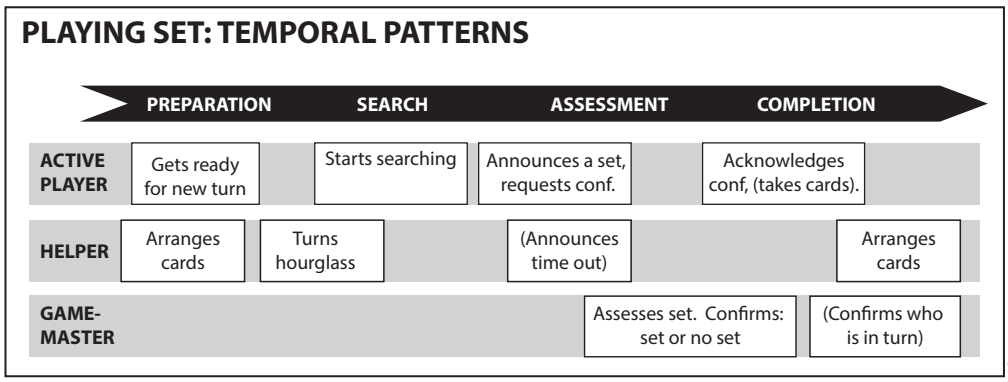

Figure 8-2. Temporal patterns. The gameplay follows a repeating turntaking pattern with small variations.

As long as the process runs smoothly, most of the communication is implicit. The participants know the procedure, and show that they do by anticipating the next action, for example by looking at the player in turn before the turn starts. If implicit communication fails, communication changes into explicit and verbal as in the following example.

> As Freja and Emma play, Åsa is busy and fails to notice the set proposed by Freja. Emma asks her twice to check the set before Åsa notices and responds to the question (20130206_A).

In most cases, new players had no problems acting appropriately within the turn-taking structure. Since card and board games are part of the basic offer of LTC activities, participants are likely to know the procedures of playing card games. Another possible explanation is that the repetition of the turn-taking procedure supports learning by example. A new player will have observed five or six other players in action for each of her own turns.

Visual arrangements

As part of playing the game, players produce and modify visual arrangements using the playing cards as the raw material. Playing the game consists of these dynamic arrangements and players' ways of attending to them. The visual arrangements are both semiotic, in the sense of carrying meaning in relationship to the game, and spatial, as they establish different zones, spaces, and directions in relation to participants' bodies. In figure 8-3, the visual arrangements produced by players are highlighted: the display, the deck of unused cards, the matching area, and individual stacks of found sets.

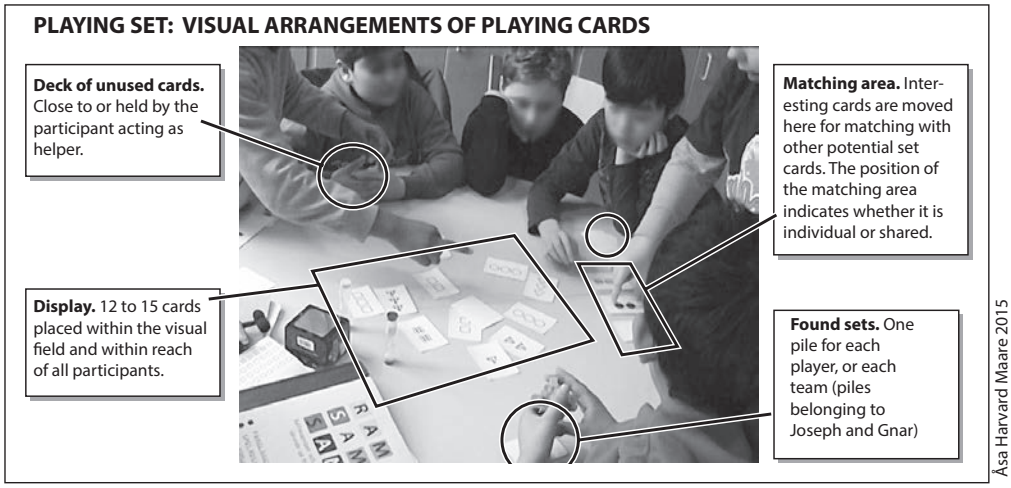

Figure 8-3. Playing set: visual arrangements of playing cards.

Each participant has an ”action space”, more or less in the shape of a semicircle with its center at the torso of the person, a radius corresponding to having the arms comfortably extended, and defined at its base by the horizontal plane of the table. In figure 8-4 two video frames are superimposed, allowing inspection of how the hands alternate between an extended position and a retracted position close to the body.

Figure 8-4. Accessibility: auditory, visual, and within hands' reach. Spatial structures established and actualized through a combination of visual arrangements of artifacts and movements directed at and framed by the visual arrangements (20130204_B).

Visual arrangements include the tangible parts of the game, but also include communication about, and coordination of, the game. In figure 8-3, the display – which normally consists of three rows with five cards in each – is in disorder. It has been shuffled around as players have engaged in helping and searching collaboratively. Greger, the active player (standing to the right) is engaged in matching cards, and the gaze of other players is directed towards the matching area in front of him. The position of the visual arrangements communicates the division of roles in the game. The matching area is directly in front of Greger, it is "his" matching area and he is not part of a team. Adam, who has taken on the function of the helper, holds the stack of unused cards. Two players have stacks of found sets in front of them.

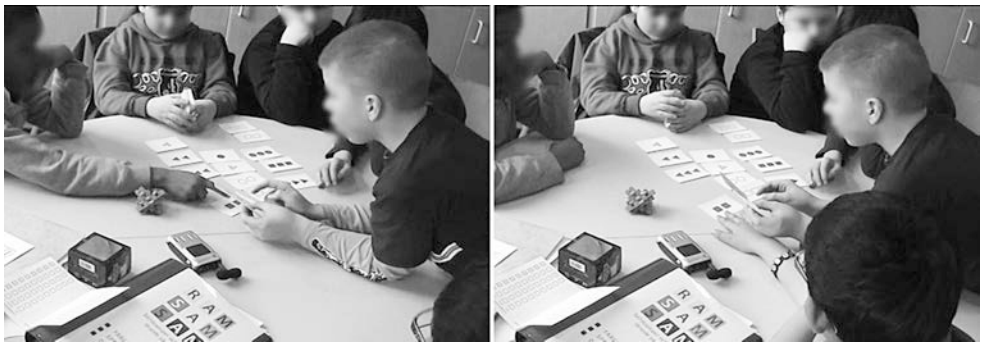

Figure 8-5. Greger is explaining what a Set is. He holds two cards in his hands, and he is searching for the words to describe the third card that would form a set. Nicholas understands what Greger tries to say, finds the card, and points at it. Greger, who is busy talking, does not notice this. Joseph then pushes the card towards Greger, who takes it and continues his explanation without interruption (20130208_A).

Visible hands

I will now look into how players use their hands. Hand movements with the intention to produce or modify visual arrangements are not included (see the section on visual arrangements). I will instead discuss instances in which hands are used as graphical overlays, or in which a hand movement acquires its meaning in relationship to arrangements of visual artifacts.

Figure 8-6 presents two examples of communicative *and* functional uses of hands with two persons involved.

- In order to assist Greger (figure 8-5), Nick points at the card Greger is searching for. Greger does not notice: his hands and the card he is holding are in the way. He is pointing to his card while he explains. Joseph uses his hand to push the new card to the side, until Greger sees it.

- It is about to be Greger's turn (figure 8-1). Some of children are talking and giggling. Åsa reaches out for the hourglass, but freezes and holds her hand still, ready to turn the hourglass which will mark the starting moment for Greger's turn. Only after the players become silent does she continue her action.
- Ella (figure 8-6) is engaged in matching three cards. She has lined up the cards in a matching area in front of her. She checks if they are a set while talking aloud to herself and touching the cards with her hands. As Freja discovers another possible combination for a set, she grabs Ella's hand and removes it from the table.
- Jessica adds new cards (figure 7-11). Leo counts the cards for each of the three rows using his hand, and tapping loudly at the empty places where Jessica is to put a new card.
- Leo indicates three cards and looks at me for confirmation (figure 7-6). With one hand, he indicates two cards and with the other hand the third card. Ivan leans forward in order to look at the cards under Leo's hand.

Certain aspects of using hands became noticeable in the above episodes.: there are no clear boundaries between communicative and functional hand movements, and the persistent use of hands as a visual overlay, directed at oneself or at others. Players "leak" information, that is, they allow relevant information about the cards they are holding and what features they are looking for to enter the public space as they think aloud and touch cards with their hand. Leaking provides feedback both to the player herself and to other players. Leaking allows information to be contributed and shared in the public space that participants create through their actions. Visual arrangements frame and provide an orientation for hand movements.

Figure 8-6. Hands of others. Left: as Sofie uses the AudioTheater, the child in the background observes Sofie's actions – and her hands - while waiting for her turn. Right: Ella assists Freja's search. Freja gets a new idea, and she grabs Ella's hand and moves it away from the table.

In chapter 3, I presented research on using hands as graphic overlays for selecting information from or adding animation to a static image (Kirsch 2012; Hutchins 2008). Similar cases of hand use can be observed in the data of Ramsamsam. Many of the hand movements here are not gestures, since they lack communicative content and do not support speech. Instead, they are part of solving a task and moving cards around, often accompanied by words. In this context, talking is often secondary to the hand movements. Even though speech and hand movements have no direct communicative intention, they have important communicative functions in making relevant information available to other participants.

Visible bodies

The spatial structures created by the playing cards achieve significance in relationship to the bodies of participant, and their action space: within sight, within hearing distance, and within arms' reach. As pointed out by Goodwin (2000b), visual artifacts are never seen in isolation. They are always percieved in relation to other artifacts, other persons, and through the attitudes and the attentional focus of other persons.

Figure 8-7 is based on the same video frame as figures 8-1 and 8-3, but this time with focus on postural arrangements and gaze direction. Most of the players are sitting at the right side of the table, and the display is also located slightly to the right. Nick, who is at the left side, is standing up, and so is the active player, Greger. A person who stands up extends her action space; she can now lean in over the table in order to gain extra arms' length. She can reach out more quickly, and has a better viewing position.

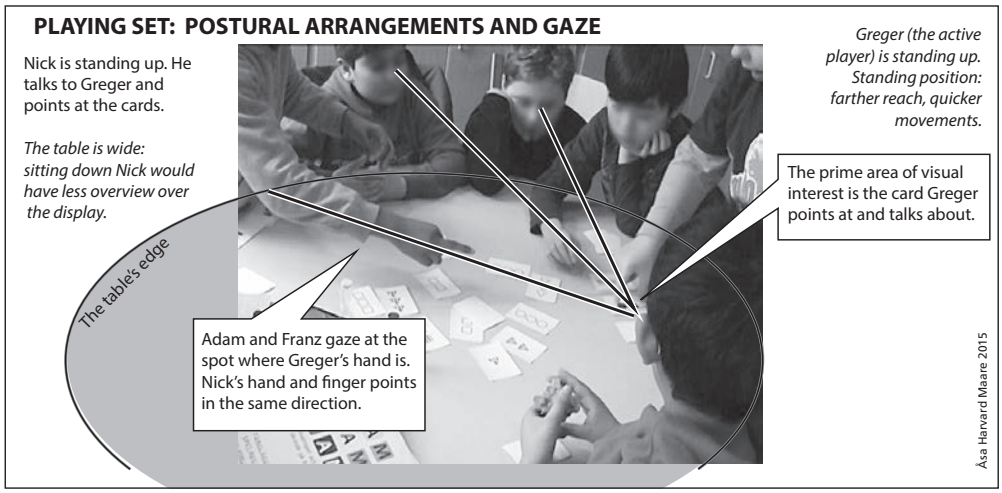

Figure 8-7. Playing Set: Postural arrangements and gaze.

Players place themselves in order to optimize their visual field. When searching for Sets, many lean in over the displayed cards in order to have a frontal view without perspective distortion, and allowing the cards to fill their entire visual field (see figure 8-8) In 8-7, Nick is standing up. Since the table is wide, he gains a better view of the displayed cards with less perspective distortion from a standing position – and a better starting position for rapid interventions.

One important aspect of body direction and position is how it reflects participants' readjustments of their posture in relationship to the visual artifacts. On the other hand, as Greger takes cards and aligns them in a "matching area" in front of him, he adjusts the visual artifacts to fit within his visual field – which he may do since he is the active player.

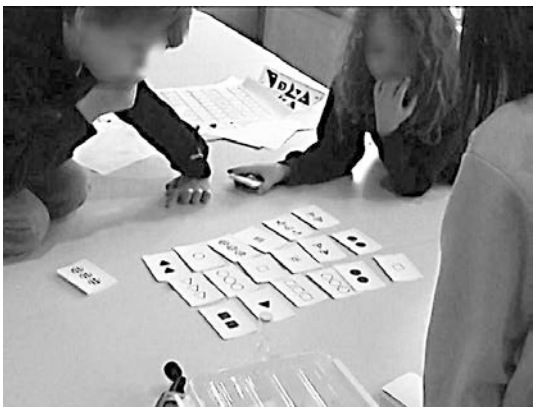

Figure 8-8. Jacob climbs on top of the table in order to have the displayed cards in the center of his visual field, Jessica stands up and leans in over the cards.

Participants' backs as information displays

As participants position themselves in relation to an area of joint attention, their backs will face the opposite direction, away from the focus of visual interest. As several people attend to a joint focus, their backs become a sign to other, non-participating but present persons about a potentially interesting locus of attention. Visible bodies constitute *"systematic, changing displays about relevant action and orientation"* (Goodwin, 2000b:157-158), and these displays are available both to co-participants and and non-participants.

Figure 8-9 consists of four frames from a video sequence of 45 minutes. The image is an enlarged detail of a table in the background of 20130204-A. It presents a scene of people gathering around a table, standing or sitting, leaning in over something, or getting up to leave. Even if the activity as such is small and has limited visibility, being partially blocked by the bodies of the participants, the activity as a whole is perceivable at some distance since the participants' bodies are visible displays of the activities. I have, in the theory chapter, discussed the importance of exploring the

premises of the LTC, and checking what other people are doing. During the 45 minutes of this episode, 22 people – teachers and children - are in some way engaged with the activity around this table, standing or sitting, observing or participating, which adds up to more than half of the persons present at the LTC.

Figure 8-9. Human backs as information displays. During the 45 minutes of the video recording, 22 persons are active at the table.

Leaking information

Many players think aloud while searching for sets. They make comments on their own actions while pointing or moving cards, and it is not clear for whom this talk is intended. Through thinking aloud and pointing and touching cards, players leak information about the task they are engaged in and the way they go about it.

Players think aloud in order to direct their attention to relevant aspects of the problem, or to use a certain procedure for solving it. Even if the reason for a player to leak information is ”epistemic,” providing feedback into her own cognitive processing, it may be interpreted by other players as an invitation to engage in joint problem solving.

Leaking information is also probably related to the difficulty of the task. Leo, who mostly searched for sets without using his hands, engaged in extensive verbal thinking-aloud – except when playing with his friend and competitor, Jacob. When he was playing with Jacob, he still engaged in thinking aloud, but with reduced informational content: this one, this one and that one! (20120218_B)

Ella uses talk to organize her search. Using her voice and movements she establishes a slow and steady rhythm of talk and touching cards. On other hand, Gnar’s

movements and utterances come in sudden outbursts, and he interrupts Ella several times. Gnar is talking to himself, but with less detail: Yes! No! (20130205_A)

Ella:	((moves three cards to the matching area))
Åsa:	There is a color problem…
Gnar:	((introduces a new card next to Ella's cards)) Yes! Yes!
Ella:	No, it is….if we put all the cards back…
Ella:	((puts all the cards back, including Gnar's))
Ella:	Empty, …, circle…((takes another card))
Ella:	…Hmmmmmm…
Gnar:	Wait I will…((moves some cards to a new construction area))
Ella:	((puts her cards back to the the display))

Excerpt 8-A. (20130205_A)

Excerpt 8-A illustrates an attempt to collaborate which falls short. Ella and Gnar don't achieve synchronization, they talk and move at different rhythms. Ella establishes a slow and steady rhythm through her talk and movements, whereas Gnar talks and moves in sudden outbursts, often interrupting Ella. Ella, on the other hand, takes Gnar's cards away: neither participant adapts to the strategy and tempo of the other.

The cards are also sometimes used as an alternative to talk, as shown in figure 8-5, in which Greger is searching for words. Two of the other players find the card he is referring to and call his attention to it without having to interrupt his speech, since their intervention is set in the visual modality. In the episode below, Leo uses the cards and hand movements to explain the game, and Pernilla expands upon the explanation by providing the words Leo needs.

Teacher Pernilla walks past. She asks Leo if he can explain the game to her.	
Leo:	((brings out one of his found sets and puts the cards on the table))
Leo:	((points at the three cards one after another)): It is the same
Pernilla:	It is circles.
Leo:	((rubbing movement on the cards)): And they are the same
Pernilla:	They are striped
Leo:	And it is one two three ((pointing at the cards in order)).

Excerpt 8-B (20130204_B)

In excerpt 8-B, Leo tackles the task of explaining the game by first producing a visual arrangement of three cards, and then using them to show the different relations that make them a set. The visual arrangement showcases the relationships to be communicated. Pernilla assists him by providing the words he needs. The way Pernilla assists Leo is similar to the way Nick and Joseph assist Greger (figure 8-5), only she contributes with words instead of cards.

Ephemeral gestures, enduring visual arrangements

The aspect that I will turn to now is the complementarity of enduring visual arrangements and ephemeral gestures and talk, following up on the theme of the ephemeral and the enduring in chapter 3.

> Making sense has a lot to do with making, because sense needs material forms. Among the entities that have forms and that are capable of generating images are words, things, hand shapes, and marks on paper, and one respect in which they differ from one another is how long they remain on the scene as social facts (Streeck, 2011:77).

In figure 8-10 there are two examples of communicative acts featuring ephemeral hand movements in combination with enduring visual arrangements. In the picture to the left, Leo has just asked me to collaborate with him. As I accept, he reaches out for my pile of found sets and puts them on top of his own pile as a sign of collaboration: the spoken agreement is made enduring by a change in the visual arrangements of playing cards. In the picture to the right: as Jacob sits down to observe the game, Leo uses his hands and arms as obstacles, blocking access to the displayed cards.

Figure 8-10. Enduring visual arrangements and ephemeral gestures. Left: Leo puts my sets in the same stack as his own as a sign of our collaboration. Right: Leo places his arms to block Jacob from taking cards in the display (20130204_B).

Ephemeral movements or actions with enduring effects on visual arrangements are used as participants communicate about the game:

- Pointing to cards, pushing a card toward a participant
- Collecting the three cards of a set and putting them in one's pile of found sets.
- Turning the hourglass over: starting a new turn
- Displaying emotion: throwing cards at the table, hitting the air.

In addition, there are different time scales connected to different parts of the body: body position and direction are relatively enduring as compared to gaze or nose direction. Hands can be used both for dynamic movements and, if holding hands still in the air, for freezing a movement and letting it persist for a more extended period (see example in figure 8-1).

Visual arrangements on the playing cards: 3D cues and orientation

Shadows, embossing, and highlights are often used in the context of information graphics with the purpose of creating illusory "layers" on the flat image surface. This is sometimes referred to as "2 ½ dimensions" (Ware 2008). Some of the prototypes in the Ramsamsam project have used highlights and shadows in order to create the illusion of several superimposed layers on the playing cards. The video recordings indicate that users respond to these depth cues in the way they use their hands when looking at or using the cards.

- The Set cards are flat, consisting of simple color shapes without embossing or shadows, shapes that are in the same plane as the white background.
- The Symmetry cards consist of nine squares with rounded corners, each with a shadow offering the illusion of relief.
- The 100-cards include both perspective and circles with highlights.

With the Symmetry cards, many players use their fingers for pushing on single squares or sliding them sideways as if they could be moved individually or turned on/off with pressure, demonstrating a motoric response to the illusion of pictorial elements floating above the white picture plane. In the videos of the "flat" Set cards there are no instances where players push at a single shape on a card; the card is attended to as a whole.

> Using an early version of the SOS cards (with embossed white squares and flat black squares without perspective effects), Hanna had found a mirrored inverted pair. She demonstrated it by placing her two cards face to face and slowly opening them as a book, showing how the embossed white squares on one card "fit" into the flat black squares of the other (20130211_A).

As the Symmetry cards are square, they have four possible orientations. For symmetrical cards, the card looks the same in two or four orientations, whereas asymmetrical cards look different depending on orientation. In early versions of the game, the orientation of the card is meaningful. For example, a pair of rotated cards is not the same thing as a pair of identical cards. However I have had to revise the game concept since players perceive the orientation of the card as accidental: as soon as they take a card they start rotating it in order to find the best orientation for mathching it with other cards.

I have deleted rotation as a feature of the card game because of this. A digital version of the card game may lead to reconsidering the role of rotation, since cards are likely to be perceived differently when they are effectively picture elements on a screen, and aligned with the orientation of the screen.

When Ella and Adina (20130211A) were searching for SOS card pairs, they found more mirrored pairs than identical pairs. It appears to be easier to find a mirrored pair than an identical pair – maybe because players hands used for searching are mirrored, too.

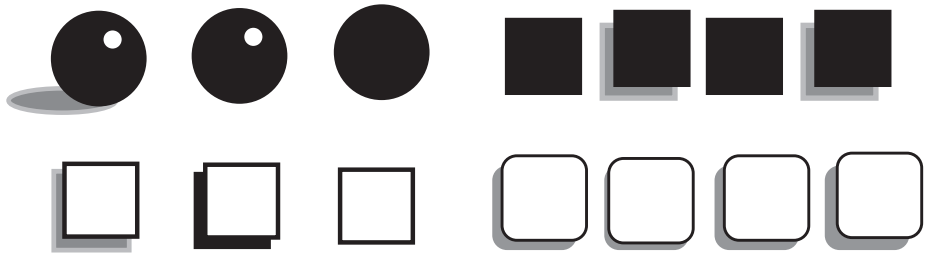

Figure 8-10. Examples of simple depth cues that give the impression of visual elements floating above the paper surface: highlights, embossing, shadows and changes in alignment.

To conclude, the video data from Ramsamsam indicates that depth cues in the playing cards have an influence on how players use their hands for pointing or touching cards, and whether the target of hand movements is the entire card or graphic elements on the cards. Symmetrical cards seem to be easier to find than identical, which also may relate to hand shapes. Cards whose design indicate that they can be rotated and used with different orientations are percieved as such: players don't see the actual orientation but start rotating them in order to find the best orientation for matching with other cards.

Conclusions on communication

The question that I set out to answer is as follows: *How did the participants communicate during a game of Set, and what was the role of visual artifacts for communication?*

In producing communicative acts, participants opportunistically engage and combine all available modes of sign production (talking, gesturing, positioning body and limbs) within the framework created by visual artifacts and other environmental factors. An important feature of visual artifacts, and the arrangements that they are part of, is that they endure. They remain on the scene, inviting further elaborations, and providing the framework for ephemeral communicative actions, talk, and gesture.

As a part of playing the game, players create and modify visual arrangements using playing cards as building blocks. Apart from being vehicles for the game, these visual arrangements carry meaning in many ways. Through their position they provide information about who plays with whom, who is the game master, to whom the found sets belong. The visual arrangements of the game (display and matching areas) are fairly stable over time, but as they are updated and reproduced there are slight adjustments and re-orientations reflecting the division of roles and the progression of the game.

In the context studied here, joint engagement in a game, it is impossible to draw a line between gestures and functional hand movements, and between self-directed and other-directed communication. Many participants ”leak” information: they think aloud, point at or move cards, and it is not clear whether this is intended for themselves or for another person. By leaking information, players make their actions and thinking public, a part of the common ground of the game. This allows observers and other players to follow the actions and offer input to the active player.

The presence of graphic depth cues like embossing, highlights, and shadowing is reflected in the way users point to and touch playing cards: shadows and embossing help to ”detach” visual elements from the surface of the paper, making them more accessible for pointing or pushing at individually.

Finally, a joint activity – consisting of certain participants directed towards a shared attentional focus, is at the same time communicating inwards, to its participants, and outwards, to ”non-participants”. If the aim is to recruit new players or learners, it is important how the activity communicates to these non-participants: what are the opportunities for observation? The scale and orientation of designed objects influence how participants arrange themselves in relationship to the artifacts they attend to, which in turn has consequences for what other players and observers may see.

9. Learning and motivation

The research questions that I will bring up in this chapter concern motivation and learning: how participants learned the activity, why they participated, and the influence of peers for each. Participation is understood in a broad sense: engaging in the game, in other persons playing, in side activities: what is participated in is the entire activity culture around the game, extending beyond the game itself.

In comparison with the previous chapter, in which the analysis was based on observations of the video data, this chapter has a different character. Learning and motivation cannot be observed directly, but have to be constructed or inferred from learners' behavior over time. I will start with two visualizations of participation over time, each in its way describing aspects of the development between episodes, drawing a map that will feed into the arguments about learning and motivation.

Participation over time

Over eight recorded sessions of playing Set, around 20 children participated, depending on the criteria for participation (observing or playing). Three of the sessions took place during mathematics lessons, the other sessions were recorded at the leisure-time center.

Individual trajectories of participation

Figure 9-1 describes individual trajectories of partcipation. All playing participants are included, but not casual observers. I was part of all eight sessions. From my field notes, I have added contextual information: who is friends with whom, what the circumstances were when a participant joined the game. The diagram format can give the impression of huge datasets – so, once more, this diagram represents a series of single events: contextualized anecdotes if you wish.

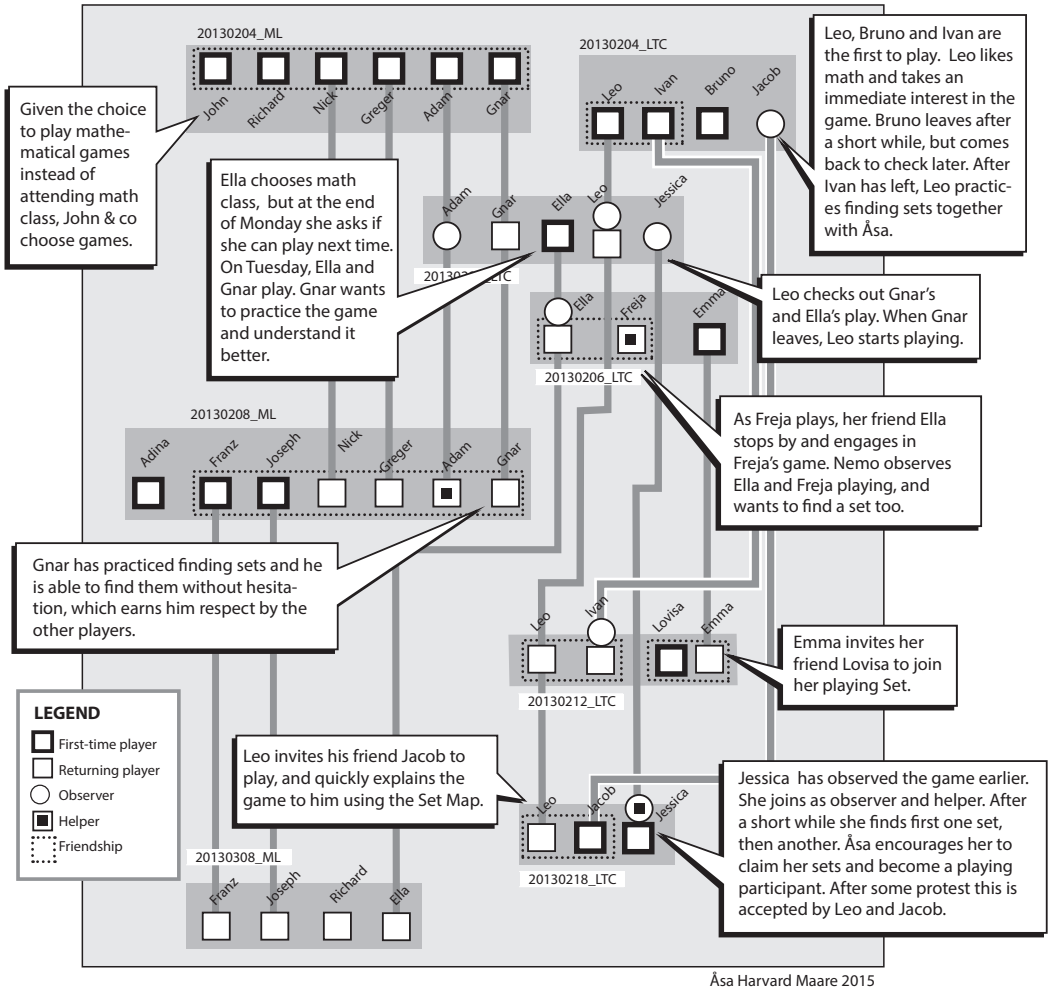

Figure 9-1. Individual trajectories of participation.

What does the diagram show? It shows that people participate for different reasons. It also shows that what is participated in changes over time. The first participants are curious about the game, and some of them have an interest in this kind of game (something the LTC teachers already knew about, and they helped me by talking to some of the children they thought would be interested). For many of the later participants, observing other children playing is an important part of their decision. The first players tend to come back and check how more recent participants are doing, which may lead to a new round of play.

Later participants not only are better informed, but the activity also gains further interest as it is practiced by more children: the activity affords sharing a project with other children, comparison with other children, and occasions for doing things

together. The first participants are likely to have an interest in the subject matter, but later participants need not to: the social context becomes in itself a reason to participate.

There are some weaknesses with this account of participation. I have already touched on the fact that the sample is small. Related to this, all eight episodes are more or less part of an introductory phase. The picture is not that of a mature activity culture, with many long-term participants.

Duration of participation

The second visualization (figure 9-2) consists of eight diagrams describing the duration of each Set session, including the duration of time participants and observers invested in the activity. The data is the same as in the previous diagram, but the perspective is different. In these diagrams the focus is on the duration of the session as a whole and of different participants' engagement as players or observers. Each diagram depicts the total length of one hour, divided into five-minute slots by vertical lines. The gray area indicates the total length of the video recording. Participant players are dark gray whereas observers are white. Capital letters indicate participating children.

The data comes from the ELAN recordings and my annotations of entry and exit points for different participants. For casual observers, I have included all who stop by and look at the activity. In the diagram the minimum duration is about 30 seconds for reasons of visibility, although the real duration may be shorter. The durations are not exact, with a margin of about 30 seconds.

In counting observers, I have included persons that stop by in the immediate proximity at the activity and direct head and body towards the activity (in many cases the faces are outside of the picture frame). Since I only used one video camera for recording, the video frame covers about half the circumference of the activity. Observers standing behind or next to the camera are not counted: the actual number of observers is likely to be higher.

What is made visible through these diagrams?

- The leisure-time center episodes are longer than the math lesson episodes. In the math lesson sessions, all start and all stop at the same moment. The leisure-time center sessions often involve changes in participants: as a participant leaves, an observer takes the vacant seat and joins as a player (in four of the five LTC episodes).

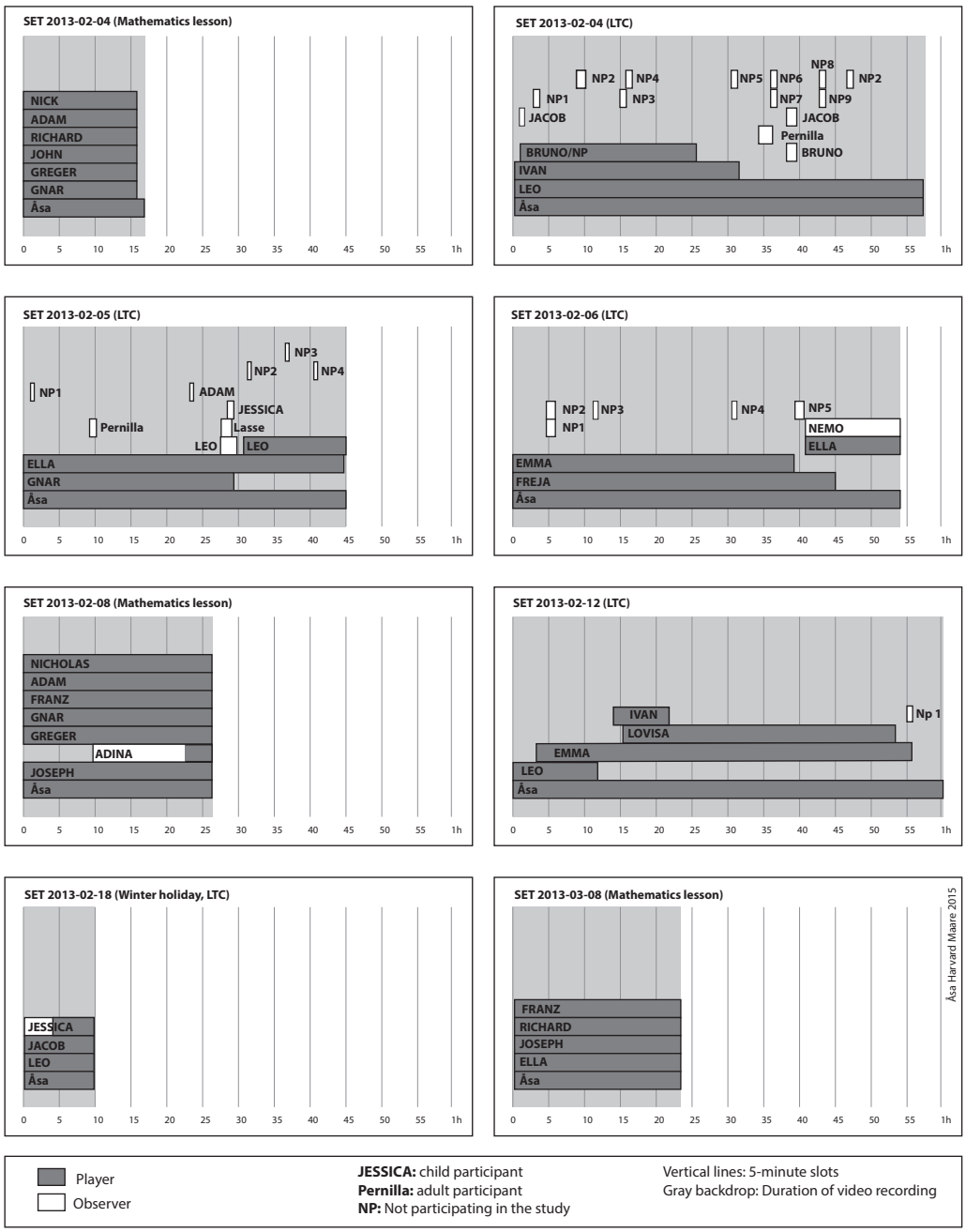

Figure 9-2. Diagram over time and participation in the single episodes.

- There are many observers stopping by to look at the activity – however, the number of observers is highest during the first play sessions.
- Children observe activities before and after participating in them, checking out who else is playing and how they manage. Children actively recruit their friends into the activity.
- During the mathematics lessons there were no observers. This is likely to be due to two reasons: the potential observers are in class, and/or observing what other children do is not an accepted activity during class.

The pattern of children stopping by and observing what other children are doing is not specific to the activities I introduced, but rather a general pattern in the social web of the LTC, as discussed in the previous chapter on visible bodies.

There is a noticeable difference between leisure-time center episodes and math lesson episodes, but I may play a role in creating that difference since I act as game master in both settings. What the diagram does not show, but what I know as having been part of the episode, is that I take care to focus the attention of all participants on the game, raising my voice in order to address the whole group, introducing and explaining. Also, it is not sure that these mathematics lessons are representative for lessons in general. A pedagogic model like cooperative learning, where learners work in groups, may share more features with the LTC episodes.

In all the LTC episodes with the exception of the first, participants had the opportunity to observe the game being played before playing. Many new players were able to ”pitch in” and start playing without special instructions. This was also the case in the math lesson episode (20130208_A) since several of the players knew the game, and new players could observe how other players did while waiting for their turn.

Comments on the duration diagrams

The duration diagrams highlight the difference of the contract regulating school time and leisure-center time, and the massive presence of observers attending to what other children do at the LTC (see figure 8-7 for a related example), especially during the first occasions. As pointed out by many studies set in LTCs (Bardon 2008; Evaldsson 1993, Corsaro 2011), the activity of roaming around and checking what other children are doing is, as judged from this small sample, quantitatively important as calculated by the time children spend observing peers.

A consequence of this is that the legitimacy of observation is important for learning. This legitimacy is two-sided: it has to be legitimate to observe for the children who are being observed, and legitimate for the observers to roam around and look at what others do instead of engaging in an activity of their own. During lesson time, observing others is less legitimate than during LTC time; this is one possible interpretation of the diagrams. There are also many occasions in school in which observing peers is decidedly illegitimate: copying friends’ answers, or attending to

peers instead of listening to the teacher. There is a strong cultural and historical heritage of considering peer observation as an obstacle to learning instead of a support.

Learning

At this point, I will put forward an answer as to how children learned to play Set, and what the role of peers was within the learning process. My perspective on learning is situated, and I will approach it as a change in participation: between the initial, unexperienced participation and the skilled participation of an expert player. While between these two positions, participants were engaged in some of the following activities:

- Players listened to instructions from a teacher (mostly in the math lesson episodes).
- Players engaged in dialogue with adults/teachers (mostly in the LTC episodes).
- Players engaged in the play of other participants: observing, advising and helping.
- Players engaged in sustained observation of the activity and the interaction between participants, gradually learning to anticipate subsequent actions.
- Players re-used actions, strategies, and words of other participants.
- Players leaked information: talking to themselves while pointing at or moving cards. This caused other players or observers to engage and assist in searching.
- Players engaged in side activities: looking at rule sheets and instructions, comparing them with the current game, solving paper-based assignments related to the game.
- Players revisited old sets: taking out the cards and looking at them again.
- Players engaged in deliberate practice, either by "solitaire" modes of playing, engaging in side activities, or playing for practice.

All of the points above are directly or indirectly connected to the game being played. In addition, activities not directly related to playing the game, like practicing a search procedure or reading the game guide, become meaningful in the perspective of playing the game later.

Getting instructions/engaging in dialogue

In the first game sessions, especially those during mathematics lessons, I started by giving the children instructions. For a new group of players, the maximum time that I could mobilize their attention for listening to my instructions was too short for the task: explanations had to continue as the game proceeded. Some children engaged in dialogue with me as teacher/game master. Other children attended to the exchange between me and other children; these children constituted a larger group than those with whom I had a dialogue. See examples: Leo in 20140204_B, Ella in 20130205_A.

Engaging in other players

Many observers, both non-playing observers and players waiting for their turn, were deeply engaged in the actions of other players. In 20130208_A, Nick is immersed in Greger's play. He offers advice, finds cards for Greger, and pushes them in his direction. Gnar also follows Greger's actions with strong emotional engagement: sighing, or crying out "Oh no!" or "Yes!".

I interpret this as a part of the process of "pitching in" (Paradise & Rogoff, 2009): the engaged observer aligns with the player's emotions and attentional focus. At certain occasions the engagement is so strong that the observer takes over from the active player (for example Nick in 20130208_A); the boundaries between self and another person blur. I did not make any similar observations connected to the game Nim where the competitive structure is stronger: success for one player is directly connected to the other player losing.

"Helping out"

As a contrast to the collaborative and tightly aligned interplay in the examples above, the following shows an example of "helping" another player, this time with very little interaction and no alignment between players.

> Adina arrives later, in the middle of the game. She has not played Set before. When it is her turn, Joseph asks if he may help. Adina accepts. Without looking at the cards she has already picked out, he collects a different set. Joseph hands over the three cards to her without any explanations (20130208_A).

This episode is typical of many, where "helping" another player does not involve any explaining, collaboration, or communication – as a contrast to players searching for sets collaboratively, with a high degree of alignments and emotional engagement.

Anticipating the actions of the game master

In our role as game masters, both Niclas and I took the time to go over, point by point, why three cards constitute a set or not. Over and over we repeated the formula of "form, fill, shape, number" while pointing to the cards. After a while, players started anticipating our actions, typically leading them to shout "OH NO!" when the

game master was only halfway through the assessment process (it is easier to find out whether three cards are not a set, than to find out that they are a set).

A learning aspect of this is how players profit from the repetitive structure, and how they use game masters as a backup: anticipating what will be said, and checking with what was actually said. Anticipating what the game master was going to say was facilitated as both game masters talked slowly while explaining, without skipping any steps.

Re-using actions of other players

An example of how players re-use the actions of other players can be found in 20130208_A. On Friday, the "math lesson group" continues playing Set. Gnar collects a set without hesitating (Set number 4 in figure 9-3) using the 3-2-1 strategy that he practiced on Tuesday. Other players observe Gnar, and the following 6 turns are attempts to use the same strategy. Of these, three lead to accepted sets.

I would ascribe the success of Gnar's strategy both to the fact that it worked for finding sets, and to Gnar's assurance as he used it.

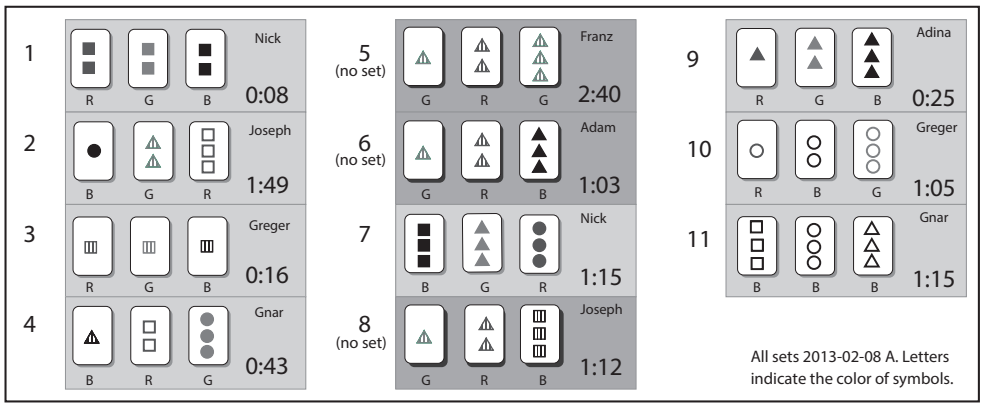

Figure 9-3. All proposed sets during 20130208_A. The time for searching is indicated.

Leaking information

Many children "leak" information as they are confronted with difficult tasks. They externalize their thinking by pointing, arranging visual artifacts, and thinking aloud. Even if there is no designated addressee, other participants may take this as an invitation to engage in joint problem solving.

In 20130206_A, Freja is the active player. Ella joins and starts looking for a set. Freja joins her, and the two players engage in a tightly connected joint search in which both leak information by pointing to cards and talking aloud – to themselves and/or to each other.

Using the notion of common ground (Clark 1996), leaking information is a strategy for making relevant information a part of the common ground and sharing it with other participants. The effects are positive both for the problem-solver herself, who gets feedback by making her thinking public, and for other participants who are given information required for understanding and for helping.

Engaging in side activities

Engaging in side activities includes filling out challenges, engaging as a helper, observing, looking at the cards without playing, looking at guides and overviews.

Many children were reluctant to play a game that they were not sure they understood. I prepared secondary artifacts, guides and challenges, both as a resource for myself and for chidren who wanted to get to know the game without playing it. The secondary artifacts were typically lying on the table in several copies.

The activity culture around the game Set also attracted interest from children who did not want to play. Side activites, both opportunities for peripheral participation as an observer or helper, and secondary artifacts with the same types of tasks as in the game, offered pathways for children who were motivated by the game but not ready to play it.

Re-visiting found sets

Another typical action is that players bring out their found sets and look at them again, or use them for explaining the game to new players. A possible explanation is that the old sets have two qualities. First, they are confirmed by the game master, which makes them reliable sources for comparing with other cards. The second quality is that they identify the player as a competent and successful finder of sets.

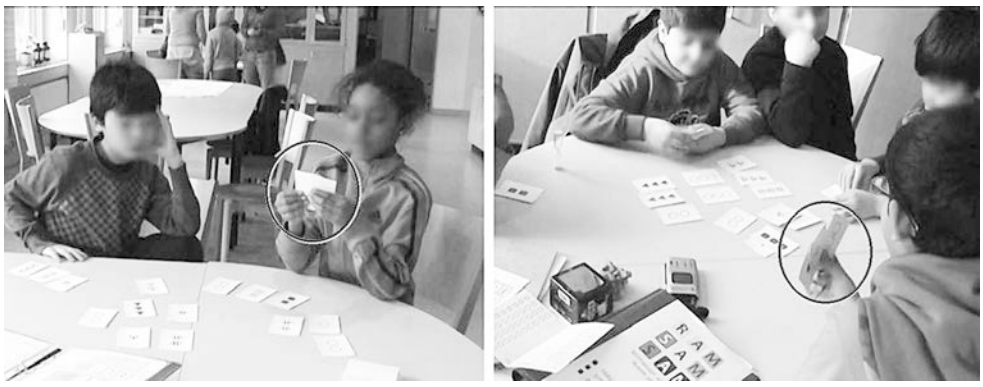

Figure 9-4. Re-visiting old sets. Ella, to the left, and Joseph, to the right, take the opportunity to bring out the cards from their old sets and look at them once more.

Deliberate practice

Deliberate practice refers to learners engaging in perfecting some aspect of their skills by repeated attempts to solve a particular problem. Deliberate practice is set outside of the primary context of use, in a non-competitive (or not-so-competitive) context.

In the recordings of Set, there are two examples of children engaged in deliberate practice. The first example is Leo, who continued to search for sets after Ivan left, and gradually became more and more adept at finding them (20130204_B). The second example is Gnar (20130204_A) who consequently practices the search strategy starting with a 3, then 2, then 1 until he masters it.

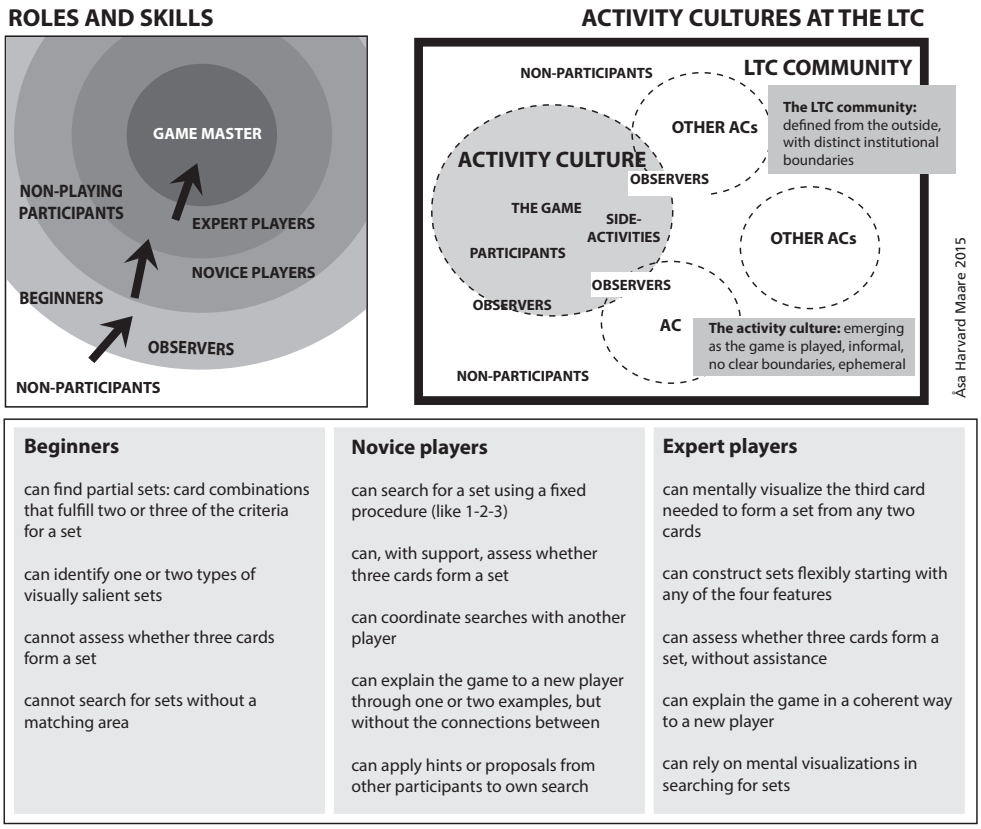

Figure 9-5. *Top left:* roles and functions in playing games. The role of helper – not in the picture - could be performed either by a playing or observing participant taking care of distributing cards and turning hourglasses. However, some players used the function of player as part of "leveling up" to a new role. *Bottom.* This diagram suggests which skills players have as beginners, novices, and experts. Beginners are new to the game; the transition to novice may take 15-30 minutes. Children who have had opportunities to observe the game often start at the level of novice. Expert, here, refers to the skill level in this particular group of childen. The different skills in the list are based on observations of the video data; however, there is a degree of simplification and generalization involved in making a diagram of this type. *Top right:* Schematic overview of an activity culture within the institutional LTC community.

Learning and moving in social space

According to Lave and Wenger (1991) learning and moving in a social space go hand in hand: new insights and new knowledge change how individuals participate in a community of practice. This is one of the aspects that I intend to follow up on in the data from Ramsamsam: what is the relation between players' skill levels and the roles they take in relation to other players? Are the two linked, as Lave and Wenger suggest, or are they two separate processes, as described in social learning theory (Bandura 1971)?

The LTC is not a community of practice in the sense of Lave and Wenger (1991). The institutional boundaries are clearly defined, and there are no doubts as to who is part of the LTC. All members know each other, at least by name. There is no core activity in the LTC community holding it together- and this is an important difference from communities of practice - but instead many informal activity cultures: short-lived, with no clear boundaries, emerging around a game or activity, recruiting members from the LTC community, and after some time, being abandoned in favor of other activities (figure 9-5, top right). As children orient themselves to the interests and preferences of other children, engagement in different activites comes and goes in waves.

Figure 9-5 gives a schematic overview of the various roles that players and observers take, and which skills accompany that role in a general sense. Using the diagrams above as a matrix framing players' social and knowledge moves, we can look at some examples of players attempting to change roles:

First example: Molly

Molly who has just fund her first set, makes a move towards the role of expert player: As game master Niclas starts explaining the game to new players, Molly interrupts him, brings out her found set and uses it to demonstrate what a set is to the new players. (20110208). In this case, Molly successfully "levels up" to an expert role without protests from the other players, using her authority as the first player finding a set.

Second and third example: Freja and Emma

Freja and Emma play together. Freja, who is the more experienced player of the two, takes on the function of helper. She supports Emma by indicating cards or reminding Emma to look for color or number. Freja rearranges the displayed cards in order to facilitate Emma's search for a set. A little later, Emma wants to rearrange the displayed cards as Freja just did. Freja corrects her: Emma is not allowed to move the cards, unless she has found a set and wants to show it (20130206_A).

Freja establishes herself as an expert player by taking on the role of helper and by supporting the novice player Emma. Emma "reads" Freja as a role model for how to play, and does the same at Freja does. Freja however makes a distinction between things she may do, as an expert players, and things Emma may do. In this case, Emma's behavior is interpreted by Freja as an attempt to assume the role of an expert player, and is contested. A similar episode, and a similar discussion, is presented in Williams (2001:13), in which a child teaches a game to another child. The "tutor" has to negotiate between the role of "being the better player" and helping the other player: he cheats (something better players can do) but protests as the tutee does the same.

Fourth example: Jessica

Jessica comes over to look at Leo and Jacob playing Set. I suggest that she assume the role of helper. After a little while she looks in my direction, makes a questioning sound, and points to three cards. I confirm that they are a set, and encourage her to take them. Leo and Jacob protest: she did not call set before taking the cards! A few minutes later the same thing happens again: Jessica finds a set, I support her in taking it, the other players protest. From that point on, Jessica takes part as both a player and a helper (20130218_B).

This example resembles that of Freja and Emma. Jessica makes a move towards the role of player – or, more correctly, I make the move by insisting on her taking the set – and this is met with hostility from the two other players. Changing roles led other players to contest Jessica's right to play.

Discussion

Freja and Molly establish themselves as expert players and allies with the game master by taking on responsibilities associated with the game master. The shift in roles is not sudden but gradual. On the other hand, Jessica and Emma are met with protests as they expand their roles. In Jessica's case, the change in roles was a consequence of acquiring new skills, and of my somewhat clumsy intervention. In Emma's case, her expansive behavior of rearranging the cards was based on a misjudgment of Freja's actions.

All four examples are arguments against an automatic link between a player's skills and the roles she takes. Molly and Freja "level up" gradually and strategically towards new roles. The sudden shift in participation by Jessica and Emma leads to protests from other players. A more likely view is that players observe the social landscape and move towards new positions when the opportunity is there, using the authority of having had success or filling in as there is a vacancy. Learning and moving in social space are certainly related, but not tightly coupled in time. Children may have good reasons to hold back from enacting new skills directly, instead waiting for a suitable opportunity to display their new skills and confront the consequences of doing so.

These examples also highlight the importance of establishing a supportive and generous environment where children feel safe to express their knowledge and take on new roles.

Conclusions on learning

The research question was: *How was the game learned, and what was the role of peers for learning?* The most important resource for learning was the game being played, as it offered numerous opportunities for observation and participation. Also, the fact that the game was played made it meaningful for players – and non-players – to study and practice the game through secondary activities. Learning through observation and participation was facilitated by the repetitive turn-taking structure, which allowed observers to predict and anticipate actions, and to re-use the actions of other players. Many children did not want to play the game until they understood it. For this group of children, secondary artifacts and peripheral forms of partipation (as observer or helper) offered non-competitive pathways into the game.

What makes it learnable? Opportunities to observe others, instructions and guides that are at a relevant level of complexity, support from adults or expert members, safety again: a tolerant environment allowing players to take on new roles. Secondary artifacts, activities that leave traces allowing the player to revisit old accomplishments, participating in the problems solved by other participants. Increased knowledge did not automatically lead players to take more central roles in the game. Successful role-changers acted slowly, using or creating opportunities for taking on more central roles (other players being absent, teaching a less knowledgeable friend).

The visual artifacts – and the game generally – supported learning by allowing players and observers to follow the actions of the active player and of the game. The structure of ”no chance and no hidden information” is well adapted to observational learning. Secondary artifacts and guides could be used for comparing with the actual game, and they offered the advantage of presenting a static view of the game, without the ongoing re-configurations of the game being played.

Motivation

Why did participants participate? First, in this concrete setting, and then in more general terms, what makes children want to engage in an activity together with peers? I will approach these two levels, the concrete and the general, by referring to the map describing participation in figure 9-1 and comparing it with the preliminary learnworthiness list from chapter 2: *reciprocity, mastery/competence, identity-building, closure*.

Among the participants on the first day were children who had an interest in the topic of mathematics, while others were curious about who I was. The participants in the mathematics lesson group joined the game through a different process of choice: they were allowed to play games *instead* of following the ordinary mathematics lesson (only one of the math lesson players returned to play again at the leisure-time center). With reference to the list, the motivations of the first day participants were curiosity and identity-building (for those already having a self-concept of being good at mathematics).

The participants coming the second day and later were better informed about the activity since many of them had observed other children play. Engaging in an activity together with friends was important for some participants, and others were invited to join by their friends. As more children participate, the activity grows in learnworthiness: it affords comparing oneself with others and sharing experiences with others. The activity accumulates common ground: there are ”better or worse ways of playing the game” recognized by the group of players (an example: re-using Gnar’s winning strategy, p.123 in this chapter). Previous participants come back to check how new participants are doing, and to inform themselves about the activity: the activity culture becomes in itself a reason to participate. The activity culture had a motivating effect also on children who did not want to participate as players: they stopped by to find out about the game, observe, or engage in side activities.

For the participants coming the second day – and those of the following days – reciprocity and mastery were important aspects. As a group of children became more or less engaged in playing and in monitoring other players, playing Set acquired the added dimension of “being part of the Set players group,” and as more played, players could compare themselves to other players and use them as role-models.

Different players took different routes into participating: via friends, in order to avoid some other activity, or because the topic interested them. Also, what children participated in changed over time: as more participants joined, the opportunities for reciprocity and achieving mastery (including comparing oneself with others) grew, and there were more role models available.

Closure: smiling

As a new set is confirmed by the game master, the players tend to smile: the player who has found the set smiles, as do other players who have helped or engaged with the search of the active player. I interpret this smile as a spontaneous expression of joy and self-satisfaction – comparable to self-satisfied smiles of babies achieving their aims, or of sports champions in a moment of triumph.

In four of the recorded episodes of Set, there are, in all, 47 confirmed sets. In 35 of those, the active player is facing the camera. In 24 cases, the player smiles upon

receiving confirmation by the game master. If other players protest against the active player, or if the player is hurrying on to a new task, there is no smile. As the game master, I am the person allowing a player to smile – but since I am either out of the frame or facing away from the camera, my facial expression is not captured.

Åsa:	Think a little, what should the third card look like?
Ella:	Circle.
Ella:	((finds the card and pushes it in position under Gnar's arm))
Gnar:	((takes the set))
Ella:	((smiles))

Excerpt 8-C (2013-02-06_A). See illustration in figure 7-7.

I interpret the smiles as a signal that the activity has reached a point of closure, and that a smiling player is satisfied with her accomplishment. The smile is likely to be seen by other children: "I want a set too!" (Nemo, 20130206_A).

Liljedahl (2005) rejected the possibility of orchestrating AHA-experiences since these are dependent on chance. The repeated moments of closure, release and self-satisfaction of smiling Set players have much in common with AHA-experiences – but they are triggered by the feedback from the game master. They indicate that experiences of success can indeed be orchestrated within the framework of a game.

Attributing merit and sharing success

A related issue is who endorses the success of a found set. Since a found set is often the outcome of many players helping each other, attributing merit is not easily done. One player may have found the set (or the third card of it) but another player wins the trick. In the following example, Franz – who plays for the first time and has so far been unsuccessful in finding sets – participates in the the success of Gnar.

> All are intensely engaged as Gnar starts searching for a set. They hardly breathe. He takes a card. Rethinks. Takes another. The friends comment, and encourage, but silently. Finally he is gets his set together. All the players signal joy and relief. Franz starts singing: "We are the champions!" Gnar burst into a smile, but turns his face towards his arm, away from the gaze of his friends (20130208_A).

Franz' joy over Gnar's set indicates that success can be shared even by participants who were not part of the accomplishment, but identify with those who were: the process of attributing success to a player or a group of players allows for some flexibility. This can be related to the game structure in which players work in parallel with the same type of task. It is harder to share success in Nim, where the success of one player is directly connected to the misfortune of the other player.

In browsing through the video data, I can see that the person who I would consider having the merit of finding the set often smiles. However, this could be attributed to

the possibility that I, as the agent, am bestowing the right to feel successful through my behavior and facial expression.

What is interesting here, in relation to the discussion about motivation and self-concept in relation to mathematics, is that players can enjoy the success of a "group accomplishment" without having played a personal part in the achievement.[19]

The role of peers

Children look at peers – or more exactly, at the entire activity including peers and other participants – in order to extract information about the potential benefits and risks of the activity, how hard it is to learn it, what kinds of pleasurable or interesting experiences it affords, how it fits in with their identity and the identity of the subgroup that they are part of. Adults and teachers may provide better models for how to perform certain actions, but peers have the advantage of being similar to the learner, and, in that sense, more informative about that activity. All learners need not to be motivated individually. When there is a momentum in the group of learners to judge an activity as learnworthy, this is likely to spread throughout the group.

Conclusions on motivation

The research questions were: *Why did children want to participate in the game, including its related activities? What was the role of peers in motivating children to engage?*

In chapter 2 I established a preliminary list of learnworthiness aspects, based on Bruner's work (1966): *reciprocity, mastery/competence, identity-building, and closure*. A child's reason to engage in an activity has to be inferred to some extent – but the overviews of trajectories of participation support the points of the list above. However, one aspect is lacking. Many of the participants are concerned about safety: the risk of being exposed to ostracism or hostile behavior, of failing in front of others, of not being held in esteem by peers. In order to include this aspect of choosing activities I will add *safety* to the learnworthiness list: not being exposed to the risk of failure, that the consequences are known, that there are examples to follow.

Austin claimed that learnworthiness is decided in the peer group (see p. 17). My data does not allow any conclusions about learnworthiness as an individual judgement or the outcome of a group process. What is clear, however, is that children look at peers in order to determine the learnworthiness of the activity: are they having fun? Who is

[19] An unavoidable parallel: the effect on the self-concept of entire nations during a World Championship in soccer.

doing this? Is it difficult? Is it for people like me? Etc. In this sense, the learnworthiness calculus (Austin 2002) is likely to spread between peers.

No fun

Throughout this book I have avoided the term "fun" as a quality in activities aimed at children, or as a design criterium. Being intensely engaged in an activity together with other persons is fun, but from the perspective taken here, engagement is the quality to retain. A second reason not to discuss activities as fun or not fun is the condescending attitude in modeling children as primarily motivated by having fun; such a model leaves no room for children to reflect, respond to different needs, or act strategically. I do not want to imply that children's choices are always well grounded and rational – no more or less than those of adults – but a model that recognizes children as capable of acting strategically provides a better foundation for design decisions.

Evaluating the Ramsamsam project

Before I close the analysis of Ramsamsam and proceed to the design implications, I want to summarize the project: its achievements, shortcomings, and unanswered questions. There are two reasons for this. One is closure, the other is to evaluate the strengths and empirical grounding of its conclusions and design implications.

The strengths of the project is the connection to the Rook, and the fact that I returned there over several years. The contact with teachers and children has been a challenge to design ideas as well as to theoretical assumptions, but the duration of the project has allowed me to capitalize on the experiences "in the field", to re-think, and re-orient.

The design aim of the Ramsamsam project was to develop activities that

- invite children to look for mathematical relationships, and to talk about them with peers.
- afford experiences with the potential to contribute to the learner's mathematical knowledge, if contextualized in classroom discourse.
- afford positive experiences of competence and success, to individual participants and to the group.

The analysis is built on activities that had the above effects (even if they were not contextualized in classroom teaching), which means that I have been able to approach them in my analysis. I have not designed any new games that meet these criteria, and the dominance of a single game in the analysis brings about a risk that the design implications will tend to replicate the same game.

I had many roles in the Ramsamsam project: designer, protagonist, and analyst. In ethnographic studies of preschools or leisure-time centers such overlaps are normally not considered a problem, but in the research tradition of conversation analysis, to which embodied interaction is connected, it is. I have attempted to be transparent by accounting for enactment and risks for bias in describing the video data.

The ambition for the project was that the games would take on a life on their own at the LTC. Even though I took care to leave copies of games and guides in between my visits, they were not used. One conclusion to draw from this is that teachers are needed in order for learning interventions in the LTC to have an effect. Another conclusion is that the activities and/or the enactment did not work out well enough for children to appropriate the game. Furthermore, the pedagogic rationale was that the activities and games were to be followed up and contextualized in classroom teaching. This did not happen for reasons out of my control. As the pedagogic rationale of the design was to provide experiences that feed into mathematics teaching, an important final link is missing from the project.

10. Implications for design

I will now change the perspective, and try to extract implications for future designs from the analysis in the previous chapters. I will use the notions of learnworthiness and learnability as my main conceptual tools. Some of the implications concern enactment – how to present and support activities – and others concern design of activities, or both.

In designing activities for the LTC and a community of learners who may choose among activites, it becomes important to consider activities as learners see them. What makes an activity learnable and learnworthy from the perspective of learners? The ”learnworthiness calculus” (Austin 2000) performed by the children is not very straightforward or predictable. Often children base their judgments on generalizations or rely on the example of peers. What matters is whether an activity *appears* learnable and learnworthy.

> **Implication for design and enactment:** ensure that the activity or game is learnable and learnworthy from the perspective of potential participants.

The most effective way to achieve the above is to arrange for the game or activity to be played or practiced, for example as teacher Lotta explains: ”If you want to introduce a new activity or game, you start it up with a few children. After that they learn from each other “ (see full citation, p. 55).

> **Implication for design and enactment:** make sure the game is played or the activity is practiced, and that this is visible to potential participants.

So far, the implications concern both learnworthiness and learnability: observing the game being played informs participants about why, and how, to engage with it. In the following sections on learnability and learnworthiness, some of the design implications will appear twice since they are important for both. Figure 10-2 will provide an overview of all implications.

Learnability implications

In the following I will start by learnability aspects, based on the lists of activities children engage in from chapter 9.

- Players engage in the play of other participants: observing, advising and helping.
- Players engage in repeated observation of the activity and the interaction between participants, gradually learning to anticipate the next actions.

Increasing visibility through design

Potential participants observe an activity in order to find out what it offers, and visibility is important for letting them see what they need to see. Visibility is also important for observational learning: is it possible to see what the game is about? Visible structures frame interaction and facilitate communication by creating common ground for participants.

As Jacob and Leo played Nim in the staircase, Jacob suddenly slowed down as he realized that there was a pattern to which numbers to choose. Leo noticed that Jacob paused, but did not understand why: he became impatient and asked Jacob to go on with his move (20130218_A). This episode can be compared to many similar ones in Set, in which players waiting for their turn often engage in the active player's search, offering advice or finding cards. A difference between the two games is that Leo cannot *see* what Jacob is thinking about.

Figure 10-1 illustrates this point by proposing a design for Nim with increased visibility and support for leaking information, thus providing players with better opportunities to follow the moves and plans of other players.

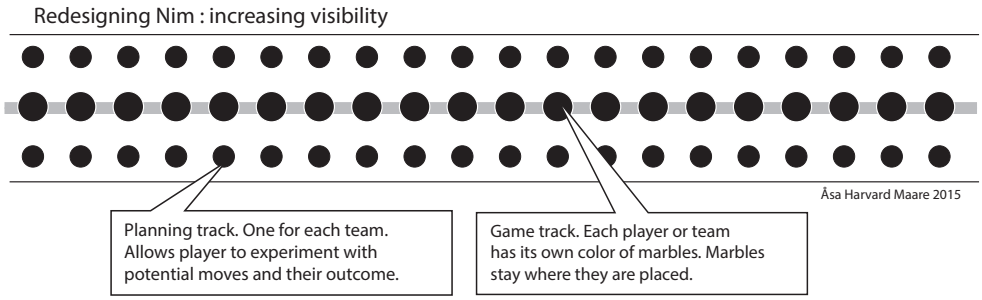

Figure 10-1. A sketch for a redesigned Nim game using the model of MDF board with holes for marbles. The target number and how many steps a player may move each time can be modified. All placed marbles in the game track are left in place during a game, and each team has its own color. In this way, the gameboard becomes a visual resource for understanding the pattern as the game unfolds.

Implication for design and enactment:

Ensure that relevant information about the task to solve is visible to players and to observers.

Legitimacy of observing what others do

- Players re-use actions, strategies, and words of other participants.
- Players leak information; talking to themselves while pointing at or moving cards. This causes other players or observers to engage and assist.

These points lead to some consideration on the level of the institution. In most LTCs it is accepted both by children and teachers that children wander around looking at what other children are doing. If this behavior is not accepted, this type of learning is compromised. In my studies it became quite clear that "lesson time" is different. During lessons, children are expected to stay in place, attend to the teacher, or engage in the project before them. It is not acceptable to wander around and observe during lesson time. The same applies to copying other children. There is a long history in education of considering copying and imitating to be less valuable forms of learning, or even to be cheating. In order to facilitate learning from peer observation, it may help to clarify that copying other children is allowed. The other side of this is to encourage players, both through design and enactment, to make their thinking visible: think aloud, use your hands to move cards.

Implications for enactment:

Ensure the legitimacy of observing what other participants are doing, and of copying other participants.

Encourage participants to make their thinking visible by leaking information: using hands, arranging game artifacts.

Secondary artifacts

The next points on the learning list concern side activities andsecondary artifacts.

- Players engage in side activities. Looking at rule sheets and instructions, comparing with the status of the game, solving paper-based assignments related to the game.
- Players revisit old sets: taking out the cards and looking at them again.
- Players engage in deliberate practice, either by "solitaire" modes of playing, engaging in side activities, or playing for practice.

Introducing new games in the leisure-time center starts, in most cases, with an adult sitting down and engaging in gameplay together with a few children. Other children will come to check out what they are doing; some will stay for a while, and perhaps start assisting other players, or start playing themselves.

This general scenario opens for some design considerations. The more intense the engagement in a game or an activity, the more observers are likely to join. As a consequence, there is a need for multiple copies of guides and secondary artifacts. The

teacher is likely to be engaged in playing as new players arrive. It is an advantage if secondary artifacts can be decoded by children without the teacher having to interrupt her participation in order to explain and instruct.

Some children are hesitant to engage as players, but still interested in finding out what the game is about. Other children are ready to engage as players, but find it difficult to figure out the game during the excitement and stress of playing it. For both groups, non-competitive side activities can provide alternative means to learn the game or the activity.

Interpreting visual symbols

As the rules were not available, many of the children used the visual symbols on cards and game boards as pointers or reminders of the game's rules. Players face the challenge of recovering or re-inventing rules based on the visual artifacts of the game. This can be supported by the design in several ways: providing icons or symbols for the most important rules or game items, striving for symmetry between icons and what they signify (cf. The Lost Diamond), and avoiding visual symbols or distinctions that are unimportant for how the game is played.

Implications for design:

Provide secondary artifacts and side activities, both non-competitive and competitive, in multiple copies.

Provide a system for saving, revisiting, and sharing old accomplishments.

Adapt to the reading skills and interpretation styles of the participants as a group: use visual symbols consistently, avoid large amounts of text.

Role of adults and teachers

- Players engage in dialogue with adults/teachers (mostly in the LTC episodes).

Implication for enactment:

At the LTC, ensure that there are teachers who engage in the activities together with children, and enter into a dialogue with them.

Contrary to the model of legitimate peripheral participation, the children at the Rook did not automatically take on new roles as their skills increased. Changing roles could lead to protests. Role-changing was contingent on vacancies: if a position was free, a new participant could claim it, be it the chair of one of the players or the role of game-master. As a consequence, there is one more implication for enactment:

Implication for enactment:

Create vacancies and allow participants to take on new roles and responsibilities, for example by splitting up and changing the composition of groups.

Learnworthiness implications

I will now go over to learnworthiness, and what can be done on the levels of design, enactment and institutional arrangements to make activities attractive for learners. The starting point is the ”learnworthiness list” from chapter 9 of what activities should afford in order to be learnworthy: reciprocity, competence/mastery, identity-building, closure and safety (see page 131).

Reciprocity

Reciprocity – engaging in joint projects with others, sharing emotions, working towards common goals, finding one's place within a group of people – is one aspect of learnworthiness. Using the Ramsamsam prototypes and a few examples from older projects, I would like to discuss how the design of artifacts and activities can support reciprocity.

In an earlier project, Psst!, we designed boxes containing sounds which children activated by placing toy characters on top of the box (Harvard & Løvind, 2002). In the first versions, the sounds that were played were determined based both on the character and on the sounds that had been played previously. As we tried the prototype with preschool children, we found that the typical way of exploring Psst was through sharing with friends. A child finding an intriguing sound wanted to show it to the other children by placing the character at the same spot once more. However, a different sound was played the second time. This was profoundly annoying to the demonstrating child. The experience of the first sound was not shared, and the child ran the risk of appearing incompetent in front of her friends. The connection between sounds and objects was changed in later versions. This anecdote tells something about the importance of reciprocity. The design can support reciprocity by being predictable and transparent, thus allowing users to achieve their objectives in a premeditated way.

Some of the children at the Rook did not want to play from the start, but they were still interested in looking at the sheet explaining the game, and in filling out the ”challenges.” The side activities allowed non-players to participate in the activity culture around the game, another aspect of reciprocity.

Implication for design:
Ensure that the activity affords reciprocity.

Supporting emerging activity cultures

Even though teachers and children in the LTC honor the idea of the child's right to make her own decisions concerning leisure time, these decisions are contingent upon many influencing factors. Institutional arrangements constrain children's choices, and

some activities are promoted at the expense of others. The marble run can serve as an example: the activity was promoted as teachers helped by clearing a space for it and starting to set it up, and through the fact that it was allowed to take over the room for a few weeks. How exactly did the institution support the marble run project and its evolving activity culture? It did so by scaffolding, making space, sitting in, engaging with, paying attention to, occasionally by inviting new children into it. A group of children took charge of the project: it did not start as a peer-driven project but rather it grew and became one.

Implication for enactment: Support the development of an activity culture around the activity by engaging in, scaffolding, and assigning a dedicated space for it.

Designing for appropriation

Most of the activities that I took part in at the LTC were initially scaffolded and attended to by teachers, before being appropriated by groups of children. Activities and artifacts which allow appropriation by children users have an advantage. Games and activities that underscore children's dependency on adults for different tasks (opening a locked cupboard in order to retrieve important materials, reading out the rules, solving conflicts) are de-motivating, both because of the interruptions they cause and the signal they send. Designing for appropriation by children can also be taken literally: artifacts adapted to the size of children's hands, robust and cheap, present in multiple copies in order to allow many children to engage in the same activity while observing each other. A part of the enjoyment is to display exaggerated emotions (see figure 1:1). Frail or light-weight artifacts reduce the space for ample movements and expressive gesture. Another aspect of appropriation is to give the artifact to children, allowing them to bring it home and share their experiences with other family members.

Implications for design:

Provide secondary artifacts and side-activities, both non-competitive and competitive, in multiple copies.

Adapt to the reading skills and interpretation styles of the participants as a group: use visual symbols consistently, avoid large amounts of text.

Make component parts robust. Missing parts not critical or replaceable, artifacts that allow players to move and gesture freely.

Mastery/competence

> We get interested in what we get good at. In general, it is difficult to sustain interest in an activity unless one achieves some degree of competence (Bruner, 1966).

In order for participants to engage, and to sustain their engagement in an activity, it is important that the game or activity offers the participant some experience of success

and of being competent. A task or a learning aim that is beyond reach is disregarded (Hannula, 2012).

Revisiting old accomplishments

Bringing out found sets and looking at them again is both good for learning and a way to enjoy the feeling of accomplishment a second time.

Implication for design:

Provide a system for saving, revisiting and sharing old accomplishments.

Flexible attribution of success

At a first glance it might seem quite straightforward to determine who is the winner and who the looser. But with closer scrutiny, the attribution of success to participant saffords some flexibility. A participant can identify with the success of the group, regardless of her own performance. If observers or players ”help” another player, there will be multiple people who share in the success.

Many players experience joy in the success of a peer, and grow in self-esteem themselves from that experience, depending on how the success is attributed. In the game Set, players took turns in solving the same type of problem, whereas Nim had a structure in which the success of one player was directly tied to the misfortune of the opponent. The Set game procedure allowed more participants to share in the success and enjoy the experience of feeling competent.

Mastery orientation vs. performance orientation

Gnar: Now I understand a little! (20130205_A)

Some children explain failure by referring to themselves as lacking the skills or the potential for learning (”If I lose this time, I don’t want to play anymore”), whereas others re-contextualize failures or mistakes as steps towards increased knowledge in a learning trajectory (“No no, I was wrong, there wasn’t a set!”) Assuming that these differences depend upon the explanatory models available to the children, observing other children’s explanations may contribute to the availability of mastery-oriented explanatory models to children who do not have access to these at the outset.

Implications for design and enactment:

Visualize both failures and accomplishments as steps in learning trajectories.

Create opportunities for children to participate in their peers’ explanations of the reasons behind success and failure.

The optimal level of difficulty

From the perspective of learning, the optimal level of difficulty is located within reach of the group but too difficult for a single member. If one member of the group solves the task, or is close to doing so, this will increase the motivation of other children and

their belief that it can be done. This concept is close to that of the Zone of Proximal Development (Vygotsky 1978), which is the difference between what a learner can accomplish on her own and what she can accomplish with the help of a skilled peer or teacher.

From a player's perspective, the optimal level of difficulty is the level at which the game can be played through without breakdowns or interruptions, while still producing a winner. If none of the players is capable of performing a turn, the game breaks down (see p. 61 on local rules for Couronne). Game players have many ways of modifying and adapting the level of difficulty of a game. If a function is deemed insufficient or unsolvable, participants may compensate by adding or modifying elements of the game. Learning the game is also a kind of modification: players modify *themselves* in order to fit the needs of the activity. Whether it is by modifying the participants (learning), the rules, or the material support, the aim is to carry out the game successfully. This means that size, shape, and material can vary within wide limits since participants will accommodate for the design by modifying gaming procedures, body position, visual attention, learning new models, or inventing new concepts or words – as long as they are motivated to engage in the activity.

Implication for design:

Ensure that the activity affords achieving competence and displaying mastery.

Support participants in modifying rules and adjusting the level of difficulty.

Ensure flexibility in attributing success to participants.

Identity-building

The experiences of children within the leisure-time center give them the occasion to compare themselves with others and to explore which styles, activities, and props are relevant for their own identity in the group. Activities with relevant role models (in this context, understood as other children and adults of the LTC) which allow learners to connect the activity to some of their ongoing identity projects are more interesting than activities with no relation to identity-building. In the following example, the position of role model becomes accessible for emulation due to the role model's absence: there is a vacancy to fill for Emma, who grows into the new role.

> A few days after playing with Freja, Emma brings her friend Lovisa and wants to play Set with her and with me. This time, Emma takes on many of the helpers' functions, similarly to what Freja did the last time (20130212_A).

Implication for enactment:

Ensure that the activity affords identity-building and relevant role models.

Create vacancies and allow participants to take on new roles and responsibilities, for example by splitting up and changing the composition of groups.

Ensure that the learning environment is safe and supportive, allowing participants to take on new roles and meet new challenges.

Closure

The next aspect I want to touch on is closure, or the ”sense of accomplishment.” Several qualities of an activity may contribute to the sense of accomplishment:

- a temporal structure alternating between tension and release
- clear goals: the activity has a starting point and an ending point (and it is not too long)
- as a participant finds the set, or resolves the problem, she is recognized for her effort
- some visible manifestation of the accomplishment: collecting cards into a pile, filling in an empty box on a training card, moving something up a ladder…

A suggestion is that the shift from tension to release, the feeling of competence, and the act of collecting some small object (stacking a card, taking a marble) -- if they are timed -- do contribute to the sense of accomplishment. Many games involve players making a small collection during play, a collection of found sets, play money, or widgets.

In the case of Set, every found set offers closure. The game advances in cycles of tension and release. It starts with tension, increases to stress and perhaps frustration. As the set is found and accepted, there is a release of tensions: players smile. The structure of tension and release is almost addictive, especially as players sense that a possible breakthrough in their understanding is underway.

Implication for design:

The activity should lead to closure and offer participants a sense of accomplishment.

Safety

Disengagement and lack of motivation may be part of a learner’s strategy for avoiding risks and failures. A safe and supportive environment reduces the learner’s need for taking measures which are counterproductive to learning.

In spite of the conventional image of children as fearless explorers, many children are cautious about the consequences of their actions when about to engage in a new activity. A learning activity and environment can be adapted to children who avoid taking risks by providing non-competitive entry paths: allowing peripheral

participation and creating opportunities for observing peers before deciding to engage themselves.

Implications for design and enactment:

Ensure that the learning environment is safe and supportive, allowing participants to take on new roles and meet new challenges.

Provide secondary artifacts and side activities, both non-competitive and competitive, in multiple copies.

Ensure that relevant information about the task to solve is visible to players and to observers.

Towards a design model for peer learning

I have enumerated a series of implications for design and enactment, based on my conclusions about learning and motivation in the design experiences and observations from the video data: a design model for designing and enacting learning activities intended for learning settings where children have the right to choose what to do. The model presented here does not address the pedagogical question about how to support learners in transforming educational aims into personal goals: the setting is informal learning.

On the next page I have summarized the implications in a diagram. The implications are not intended to make sense alone, rather they are intended as an overview of the major points made throughout chapters 5-9. Artifact design, enactment, and institutional culture all contribute to learning activities, and it is often difficult to draw the line between the three. Some of the ”implications for design” are equally implications for enactment, or implications for arrangements at the institutional level.

This list can be used for analyzing existing games and activities as a baseline for new design proposals, or as a tool for iterating prototypes or modifying the enactment of activities or prototypes. I have used a small part of it for revising the Symmetry prototypes, but most of the implications have not been tested empirically: at this moment these are the conclusions of the Ramsamsam project, and their applicability rests to be demonstrated in future design projects.

DESIGNING FOR PEER LEARNING

The activity or game has to be percieved as learnable and learnworthy by its potential participants: **Ensure that the game is played or the activity is practiced, and that this is visible to potential participants.**

LEARNABILITY	LEARNWORTHINESS
Implications for Design	
Ensure that relevant information about the task to solve is **visible** to players and to observers.	Ensure that the activity/activity culture affords **reciprocity**.
Provide **secondary artifacts** and side-activities, both non-competitive and competitive, in multiple copies.	Ensure that the activity affords achieving **competence** and displaying mastery.
Adapt to the **reading skills** and interpretation styles of the participants as a group: use visual symbols consistently, avoid large amounts of text.	Ensure that the activity affords **identity-building** and relevant role-models.
Visualize both failures and accomplishments as steps in **learning trajectories**.	The activity should lead to **closure** and offer participants a sense of accomplishment.
Provide a system for saving, revisiting and sharing old **accomplishments**.	Ensure that the learning environment is **safe** and supportive, allowing participants to take on new roles and meet new challenges.
Support participants in **modifying rules** and adjusting the level of difficulty.	**Implications for Enactment**
Ensure flexibility in **attributing success** to participants.	Ensure the **legitimacy of observing** what other participants are doing, and of copying other participants.
Make component parts **robust**. Missing parts not critical or replaceable, artifacts that allow players to move and gesture freely.	Encourage participants to make their thinking visible by **leaking information**, pointing, arranging visual artifacts.
	Ensure that there are **teachers** that engage in the activities together with children, and enter in dialogue with them.
	Support the development of an **activity culture** around the activity by engaging in, scaffolding, and assigning a dedicated space for it.
	Create **vacancies**, allowing participants to take on new roles and responsibilities
	Create opportunities for children to participate in their **peers' explanations** of the reasons behind success and failure.

Figure 10-2. A summary of the implications for design and enactment.

Secondary artifacts: the Symmetry guide

Halfway through the period of my field studies at the Rook, I abandoned temporarily the SOS prototype as it didn't work out with the setting and the participants. However, the experiences of using SOS cards and gameboard have fed into the analysis here and there, and I want to point at the Symmetry Guide as an example of a secondary artifact intended for children 7-9. It is shown here on a single page, but the version that I have used in schools is layouted as a booklet with one example per page. The game consists in finding symmetric pairs, simple pairs of symmetrical cards or complex pairs of cards that may become a symmetrical pair through a number of transformations (inverting, translating etc.).

The Guide was revised using the implications for design: information is redundant (words *and* visual symbols for operations), principles are explained through concrete examples starting with easy examples and progressing towards the difficult. The design is simple, with a minimum of details asking for attention.

Note that this is work in progress: the names for the different kinds of pairs has not yet been established.

Figure 10-3. Finding symmetrical pairs.

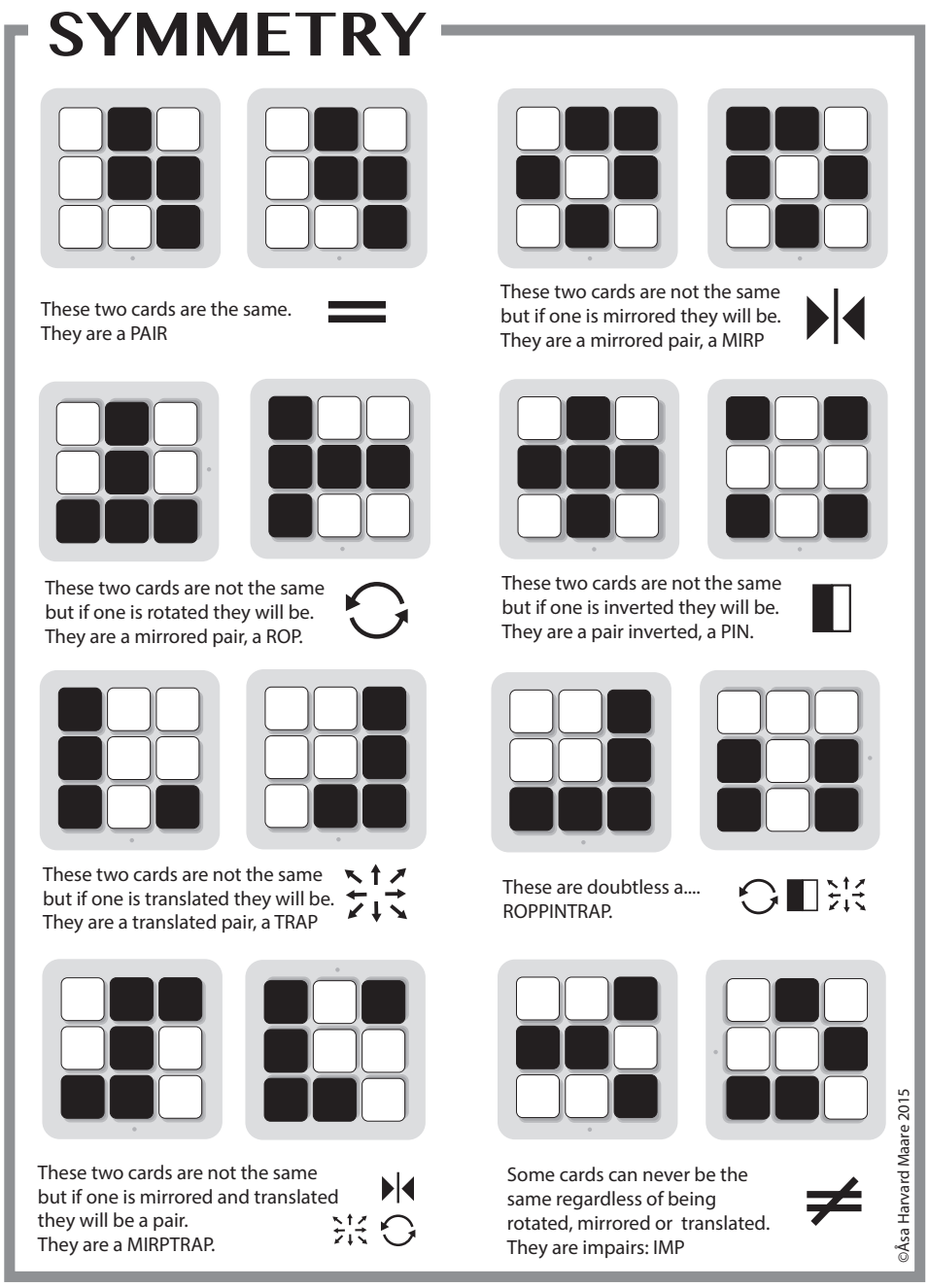

Figure 10-4 Symmetry Guide: words and visual symbols for operation, redundancy, step-by-step explanation. In the version used with children, examples are presented on separate pages.

11. Discussion

Streaming and segregation

At this point, I would like to take a step back from the Rook and address the wider educational and political backdrop of the Swedish school system. In order to put the observations from the Rook into a new perspective, I will include the concepts of streaming and segregation, linked processes with with consequences for many Swedish schools.

Streaming in school systems refers to the channeling of learners into different ”tracks”: practical and theoretical, with different pedagogical models depending on learners' performance or their district. Sweden used to have an educational system with a low degree of streaming, but after a process of deregulation and decentralization, and a long series of school reforms over the last 25 years, the system now has a high degree of streaming even by international standards. The motivation behind this system of free school choice, and including an economic model in which public funding follows the child to the selected school, was to promote competition and thus increase quality (Malmberg et al. 2014). The outcome of the reform, from the perspective of schools with a high degree of cultural and ethnic diversity, is that concerned parents with sufficient resources tend to move their children to schools with less cultural diversity (Skolverket 2009, in OECD 2011). As a consequence, classes in multicultural schools have a smaller proportion of first-language learners, and fewer learners from family backgrounds with higher levels of education .

> A Swedish analysis (Skolverket 2009) of declining student achievement highlights the influence if increasing segregation in the Swedish school system and the negative effects of decentralization and streaming. Individualisation in teaching practices, or a shift of responsibility away from teachers to pupils, also had a negative impact. These factors increased the effect of student socio-economic background, whether by highter concentration of pupils from similar backgrounds in the same schools or strengthening the importance of home support, where parents' level of education assumed greated significance for pupils' educational attainments (ibid., p. 23).

This is all well known from numerous research studies, including the PISA surveys. The reason to address this issue here is that it is actualized in the Ramsamsam study in two distinct ways. Firstly, school segregation is an ongoing process. It does not only happen at the point of transition between preschools and schools. Rather, the initial

group of children splits apart little by little, as concerned parents with sufficient resources choose to move to new neighbourhoods or transfer their children to other schools. For each child who leaves, the pressure on those who remain increases (Malmberg et al. 2014; Schelling 1969). The equilibrium of schools and neighbourhoods with culturally diverse inhabitants and learners is vulnerable, and if some of the inhabitants choose to move, this may cause mixed schools or neighbourhoods to tip over into being uniformly Swedish or immigrant (ibid.), with serious consequences both for learning and for integration.

The second consequence of streaming and segregation concerns the working climate for those children and teachers who remain. Classmates are important, both socially and as a referential framework for a child to establish her own identity in relation to the group, to school, and to family. Austin (2002) describes the learnworthiness of a school subject as an outcome of a process in peer groups in which different school subjects and activities are judged to be more or less important, relevant, ”cool”, interesting, etc. than others. On the other hand, there is evidence that the parents' level of education is important for children's understanding of school and its requirements, and in a longer perspective, their chances of being successful in school. If we put these two pieces together, the picture that results shows that the selective removal of children with higher-income and educated parents deprives the class of an important resource for learning.

Peer groups are often overlooked in educational debate – or treated uniformly as a source of negative influence. It is important that we shift the perspective and focus on the potential and positive effects of peers for learning:

> In our own work we have identified a myriad of ways in which peers can influence learning, such as helping, tutoring, providing friendship, giving feedback, and making class/school a place students want to come each day […]. Peers can assist in providing social comparisons, emotional support, social facilitation, cognitive restructuring, and rehearsal or deliberative practice. (Hattie 2009:104-105)

Learning interventions in the LTC

One of the issues in the Ramsamsam project is how to resolve the dilemma of enacting voluntary participation in learning activities defined by an educational agenda. In the previous chapters I have discussed how this can be done, using learnability and learnworthiness as design tools. Using the LTC for learning interventions with direct connection to curricular goals is more than a matter of how – it is, in a way, a violation of the implicit contract of the LTC.

However, one can make arguments for LTC interventions which target mathematics: it is possible to target groups of learners who need interventions, the timing is

appropriate (during the first years of school), the high level of attendance in the 6-9 year old age group. Through its institutional profile, the LTC affords learning in groups with a great deal of agency for the participating children, based on teachers and learners working side by side. Since children attend the LTC together with their classmates, experiences in math class provide common ground for the LTC and vice versa. In addition, time spent at the LTC is not earmarked for curricular aims, making it easier to enact activities that take time, in which children can explore and return to over several weeks.

There are also arguments against LTC interventions: the children most in need of an invervention are not likely to be participating, since children (like adults) tend to seek out activities that they are already good at. On the other hand, following the argument of Austin (2002), if there is momentum in a peer group to consider a topic learnworthy, this will transfer to other members, even those who have not participated in the intervention. Increasing the focus on ”useful knowledge” in the LTC may compromise children's opportunities to formulate their own learning projects (Haglund 2009). Finally, learning interventions in the sense described here depend on teachers introducing the activities and supporting children as they engage in the activities and with each other.

It would be interesting in future studies to look further into visual and recreational mathematics for activities which are relevant but not too close to curricular activities: patterns, tessellations and tilings, coloring images, magical squares, isometric “minecraft” drawings, tic-tac-toe, 3D puzzles, mathematical constructions using Lego or centicubes (Furness, 2001; Gardner, 2001; Dahl, 1998), activities which tie together aesthetics, mathematics, and personal exploration:

> Searching for and creating mathematical patterns adds an aesthetic dimension to mathematics. It also affords experimentation: what happens if I color both the 4-table and the 6-table in the 100-board? Is it possible to combine squares with equilateral triangles in a mosaic? Suddenly there is an opening towards mathematical research and towards personal mathematics – mathematics made by you (Furness 2001:4, in my translation).

Applicability for digital design

In this project I have used paper artifacts and playing cards as the design material rather than digital media. This raises the question whether the conclusions of the projects, which are based on the analysis of paper playing cards, can be applied to digital learning software or games.

Ten years ago, digital technology was approached as ”different” and ground-breaking, forcing researchers and educators to rethink media, learning, and communication.

Today, it does not make sense to maintain the division between analog and digital, traditional and new media. The ”new normal” is parallel publishing: a game or a pedagogical artifact exists on many media platforms, both paper-based and digital. This is the case with newspapers, which are published both on paper and on the web, with television shows including characters who are available as plastic toys or comic book characters, and with money, shifting between the gestalts of plastic cards, paper bank notes, metal coins, and disembodied numbers in digital space. In short, I envision games and learning activities as both paper-based and digital.

However, these two materializations bring out different qualities in a game or learning activity. In a digital game, the computer takes care of many functions: giving feedback, enforcing rules, managing turn-taking. Many of the social and logistic tasks connected to playing a game are taken over by the computer. This presents many advantages, since attentional resources can be used for solving complex game-related tasks. On the other hand, turn-taking and interpreting rules are important social skills that need to be practiced.

There are many digital games built around the concept of playing cards, and most of these respect the cultural and material constraints of paper playing cards: they have two sides, the direction of orientation (which end points upwards) is irrelevant, a deck of cards consists of 50-100 cards. A game designer can use the digital format for changing these constraints, by introducing decks with more cards, or making orientation a feature of the card, or changing the relationship between front and back. On the other hand, paper cards have many affordances that digital cards lack: in building visual arrangements of paper playing cards, players can adapt the game to the physical environment and the number of participants. The visual field of players is wider and more flexible than a computer screen. Cards can be shuffled, stacked, arranged in various shapes allowing for a rich array of combinations of hand movements and card arrangements – which in turn influences the opportunities for observers or potential participants to follow and engage with the game.

In short, the issue of how visual artifacts are used concerns paper-based playing cards specifically, whereas the discussion of motivation and learning in the LTC is independent of the media platform.

Using visual artifacts: a situated and embodied perspective

Not so long ago, graphic design as a discipline was mainly artistic – or technical. Today, it is gradually developing into an academic discipline. This is a challenge both for the traditional expression of knowledge in graphic design, and for scholarly research standards when applied to a practical and aesthetic field, as discussed in chapter 4.

The scholarly approach to graphic design has contributed with new insights. Eye-tracking methodologies have opened windows into the real-time processes of looking at visual artifacts, and the connection between visual artifacts, eyes, and brain (Gidlöf 2015; Holsanova 2013a, 2013b; Holsanova et al. 2009, Johansson 2013, see also Harvard Maare 2014). Recent research into reading has also raised questions about long-standing graphic design ”truths” about the legibility of serif and non-serif typefaces, or comparing capitals letters with lower case (Arditi & Cho 2007).

The perspective that I have taken is that of co-present users engaging with visual artifacts, a perspective that is common in interaction design but not in graphic design. This changes the object of study from visual artifact per se into entire communicative scenes including spatial settings, furniture, architecture, present human actors, and their visible bodies (Goodwin 2000b; Lawson 2001).

One of the issues driving my research has been how to approach visual artifacts through the ways they are used and the ways in which they are invested with meaning by co-present participants. The viability of this particular approach depends on the setting studied, but I hope to have demonstrated its usefulness in learning contexts involving multiple participants communicating both with each other and with designed artifacts. As participants arrange themselves in order to be able to see and able to use their hands, they create certain spaces for joint actions while blocking others. Design aspects like scale and orientation play a role for learning and collaboration. Other contexts which could be explored using similar methods is the use of maps in the field, the practice of filling in tax declarations, or the joint reading of picture books.

Suggestions for future research

In chapter 2 I discussed learning mathematics through a second language, and I would like to continue this theme here. Teachers and schools are today faced with the challenge of teaching pupils with many different first languages, some of them with almost no knowledge of Swedish (Tallberg Broman et al. 2002). A continuation of the Ramsamsam project could address this problem through research and design of visual learning environments for second language learners, combining insights and methods from gesture studies, embodied interaction, pedagogy, and graphic design. As stated by Cummins (1998), the disadvantages of learning through a second language can be minimized by creating learning environments which provide support for accessing and using multiple languages for learning. The analysis of the Ramsamsam project presented here points in the same direction. Visual artifacts for learning can be made to support second language learners by creating common ground around learning tasks, building a context for decontextualized topics of learning, and by facilitating the sharing of language resources between learners and teachers.

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